Geologic Map of the MTM -85280 Quadrangle, Planum Australe Region of Mars

1 :500,000 scale

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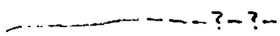
DFACRIPTION 01 MAP **UNITS**

Dust **mantlc--Bright,** red material covering underlying units without obscuring topographic features. **Interannually** variable distribution. Unit shown as it appeared in 1977. *Interpretation:* Thin (less than a few meters) dust layer deposited from atmospheric suspension, removed by winds in some areas. Ephemeral, perhaps deposited during major dust storms

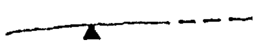
Ad Dark material--Dark, neutrally colored material in topographic depressions in northern half of quadrangle. *interpretation:* Dark, saltating sand or agglomerates of dust formed upon erosion of layered deposits. Agglomerates tnay be filamentary sublimation residue particles composed of magnetic dust grains (Herkenhoff and Murray, 1990a). Color and albedo of unit consistent with incomplete dune cover over] ying brighter material

Al Layered deposits--Widespread, horizontal] y layered unit having generally smooth surface at available image resolution. Color and albedo intermediate between those of dust mantle and dark material (table 1). Unit extensively eroded in places; covered by dust mantle in many areas. *Interpretation*: Deposits of dust and water ice in unknown proportions. Water ice not expected to be stable at surface of low-albedo units (Toon and others, 1980; Hofstadter and Murray, 1990), so lag or weathering rind probably covers surface. Color and albedo suggest that nonvolatile component of layered deposits is composed of bright dust and minor dark dust or sand

Hdu Upper member, **Dorsa** Argentea **Formation**--Forms cratered plains in **Chasma Australe,** overlain by layered deposits and dark material. Marked by occasional sinuous ridges about 1 km wide and up to 20 km long. ***Interpretation:*** Volcanic plains exposed by erosion of layered deposits to form **Chasma Australe.** Origin of sinuous ridges uncertain, may be volcanic or glacial features (Howard, 1981; Tanaka and Scott, 1987; **Kargel,** 1993)



Contact--Dashed where uncertain or broadly gradational; queried where doubtful


Scarp--Line marks bottom of slope, barb points downslope. Dashed where uncertain; used as contact in places


Ridge--Symbol on ridge crest


Trough or groove


Crater rim crest

INTRODUCTION

Published geologic maps of the south polar region of Mars have been based on either Mariner 9 (Condit and Soderblom, 1978; Scott and Carr, 1978) or Viking Orbiter (Tanaka and Scott, 1987) images. The extent of the layered deposits mapped previously using Mariner 9 data is different from that mapped using Viking Orbiter images, and the present map agrees with the latter (Tanaka and Scott, 1987) map,

The residual polar ice cap, areas of partial frost cover, the layered deposits, and two nonvolatile surface units--the dust mantle and the dark material--were mapped by Herkenhoff and Murray (1990a) at 1:2,000,000 scale using a color mosaic of Viking Orbiter images. This mosaic and an additional Viking color mosaic were used to confirm the identification of the non-volatile Amazonian units for this map and to test hypotheses for their origin and evolution. 'l'he colors and albedos of these units are presented in table 1 and figure 1. Because the resolution of the color mosaics is not sufficient to map these units in detail at 1:500,000 scale, contacts between them were recognized and mapped using higher resolution black-and-white Viking and Mariner 9 images.

Only two possible impact craters in the layered deposits have been found in the area mapped; both are slight] y elongate rather than circular. One was recognized by Plaut and others (1988); the other, about 3 km in diameter, is at lat 82.80 S., long 277°. Although the crater statistics are poor (only 16 likely impact craters found in the entire south polar layered deposits), these observations generally support the conclusion that the south polar layered deposits are Late Amazonian in age and that some areas have been exposed for at least 120 million years. However, the recent cratering flux cm Mars is unknown, so that absolute ages of surface units are uncertain.

