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intermediate values of $FeO/(FeO + Fe_2O_3)$ are shown in Figs. 1 and 2. Their Mössbauer spectra show more comparable amounts of hematite and pyroxene than the heavily and slightly oxidized samples. The reflectivity data for both have a band minimum near 910 nm, which could result from (1) a composite of hematite (840–870-nm) and pyroxene (940-nm) bands; (2) a different pyroxene characterized by a 910-nm band; (3) a composite band derived from a pyroxene ferrous band and a pyroxene ferrous-ferric charge transfer band; and (4) another ferric mineral (e.g., goethite) having a band in this region. Alternative (4) is excluded by the Mössbauer data specifically for the case of goethite. None of the other alternatives can be excluded. However, a pyroxene 910-nm band usually implies a second band near 1800 nm [13], which we would probably observe, and [12] did not observe ferrous-ferric charge transfer transitions in two-band pyroxenes they subjected to thermal oxidation in air. Thus, there is some evidence to favor the interpretation involving composite hematite-pyroxene bands. This is particularly the case for MAN-74-217, where the 750-nm relative reflectivity maximum and 620- and 520-nm inflections are evidence for a strong spectral contribution from hematite.

Implications for Interpretation of Martian Spectral Data: Visible and near-IR martian bright-region spectral data (400 to ~2000 nm) returned from groundbased telescopes and the Phobos-2 encounter are characterized by a shallow band minimum in the near-IR whose position varies between approximately 850 and 1000 nm [14,15]. It is reasonable to assign these endmember band positions to hematite and pyroxene respectively [8,14,15]. Assignment of band positions near 910 nm is more equivocal. Murchie et al. and Geissler et al. [14,16] favor another ferric phase (like goethite) as the interpretation for Phobos-2 bands in the region of 910 nm, although they do not exclude composite hematite-pyroxene bands. The results of this study show for naturally occurring materials that composite hematite-pyroxene bands have minima in the 910-nm region. Thus, many of the anomalous Phobos-2 spectra can be explained by assemblages whose endmembers (hematite and pyroxene) are accepted to be present on Mars. Furthermore, our results show that a mineralogically diverse suite of rocks can be generated at essentially constant composition, which implies that variations in martian surface mineralogy do not necessarily imply variations in chemical composition.

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MARTIAN SPECTRAL UNITS DERIVED FROM ISM IMAGING SPECTROMETER DATA.

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Introduction: Based on results of the Viking mission, the soil layer of Mars has been thought to be fairly homogeneous and to consist of a mixture of as few as two components, a "dark gray" basaltic material and a "bright red" altered material [1,2]. However, near-infrared reflectance spectra measured recently both telescopically and from spacecraft indicate compositional heterogeneity beyond what can be explained by just two components [3,4]. In particular, data from the ISM imaging spectrometer [4,5], which observed much of the equatorial region at a spatial resolution of ~22 km, indicate spatial differences in the presence and abundance of Fe-containing phases, hydroxylated silicates, and H_2O [4,6–8]. We have used the ISM data to define, characterize, and map soil "units" based on their spectral properties. The spatial distributions of these "units" were compared to morphologic, visible color, and thermal inertia features recognized in Viking data.

Analysis: We investigated ISM data "windows" that cover eastern Tharsis, Valles Marineris, Arabia, Syrtis Major, Isidis, and Amenthes. These areas contain examples of most of the variations in color, reflectance, and thermal inertia recognized in Viking data [2]. The windows were registered with the digital topographic map of Mars using spacecraft pointing information and correlation of topographic relief features with variations in depth of the 2.0-μm atmospheric CO_2 absorption. The ISM data were reduced to a suite of "parameter" images that describe key sources of spectral variability, including reflectance, strength of a narrow absorption at 2.2 μm attributed to metal-OH, depth of the 3.0-μm H_2O absorption, depth of the broad 2-μm absorption attributed to Fe in pyroxene, and NIR spectral slope. Representative spectra were extracted for regions displaying different spectral characteristics to validate these differences and to characterize the shape and position of the 1-μm and 2-μm absorptions due to ferric and ferrous iron.

The parameterized ISM data were then classified using principal components analysis. Three principal components were found capable of accounting for most of the observed variations in NIR spectral properties. Spatial variations in the contributions or "loadings" of the principal components define coherent regions of soils having distinctly different spectral properties.

Results: The observed martian soils can be divided into broad groupings (Table 1) based on systematic, spatially coherent differences in their spectral attributes. The two largest groupings correspond with materials that are "bright red" and "dark gray" at visible wavelengths. "Normal bright soil" exhibits a high albedo, an intermediate 3.0-μm absorption, a relatively strong 2.2-μm absorption, and a flat spectral slope; "normal dark soils" exhibit a strong 2-μm pyroxene absorption and a relatively weak 3.0-μm absorption. Each group can be subdivided further based on position and shape of the ferric iron absorption in bright regions, and in dark regions, spectral slope, strength of the 3.0-μm absorption, and position and shape of the 1-μm and 2-μm absorptions due to Fe in pyroxene. "Transitional" soils, which occur largely at borders of "normal" bright and dark soils, are intermediate to "normal" bright and dark soils in most respects but have a negative spectral slope.

