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MARTIAN SURFACE PROPERTIES

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OBJECTIVE

The objectives of this proposal were: 1) to characterize surficial geologic units through integration of IRTM-derived regolith properties with other existing remote sensing data; 2) to determine the physical and spectral properties of volcanic units in the mid-latitudes of Mars through the synthesis of the highest resolution IRTM, radar, and imaging data available; 3) to identify and characterize aeolian terrains on Mars using physical surface characteristics determined from remote sensing data.

INTRODUCTION

This work was a multi-year project (initiated in 1981) to assess geologic terrains and surface processes. In the first phase a model was developed to determine the block population, thermal inertia of the fine material, and thermal emissivity of the martian surface materials using IRTM thermal and spectral data. This model was then used to produce global maps of block population and thermal emissivity and to study the properties of specific aeolian terrains. On completion of that, work has been completed (Appendix II) and analysis of the global variation in surface properties was initiated. The surface properties derived from the IRTM data (along with photogeology, Earth-based radar, and Earth-based and Viking Orbiter spectral observations) were applied to a detailed study of particular areas in order to constrain models of surface processes. Particular emphasis was placed on characterizing aeolian and volcanic terrains, and observing global dust deposition and duricrust formation. In addition, the Viking Lander 1 and 2 sites were compared to global properties to see how representative these areas were.

RESULTS

A great deal has been learned about the surface properties, processes, history, and age of the martian surface by further analysis of the IRTM data, and by integration of these data with other remote and *in situ* observations.

Global Properties

The abundance of rocks on the surface was mapped globally using a model derived to relate the observed differences between the four IRTM temperature measurements, and the fraction of the surface covered by rocks. This map shows that all areas on Mars at a scale of 1° latitude by 1° longitude have rocks exposed at the surface, and no areas have more than 25-30% rock cover. Rocks are most common in high-inertia regions, such as Valles Mariners and Acidalia Planitia, and are less abundant in Tharis, Arabia, and Elysium.

These observations were used to assess the importance of major dust storms in the deposition and removal of fine dust material, both at present and in the past. Thermal, radar, and visual remote sensing observations were used to determine the location and physical properties of regional dust deposits, located in Tharsis, Arabia and Elysium. The surfaces are covered by fine (~2-40 μm), bright (albedo > 0.27) particles, with fewer exposed rocks and coarse deposits than found elsewhere. Dust is currently deposited uniformly throughout the equatorial region at a rate of ~40 μm/global storm. Over geologic time the rate of accumulation may vary from 0 to 250 μm/year due to changes in atmospheric conditions produced by orbital variations. Dust deposited during global storms is subsequently removed only from dark regions, resulting a net accumulation in the low-inertia, bright regions. The thickness of these current dust deposits is 0.1 to 2 meters. The thermal inertia places a lower limit of ~0.1 m on the thickness of these deposits, while the sparse but ubiquitous presence of exposed rocks and the degree of visible mantling indicate that the thickness is less than 5 meters. Dual-polarization radar observations of a very rough texture in Tharsis are consistent with this model, with a ~2 m thick dust layer burying most of the surface rocks but permitting radar sampling of the rough sub-surface. Based on their thickness and rate of accumulation, the age of these deposits is 10^5-10^6 years, suggesting a cyclic process of deposition and removal. One possible cause may be cyclic variations in the magnitude and location of maximum wind velocities related to variations in Mars' orbit. At present, perihelion and maximum wind velocities occur in the south whereas regional dust deposits occur in the north, suggesting net transport from south to north. Orbital parameters oscillate with periods ranging from 5×10^4 to 10^6 years. The agreement between these periods and the dust deposit age suggests a possible link. At different stages in orbit evolution, maximum wind velocities will occur in the north, with subsequent erosion and redistribution of the accumulated fines. Based on this model, much of the uppermost martian surface is very young and is being continually reworked.