The Viking Orbiter 2 images used to construct the base were taken during the southern summer of 1977, with resolutions no better than 180 m/pixel. (The "less than 100 m per picture element" in Notes on Base of the controlled photomosaic base [U.S. Geological Survey, 1986] is incorrect.) A digital mosaic of Mariner 9 images was also constructed to aid in mapping. The Mariner 9 images were taken during the southern summer of 1971-72 and have resolutions as high as 90 m/pixel, However, usefulness of the Mariner 9 mosaic is limited by incomplete coverage and atmospheric dust opacity.

PHYSIOGRAPHIC SETTING

The area of this map is mostly within Planum Australe, a plateau of layered deposits about 1,600 km long and 1,200 km wide (U.S. Geological Survey, 1989, sheet 1). Its thickness is uncertain due to the poor geometry of available stereopairs (S. S. C. Wu, oral Commun ., 1990). The plateau is characterized by the smoothly sculptured landforms of the layered deposits (see fig. 2). Part of Chasma Australe, a large reentrant in the layered deposits, appears in the northeast corner of the map area.

Dzurisin and Blasius (1975) combined Mariner 9 radio-occultation and stereo-photogrammetric data to find that the area covered by the residual south polar ice cap is 1 to 2 km higher than the surrounding layered deposits. Their data are too limited in lateral extent to be used to reliably estimate the total thickness of the layered deposits, however. Areas of relative] y complete frost cover are typically level, while defrosted scarps slope 10 to 5° overall. In some cases, the scarps form low-relief troughs that are asymmetrical in cross section. While stereophotogrammetric data are lacking in this map area, brightness variations in various images of the layered deposits suggest that similar topographic relationships exist here and in other areas of layered terrain outside the residual polar ice cap. Only the most prominent scarps and troughs in the layered deposits are shown on this map.

STRATIGRAPHY AND STRUCTURE

The oldest unit on this map is the upper member of the Hesperian-age Dorsa Argentea formation, exposed in the floor of Chasma Australe in the northeast corner of the map. The upper member is distinguished from the layered deposits by its numerous craters, mountains, and sinuous ridges. Tanaka and Scott (1987) used Viking Orbiter images to recognize flow fronts in areas outside this map in the member, indicating a volcanic origin. They and others recognized braided and sinuous ridges in the member that have been variously interpreted as volcanic, aeolian, tectonic, fluvial or glacial features (Kargel, 1993). None of these hypotheses for the origin of these ridges can be ruled out completely using observations of the few ridges in this map area. Better understanding of these features will require higher-resolution imaging from future spacecraft.

The layered deposits (unit Al) are recognized by their distinct bedded appearance and intermediate color and albedo; they appear to be the youngest bedrock unit in the south polar region. The horizontal to subhorizontal beds that make up the layered deposits are especially well exposed on this map around Chasma Australe. Similar layered exposures have been recognized in the north polar layered deposits (Cutts, 1973; Cutts and others, 1976; Blasius and others, 1982; Howard and others, 1982). In both polar regions, layers are apparent in such places due to their terraced topography, especiall y where accented by differential frost retention (Herkenhoff and Murray, 1990b). Photoclinometric analysis of an exposure of layered deposits outside the map area (Herkenhoff and Murray, 1990b) indicates that similar layers are 100 to 300 m thick, but thinner layers, if present, cannot be detected due to limitations in image resolution. Thinner layers (14 to 46 m thick) were found by Blasius and others (1982) in the north polar layered deposits, which suggests that finer layering may also exist in the southern polar deposits. Slopes of as much as 20° occur outside this map area between nearly horizontal terraces at lat 87.0° S., long 346° (Herkenhoff and Murray, 1990b). No definite angular unconformities have been found within the south polar layered deposits, unlike the north polar deposits, where better image resolution allows them to be recognized (Cutts and others, 1976). As described in the next section, water ice in the layered deposits is probably protected from solar heating and sublimation by a weathering rind or lag deposit on the surface.