TABLE 1. Properties and geologic correlations of ISM spectral units.

Arbitrary Unit Designation	3-μm "Water" Band Depth	2-μm "Pyroxene" Band Depth	Spectral Slope	2.2-μm "M-OH" Band Depth	Center of Ferric Band	Geologic Correlations
Low Albedo						
Normal dark I	Weak	Strong/v. strong	Intermed.	Weak/absent	—	Parts of plateau plains, floor of Valles Marineris
Normal dark II	Weak	Intermed./strong	Negative/v. negative	Weak/absent	—	Parts of plateau plains
Normal dark III	Intermed.	Intermed./strong	Negative	Weak/absent	—	Plateau plains in Arabia
High Albedo						
Normal bright I	Intermed./strong	Weak/absent	Flat	Strong	0.85 μm	Low-thermal-inertia regions of Tharsis; parts of Amenthes
Normal bright II	Intermed./strong	Weak/absent	Very Flat	Strong	0.92 μm	Low-thermal-inertia regions of Arabia
Transitional	Intermed./strong	Weak	Intermed./v. negative	Intermed./strong	—	Libya Montes; parts of Amenthes; bright-dark borders
Anomalous						
Hydrated dark	Strong	V. strong	Flat/very flat	Weak/absent	—	Layered material in Melas, Eos. Ch.
Intermediate	Intermed.	Intermed.	Flat/intermed.	Weak/absent	—	Layered material in Hebes, C. Candor Ch.
Hydrated bright I	V. strong	Weak/absent	Flat	Strong/ v. strong	~0.86 μm	Basin fill of Isidis
Hydrated bright II	V. strong	Intermed.	Very flat	Intermed.	—	"Dark red" plains in Western Arabia
Hydrated bright III	V. strong	Weak/absent	Very flat	Intermed.	0.89 μm?	"Dark red" plains in Lunae Planum
Hydrated bright IV	V. strong	Weak	Negative/v. negative	Weak/absent	—	Layered material in E, W Candor Ch.

The remainder of the data, about 15% of the observed surface, are "anomalous" and can be divided into as many as six additional groupings, which are distinct spectrally from "normal" bright, "normal" dark, and "transitional" soils. Parts of Lunae Planum and western Arabia with a "dark red" visible color are intermediate to "normal" bright and dark soils in some respects, but, unlike "transitional" areas, they have a flat spectral slope and they exhibit a stronger 3.0-μm absorption than do either "normal bright" or "normal dark" soils. Low-albedo layered materials in Valles Marineris have a stronger 2-μm pyroxene absorption than most dark regions, yet also a stronger 3-μm absorption than most bright regions. High-albedo layered materials are very heterogeneous, with some regions characterized by a higher albedo and very strong 3.0-μm absorption, and others exhibiting an intermediate albedo and a 2-μm pyroxene absorption. Isidis resembles "normal bright soil" in most respects, but has a much stronger 3.0-μm absorption.

Discussion: "Normal bright soils" are correlated spatially with low-thermal-inertia regions interpreted as accumulations of "dust" by airfall [2,9,10]. The ferric absorption at 0.85 μm throughout the Tharsis region and in Amenthes is indicative of hematite, but the absorption at 0.92 μm throughout Arabia indicates the presence of one or more additional Fe phases, possibly goethite or ferrihydrite [8,11]. This difference implies that all low-thermal-inertia regions cannot be airfall derived from a single, well-mixed reservoir, and that regional lithologic differences have survived eolian mixing. The intermediate albedo and absorption strengths in "transitional" soils appear to a first order to be consistent with mixture of local "normal" bright and dark components; their negative spectral slope is consistent with a bright component either coating or mixed intimately with a darker substrate [12,13].

In contrast, "anomalous" soils are mostly intermediate to high albedo, but lie outside the low-inertia regions. They exhibit greater spectral heterogeneity than "normal" bright and dark soils, they are distinctive from "transitional" soils, and they are correlated spatially with independently identified high-thermal-inertia features and geologic units. As such they may represent indurated materials and/or exposures of specific geologic deposits. For example, intermediate-albedo "dark red" soils in Lunae Planum and Arabia correspond to high thermal inertia surfaces previously interpreted as cemented duricrust [2]. Their strong 3.0-μm absorptions suggest enrichment in a water-bearing phase, perhaps hydrated salts that act as the duricrust's "cement" [cf. 14]. The Isidis unit also corresponds with a thick, unconformable, basin-filling deposit [15] having anomalously high thermal inertia [2,10]. This unit's high inertia and strong 3.0-μm absorption would also be consistent with induration of soil by water-bearing cement, but its high albedo and relatively strong 2.2-μm absorption indicate a different compositon of cemented particulates than in "dark red" soils.

The "intermediate," "hydrated dark," and "hydrated bright" units in Valles Marineris correspond with different plateaus of eroded layered materials. Previous analysis of ISM data covering these deposits has also shown that their absorptions due to Fe vary in position and strength, indicating the presence of pyroxenes of different composition [6,7] and local enrichments of ferric minerals [16]. This heterogeneity in the layered materials' spectral properties supports previous inferences based on stratigraphic relations that layered materials were emplaced under differing environmental regimes [17,18].

