VARIATIONS OF MARTIAN SURFACE ALBEDO: EVIDENCE FOR YEARLY DUST DEPOSITION AND REMOVAL

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Dust deposition and removal is an important process in the evolution of the martian surface. Mars has been observed to have variable surface markings from the earliest telescopic views of the planet. These changes have since been seen to be related to aeolian activity, primarily through the reworking of bright dust deposited following major global dust storms (1,2). Viking Infrared Thermal Mapper (IRTM) observations of albedo have also revealed significant changes in surface brightness through time, again primarily associated with major global dust storms (3,4). All of these observations indicate that there is a significant amount of dust that is deposited during the decay of global storms which is subsequently reworked and redistributed. The purpose of this study is to determine the degree, spatial distribution, and timing of the deposition and removal of dust-storm fallout, and to relate the current patterns of dust deposition and removal to the long-term evolution of the martian surface.

A model has been proposed (5) for the development of regional dust deposits that form through the preferential accumulation of dust-storm fallout into specific northern hemisphere regions. In this model, dust is deposited uniformly during the decay phase of each major storm, but is subsequently removed only from regions that are seen today as classic dark areas. Thus, dark regions remain unmantled by dust, whereas bright regions have developed a 1-2 m thick mantle of fine, bright dust (5). This model can account for the high thermal inertia (coarse) material observed in dark regions, together with their relatively high rock abundance (6), and low albedo. Conversely, bright regions have fine particles (5-40 μm) and fewer exposed rocks, presumably due to mantling of the coarse material by dust.

In order to directly observe the seasonal changes in surface brightness associated with dust deposition and removal, the albedo of specific regions in both hemispheres has been determined through time. The IRTM data were collected into 1° latitude by 4° longitude bins, at 3 hour intervals for each 10° of L_s. Using these data, the albedo changes for a given area have been investigated from the beginning of the Viking mission (L_s 84°), through the first (L_s 190-240°) and second (L_s 270-340°) global dust storms that occurred in 1977. Global data are available through L_s 120° of the second year, allowing a year to year comparison of surface albedo.

The albedo variations as a function of season are shown in Figure 1 for representative bright and dark regions. All of the areas studied show a marked increase in brightness associated with the two global storms, due primarily to the presence of dust in the atmosphere. The increase in brightness, even for bright regions, indicates that the albedo and scattering phase function of suspended dust varies from dust on the surface. The maximum brightness at the peak of the second storm was nearly equal for most bright and dark regions, indicating that the atmospheric dust was optically thick. For some dark regions, however, such as Solis Planum, the albedo remained relatively low even at the height of the storm activity, suggesting that the atmospheric dust was not globally uniform nor well mixed. Many areas show a non-uniform decrease in brightness during the decay phase, again suggesting spatial variations in dust load and non-uniform mixing, possibly due to episodic injection of dust into the atmosphere locally (7).

The albedo of most regions had returned to the pre-storm value by L_s 355°, indicating that the atmosphere had cleared to pre-storm levels by that time. This conclusion is supported by Viking lander observations, which show that the opacity over the two lander sites had decreased to pre-storm levels by L_s 360° (7). Therefore, surfaces that remained brighter after L_s 360° than they were prior to the two storms are thought to be covered by a thin layer of bright dust fallout.

The distribution of surfaces that remained bright following the storms, and those where the surface quickly returned to its pre-storm albedo follow a consistent pattern. The albedo of bright regions, such as Arabia and Tharsis, rapidly returned to pre-storm values, and was close to the albedo of the previous year (Fig. 1a). Many dark regions also darkened to nearly their pre-storm levels by L_s 360° (Fig. 1b). This pattern holds particularly well for southern hemisphere dark regions. This behavior is consistent with the model of deposition described above; in dark regions the dust is rapidly removed with little net accumulation, whereas in bright regions a dust mantle already exists so that the deposition of additional bright dust does not affect the surface albedo.

There are several dark regions that differ from the general trends described above and provide insight into the level of dust activity that occurs throughout the year. Syrtis Major and Acidalia Planitia are among the few regions that remained significantly brighter at L_s 360° than they were before the global storms began. These areas did, however, continue to darken with time, returning to nearly their pre-storm albedo by L_s 120° (Fig. 1c). It is interesting to note that the albedo of these and some other regions was still slightly higher at this time than it was the previous year, suggesting that some dust still remained on the surface. This finding is consistent with observations at the Viking lander 1 site where dust was deposited following the global storms and was not removed until over a year later (8). These observations support the hypothesis that Syrtis Major and Acidalia Planitia act as local dust sources during inter-storm periods, producing enhanced dust loading in the northern hemisphere (9).

In summary, observations of seasonal changes in surface albedo reveal regional differences in the deposition and subsequent erosion of dust-storm fallout. Southern hemisphere dark areas quickly return to close to their pre-storm albedos, suggesting rapid removal of any dust that was deposited. Northern hemisphere dark regions are brighter post-storm, but gradually darken to pre-storm levels over a Mars year. In doing so they act as local sources of dust during otherwise clear periods. Dust does not appear to be removed from bright regions, resulting in the 1-2 m thick deposits observed today.