No faulting or folding of the deposits has been observed, but there is an unusually steep, irregular scarp in the layered deposits at 83. 3°S, 297°W, near the upper edge of the flank of a low-relief trough, The scarp is poorly resolved in a 91 m/pixel Mariner 9 image, and appears to be fluted with individual flutes up to 1 km across. This scarp is barely visible as a bright line (due to illumination geometry) in the best Viking Orbiter image of this area, Similar bright lines are visible in other parts of this Viking image, but in most cases corresponding features cannot be seen in Mariner 9 images of the same area, Hence, these other features are not mapped. Unlike the steep scarps in the north polar layered deposits (Thomas and Weitz, 1989), these scarps do not appear to be the source of dark, saltating material, The scarps appear to cross the. boundaries of color/albedo units rather than parallel them, as seen in the north polar region. However, the relatively low resolution of the images that show these features does not allow detailed comparison with high-resolution north polar observations of the relationship between steep scarps and dark dunes. Higher-resolution images of these features from future Mars missions are needed to determine their origin and role in layered deposit evolution.

The dark material (unit Ad) and the dust mantle (stipple) unconformably overlie the layered deposits, indicating relatively recent deposition by saltation and from atmospheric suspension, respectively. The location of dark material in topographic depressions here and elsewhere in the south polar region indicates that it is transported by saltation (Herkenhoff and Murray, 1990a). In this quadrangle the dark material is not as dark and is redder than in some areas of dark material outside the map area. The observed color and albedo may be due to incomplete burial of the underlying (brighter, redder) units or to a partial dust cover. Local saltation of the dark particles in the unit would be expected to eject dust grains into suspension or to allow them to trickle down between dark particles and out of sight, so the partial-dust-cover alternative is unlikely. Deposition or redistribution of this unit may be continuing at the present time. Image resolution is insufficient to resolve dune forms, but dunes probably cover part of the underlying surface in some areas. The unit may be composed of sand-size particles or low-density aggregates of dust grains, The very low thermal inertias in this region deduced by Paigeand Keegan (1994) indicate that solid sand grains arenot abundant in the map area. The dark material is therefore more likely composed of low-density aggregates of dust particles or very porous grains such as basaltic cinders. We cannot distinguish between these two hypotheses using the available data in the map arm. If the dark material is made of solid or porous sand grains rather than sublimation residue particles, codeposition of dust and sand to form the layered deposits is implied. Saltating sand will inject dust into suspension, so that the dust must somehow be cemented to permit codeposition with sand (Herkenhoff and Murray, 1990a).

The bright, red dust mantle does not appear to obscure topography, so it is probably no more than a few meters thick. Furthermore, the extent of the dust mantle changed in many places during the 3 Mars years between the Mariner 9 and Viking Missions, indicating that it is ephemeral. Its boundary is mapped here as it appeared during the Viking Mission in 1977. A new Viking Orbiter 2 color mosaic of the study area, taken during orbit 358, was constructed using controlled images provided by T. Becker of the U. S. Geological Survey in Flagstaff. Analysis of this color mosaic indicates that the bright red unit extends beyond the layered deposits, supporting our previous interpretation of this unit as a dust mantle (Herkenhoff and Murray, 1990a). This interpretation is also consistent with thermal modeling of Viking IRTM data that shows that the thermal inertia of the surface of the layered terrain is very low (Paige and Keegan, 1994). The boundai y between the dust mantle and the layered deposits in the northwest corner of the map appears "streaked" in many cases. The direction of the streaks is roughly parallel with the dip of the flanks of the large troughs in the layered deposits, suggesting that gravity has played a role in their formation. However, as discussed above, the overall slopes of the trough flanks are probably very low (less than 5°), so the streaks are unlikely to be solely the result of mass movement.

