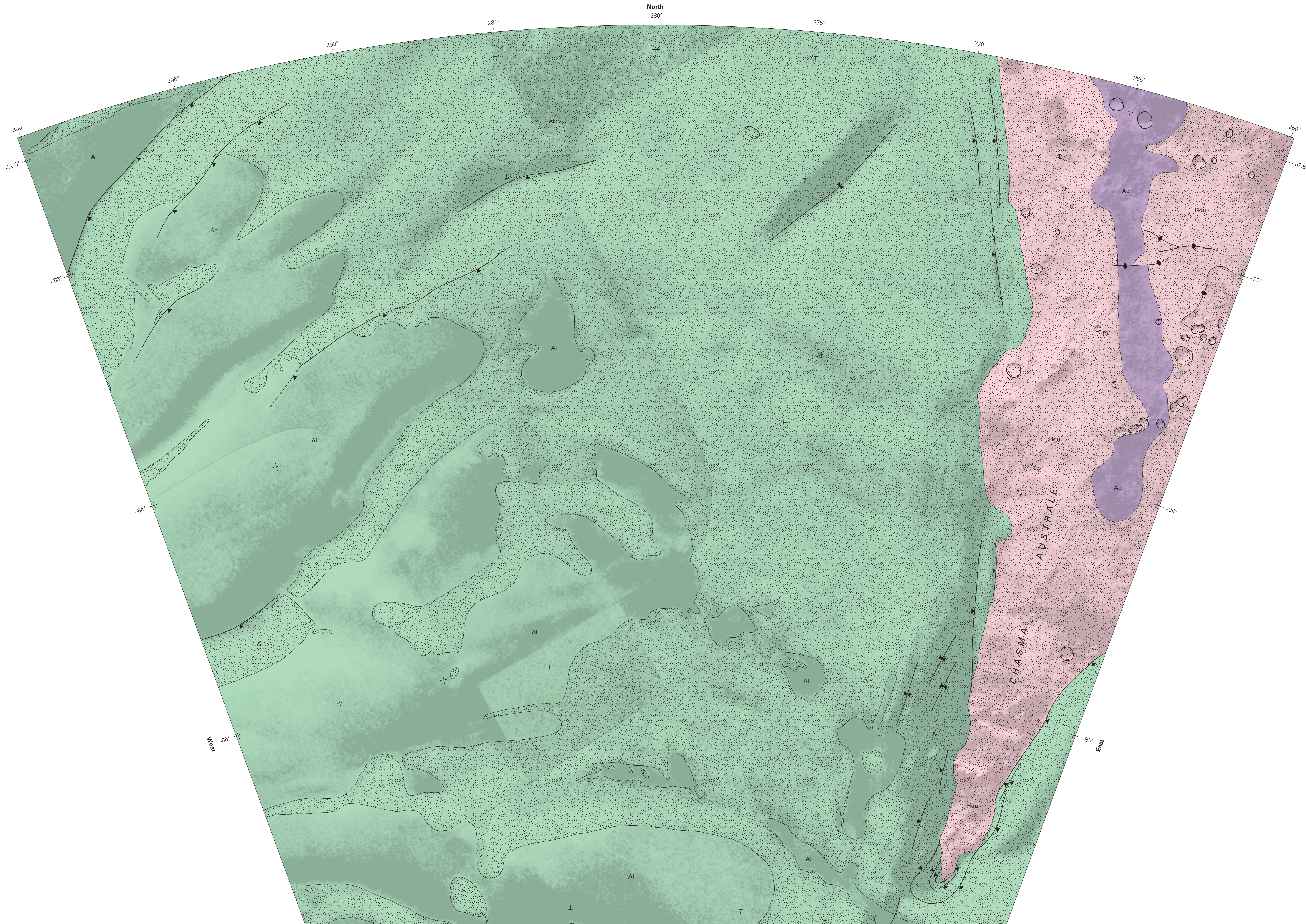
U.S. DEPARTMENT OF THE INTERIOR
U.S. GEOLOGICAL SURVEY

Prepared for the
NATIONAL AERONAUTICS AND SPACE ADMINISTRATION

ATLAS OF MARS
1: 500,000 GEOLOGIC SERIES
PLANUM AUSTRALE REGION—MARS
M 500k –85/280 G, 1998
MAP I–2595



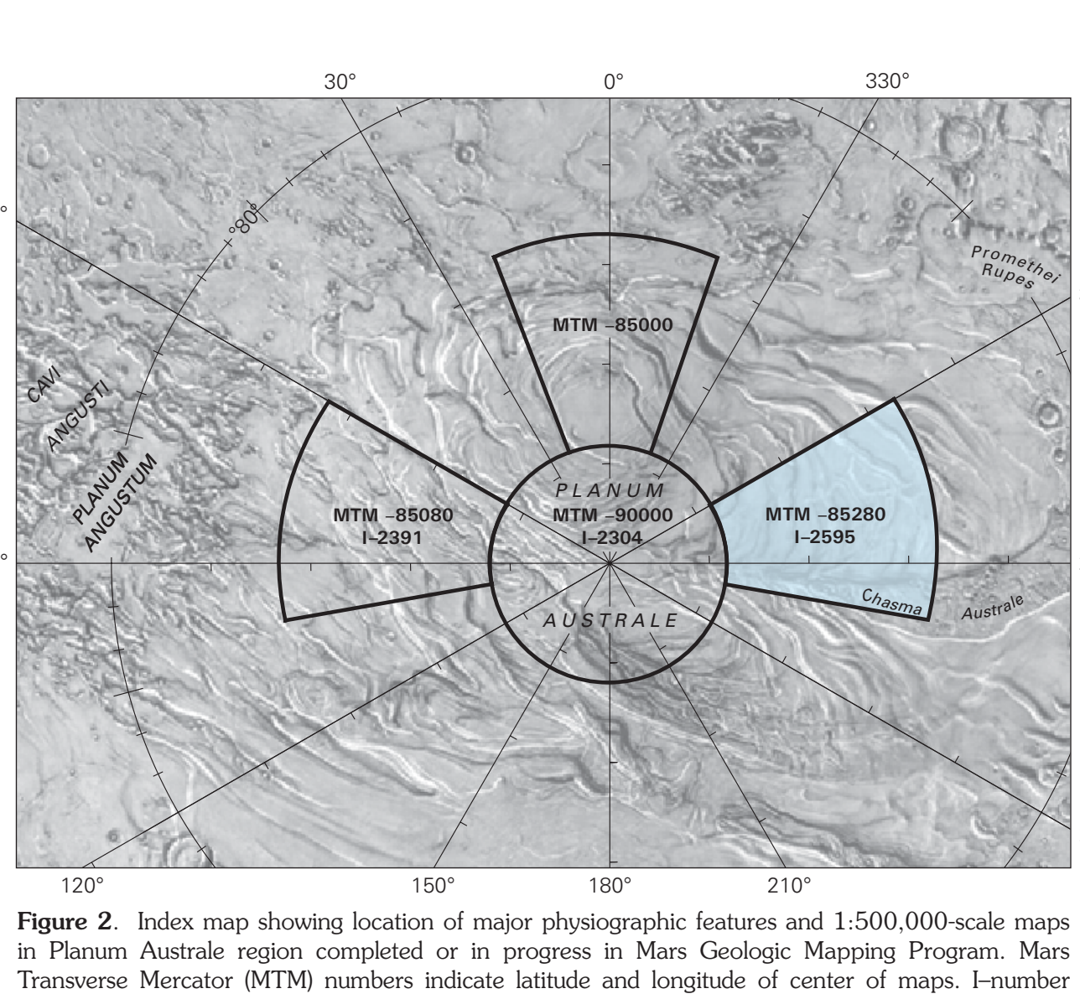


Figure 2. Index map showing location of major physiographic features and 1:500,000-scale maps in Planum Australe region completed or in progress in Mars Geologic Mapping Program. Mars Transverse Mercator (MTM) numbers indicate latitude and longitude of center of maps. I–number indicates published map.

Base from U.S. Geological Survey, 1986 .