References

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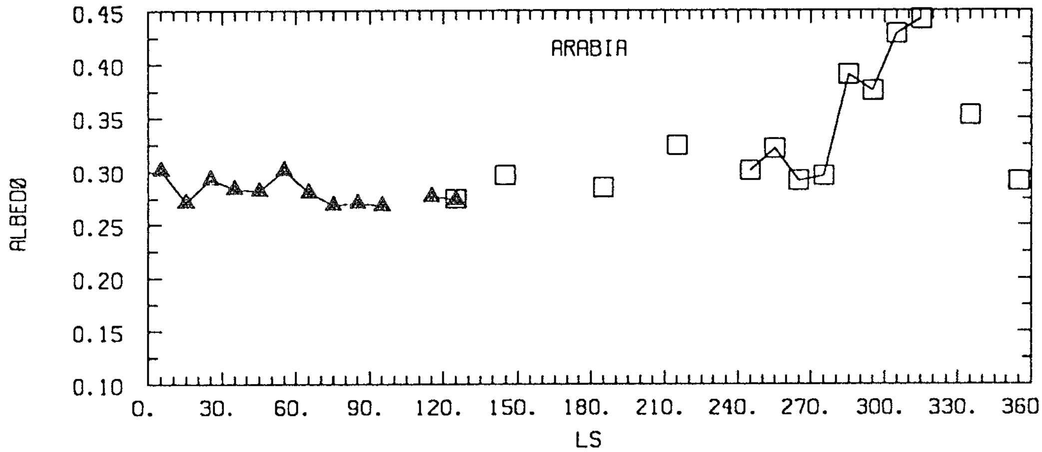

Figure 1. Variation of albedo with season. Open squares represent data from the first year following the arrival of Viking at Mars. a) Arabia, typical of bright region behaviour.

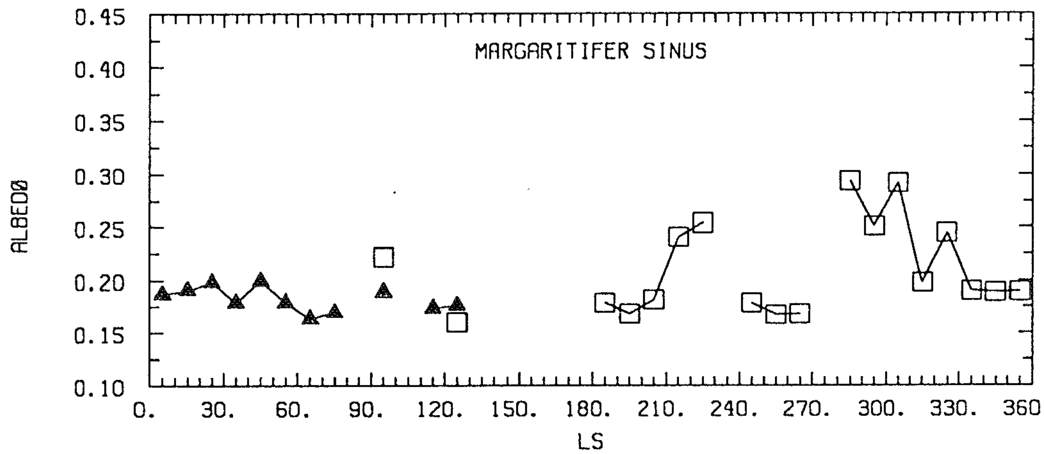

Fig. 1b). Margaritifer Sinus, representative of southern hemisphere dark regions.

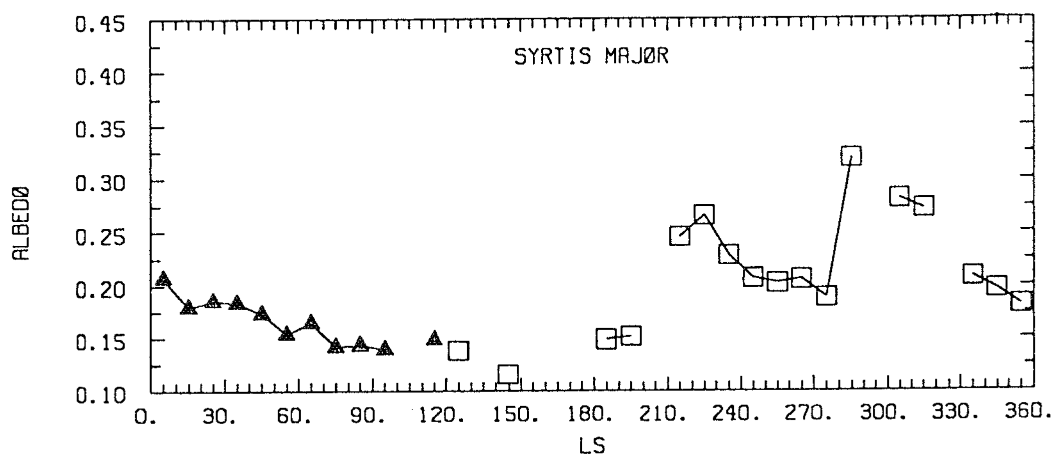

Fig.1c). Syrtis Major, showing the long residence time of dust on the surface in northern hemisphere dark regions following the global dust storms.