GEOLOGIC PROCESSES AND HISTORY

The polar layered deposits are widely believed to have been formed through deposition of water ice and dust, modulated by global climate changes during the last few million to hundreds of million years (Murray and others, 1972; Cutts, 1973; Soderblom and others, 1973; Cutts and others, 1976, 1979; Squyres, 1979; Toon and others, 1980; Carr, 1982; Howard and others, 1982; Pollack and Toon, 1982; Plaut and others, 1988). However, the details of the relation between theoretical variations of Mars' orbit and axis and geologic observations are not clear (Thomas and others, 1992). In particular, the apparent contrast in ages of the north and south polar layered deposits, as indicated by their different crater densities (Cutts and others, 1976; Plaut and others, 1988), is paradoxical. The geology of this quadrangle illustrates some of the processes that are important in the evolution of the southern deposits.

With the exception of areas covered by the residual polar ice cap, the south polar layered deposits appear to have undergone net erosion in the recent geologic past. A larger fraction of the north polar layered deposits is covered by the north polar residual ice cap, so that erosion of the northern deposits can occur only in the relatively small areas that are free of perennial ice. Solar heating of the exposed deposits causes sublimation of the water ice within them (Toon and others, 1980; Hofstadter and Murray, 1990), probably forming a lag deposit of nonvolatile material. Such a nonvolatile layer would protect underlying water ice from further sublimation. Herkenhoff and Murray (1990a) proposed that minor amounts of dark magnetic dust exist in the layered deposits along with the bright, red dust mantle that covers much of the Martian surface. The magnetic dust may preferentially form filamentary sublimation residue particles (Storrs and others, 1988) that eventually break free of the surface and saltate, ejecting the remaining dust into suspension. Dark particles 100 microns to 1 mm in size will continue to saltate until trapped by an obstacle or depression, where they could form isolated patches of the dark material. Eventual destruction of such particles could allow the dark dust to be recycled back into new layered deposits from atmospheric suspension.

The above scenario is consistent with the color, albedo, and geology of the units mapped here. The thin dust mantle appears to be a temporary feature, perhaps deposited during a major global dust storm such as that observed in 1971. Where the dust has been removed by winds, the water ice in the layered deposits is protected from further sublimation by a weathering rind of dust and residue particles. The "streaks" observed in the northwest comer of the map are interpreted as the result of local removal of the dust mantle by saltation of dark material. The orientation of the streaks is consistent with the direction of strong off-cap winds expected during the southern summer, when seasonal $C0_2$ frost is subliming rapidly. The atmospheric boundary layer may be affected by the presence of the low-relief troughs, perhaps reducing its ability to maintain saltation. In any case, this area is a prime target for high-resolution imaging from future spacecraft.

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Table 1. Lambert albedos and colors of surface units in map area

Unit	Violet	Red	R/V
Dust mantle (stipple)	0.04-0.05	0.14-0.18	3.2-3.8
Dark material (unit Ad)	0.02-0.05	0.04-0.10	1.8-2.1
Layered deposits (unit Al)	0.03-0.05	0.10-0.13	2.5-3.2

FIGURE CAPTIONS

Figure 1. Violet Lambert albedo plotted against red Lambert albedo for three surface units in vicinity of south residual polar cap of Mars (exposures outside map area). Lambert albedos derived by dividing observed reflectance (corrected for atmospheric scattering) by cosine of incidence angle. Error bars represent combination of 13 percent uncertainty in absolute albedos and sampling errors in 5x5-pixel areas. Albedo variations along lines of constant red-to-violet ratio (R/V) mainly due to slope differences.