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EDDY TRANSPORT OF WATER VAPOR IN THE MARTIAN ATMOSPHERE. J. R. Murphy[1,2] and R. M. Haberle[1], [1]SJSU Foundation, [2]NASA Ames Research Center, Moffett Field CA 94035, USA.

P. 1

Viking orbiter measurements of the martian atmosphere suggest that the residual north polar water-ice cap is the primary source of atmospheric water vapor, which appears at successively lower northern latitudes as the summer season progresses [1]. Zonally symmetric studies of water vapor transport indicate that the zonal mean meridional circulation is incapable (due to its weakness at high latitudes) of transporting from north polar regions to low latitudes the quantity of water vapor observed [2]. This result has been interpreted as implying the presence of nonpolar sources of water, namely subsurface ice and adsorbed water, at northern middle and subtropical latitudes. Another possibility, which has not been explored, is the ability of atmospheric wave motions, which are not accounted for in a zonally symmetric framework, to efficiently accomplish the transport from a north polar source to the entirety of the northern hemisphere. The ability or inability of the full range of atmospheric motions to accomplish this transport has important implications regarding the questions of water sources and sinks on Mars: if the full spectrum of atmospheric motions proves to be incapable of accomplishing the transport, it strengthens arguments in favor of additional water sources.

Preliminary results from a three-dimensional atmospheric dynamical/water vapor transport numerical model will be presented. The model accounts for the physics of a subliming water-ice cap, but does not yet incorporate recondensation of this sublimed water. Transport of vapor away from this water-ice cap in this three-dimensional framework will be compared with previously obtained zonally symmetric (two-dimensional) results to quantify effects of water vapor transport by atmospheric eddies.

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IRTM BRIGHTNESS TEMPERATURE MAPS OF THE MARTIAN SOUTH POLAR REGION DURING THE POLAR NIGHT: THE COLD SPOTS DON'T MOVE. D. A. Paige[1], D. Crisp[2], M. L. Santee[2], and M. I. Richardson[1], [1]Department of Earth and Space Sciences, UCLA, Los Angeles CA 90024, USA, [2]Jet Propulsion Laboratory, Pasadena CA 91106, USA.

The Viking Infrared Thermal Mapper (IRTM) polar winter season observations in the 20-μm channel showed considerable temporal and spatial structure, with minimum brightness temperatures well below the surface CO_2 frost point of ~148 K [1,2]. Brightness temperatures as low as 134 K in the south and 128 K in the north were observed. To date, these low brightness temperatures have not been uniquely explained. In the 1976 paper, Kieffer et al. [1] suggested three mechanisms: (1) low surface emissivities, (2) presence of high-altitude clouds, and (3) depressed solid-vapor equilibrium CO_2 frost kinetic temperatures due to reduced atmospheric CO_2 partial pressures at the surface. Hess [3] cast doubt on mechanism (3) by showing that vertical and horizontal gradients in average molecular weight of the polar atmosphere could only be stable under special circumstances.

In 1979, Ditteon and Kieffer [4] published infrared transmission spectra of thick, solid CO_2 samples grown in the laboratory. The results showed that in wavelengths away from the strong CO_2 absorption features, the transmissivity of their samples was quite high, and concluded that the low brightness temperature observations could be explained by low surface frost emissivity. Warren et al. [5] have used Ditteon and Kieffer's laboratory data in conjunction with scattering models to show that the spectral emissivities of martian CO_2 frosts could take on almost any value from 0 to 1 depending on CO_2 grain size, dust and water ice content, or viewing angle.

Hunt [6] showed that the polar night brightness temperatures could be explained by the radiative effects of CO_2 clouds. Using the results of a one-dimensional atmospheric model in conjunction with IRTM observations, Paige [7,8] showed that the spatial and temporal occurrence of low brightness temperatures are consistent with the notion that they are due to CO_2 clouds. Subsequently, Pollack et al. [9] published the results of Global Circulation Model (GCM) experiments that showed that CO_2 should condense in the atmosphere over the winter pole and that this condensation is enhanced by the presence of dust.

In the 1977 paper, Kieffer et al. [2] published midwinter brightness temperature maps that showed some evidence of temporal variation. These temporal variations have since been interpreted by others as illustrating dynamic motions of the lowest of the low brightness temperature regions. However, Kieffer et al. [2] state that the possible motion of individual features cannot be established from the analysis presented in the 1977 paper.

In this study, we have examined a series of IRTM south polar brightness temperature maps obtained by Viking Orbiter 2 during a 35-day period during the southern fall season in 1978 (L_s 47.3 to 62.7, Julian Date 2443554 to 2443588). These maps represent the best spatial and temporal coverage obtained by IRTM during a polar-night season that have not been analyzed in previous studies. The maps show a number of phenomena that have been identified in previous studies, including day-to-day brightness temperature variations in individual low-temperature regions [1], and the tendency for