Global remote sensing observations were also used to derive a simple, self-consistent model for the surface layer. The data sets used include radar cross-section measurements at several wavelengths, radio whole-disk thermal emission observations at two wavelengths, the global distribution of thermal inertia, deviations of diurnal temperatures from those of a homogeneous model, and thermal spectral estimates of surface rock abundance and of the thermal inertia of the non-rocky component of the surface. The data sets which most constrain the interpretation are the rock abundance map and the correlation of thermal inertia with radar cross-section; these require the rock abundance to not vary significantly from place to place, and simultaneously require the density and thermal inertia of the fines to vary in a consistent manner. The simplest model which can explain all of the data involves a global case-hardened crust ("duricrust") which varies spatially in its degree of formation. In general, low-thermal-inertia regions have a poorly-developed crust and high-inertia regions have a well-developed crust; there are, however regions that consist of coarse particles, which do not fit this model (e.g., Chryse). This model is consistent with the ages of low-inertia regions, and with aeolian mechanisms for their development. The duricrust is thought to form via the mobilization of salt ions within a layer of water adsorbed within the regolith, and its formation may be associated with the exchange of water between the regolith and atmosphere which occurs on the 10^5- and 10^6-year timescale.

<u>Viking Lander Sites</u>

The models discussed above were compared to observations at the two Lander sites to determine whether these sites were representative of Mars as a whole. It was found that the Lander sites do <u>not</u> fit most of the global trends of remote-sensing data. The presence of a duricrust in the top meter of the surface is inferred for most regions of high thermal inertia, but the duricust is thinner at the Lander sites than elsewhere. Regions of low thermal inertia are covered by greater than several centimeters of unconsolidated dust. A thin, microns-thick layer of bright dust appears at the surface at the Lander sites, and these locations may be regions of incipient formation of low thermal inertia. Thus, the Lander sites are intermediate in structure between classical bright and dark regions, and are distinctive from most of the rest of the planet.

<u>Tharsis Volcanoes</u>

Photographs and other remote sensing data of Ascraeus Mons were analyzed in order to relate the remotely determined surface properties to the geology of the volcano. Photogeologic analysis indicates that Ascraeus Mons is similar to terrestrial basaltic shield volcanoes in both surface morphology and estimated rheologic properties. Lava flows are interpreted to include pahoehoe, aa, and toey pahoehoe, with deposits of aeolian or pyroclastic materials on the surface above 15 km elevation. The wavelength dependence of albedos on Ascraeus Mons parallels the reflectance spectrum of classical high albedo regions (e.g. Arabia), which suggests that dust is present throughout the volcano summit area. High spatial resolution infrared sequences show no correlation between the thermal properties and surface terrains, including various lava flow terrains, consistent with dust deposits at least 2 cm thick on all terrains. Caldera walls have the highest thermal inertias of the volcano but bedrock exposures probably account for $< 15\%$ of the observed area. Thermal inertias increase down the flanks of the volcano, but the areal abundance of high thermal inertia materials ($I = 30$) decreases; downslope sediment transportation and sorting could account for both of these trends. The properties of Ascraeus Mons at visual and infrared wavelengths are dominated by surface materials that do not appear to be directly associated with the underlying terrains suggesting resurfacing by windblown dust.

Lunae Planum-Kasei Vallis

The Kasei Vallis-Lunae Planum region of Mars was investigated using radiometrically calibrated 3-color Viking Orbiter image data, high-resolution Viking monochromatic images, Viking Infrared Thermal Mapper (IRTM) data, and visible and near-infrared reflectance spectra of regions on Mars and terrestrial analog materials. IRTM thermal inertia values for Lunae Planum are relatively low, indicating a fine-grained surface. Thermal inertia values for Kasei channel floors are higher, especially in association with very dark patches and streaks which have among the highest thermal inertia values observed for Mars. The bright and reddest surface exposures in this region have colors (albedo ratios) similar to the low-inertia, high-albedo regions. The lowest-albedo areas in this study region are the high-inertia streaks on the channel floors, which have a significantly lower Red/Violet ratio than any previously observed dark, non-volatile martian materials. These reflectance properties are consistent with unweathered or only slightly weathered basalt or basaltic glass. Combined with thermal inertia size estimates of 1-4 mm and morphologic evidence, it appears that these dark exposures are aeolian dune deposit fragments. The individual particles are apparently mobile enough at the present time to prevent significant accumulation of aeolian dust or surface weathering products.

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