Figure 2. Index map showing location of major physiographic features and 1:500,000-scale maps in Planum Australe region completed or in progress in Mars Geologic Mapping Program. Mars Transverse Mercator (MTM) numbers indicate latitude and longitude of center of maps. I-number indicates published map,

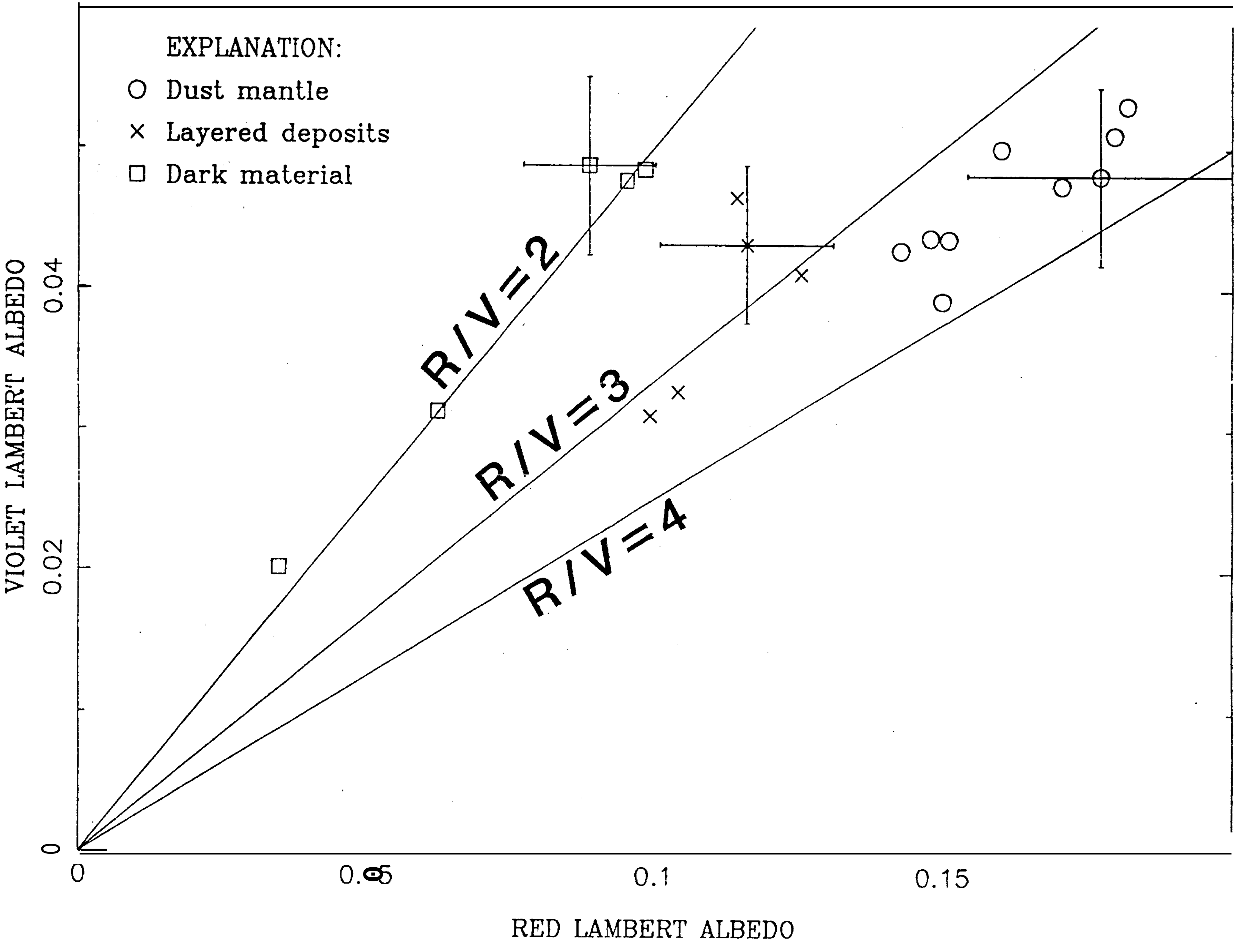
EXPLANATION:
Dust mantle
Layered deposits
Dark material
R/V=2
R/V=3
R/V=4
VIOLET LAMBERT ALBEDO
0
0.02
0.04
RED LAMBERT ALBEDO
0
0.05
0.1
0.15

FIG. 2