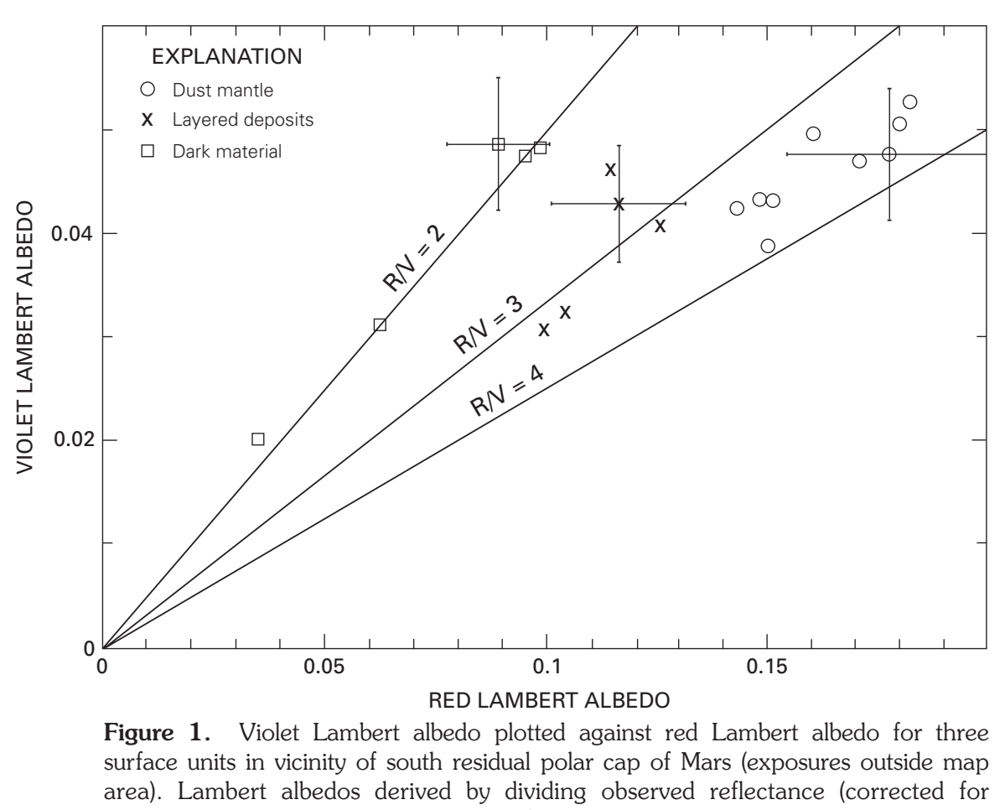


Figure 1. Violet Lambert albedo plotted against red Lambert albedo for three surface units in vicinity of south residual polar cap of Mars (exposures outside map area). Lambert albedos derived by dividing observed reflectance (corrected for atmospheric scattering) by cosine of incidence angle. Error bars represent combination of 13 percent uncertainty in absolute albedos and sampling errors in 5×5-pixel areas. Albedo variations along lines of constant red-to-violet ratio (R/V) mainly due to slope differences (Herkenhoff and Murray, 1990a). Colors of units are consistent with colors of similar units in north polar region (Thomas and Weitz, 1989).

Table 1. *Lambert albedos and colors of surface units in the south polar region (Herkenhoff and Murray, 1990a). Ranges indicate variations in color and albedo among various areas sampled*

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

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Edited by Derrick D. Hirsch; cartography by Mike Dingwell
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SCALE 1:500 000 (1 mm = 500 m) AT -87.5° LATITUDE
POLAR STEREOGRAPHIC PROJECTION
10 0 10 20 30 40 50 60 70 80 90 100
KILOMETERS

GEOLOGIC MAP OF THE MTM –85280 QUADRANGLE, PLANUM AUSTRALE REGION OF MARS

By
Ken Herkenhoff
1998

CORRELATION OF MAP UNITS

SYSTEM		Number of craters larger than 2 km in diameter per million square kilometers*
AMAZONIAN	▨ Ad	Less than 5
	Al	7 10
	unconformity	
		400
HESPERIAN	Hdu	
		800

*Plaunt and others, 1988

DESCRIPTION OF MAP UNITS

▨ **Dust mantle**—Bright, red material, widespread in map area, interannually variable distribution. Unit shown as it appeared in 1977. *Interpretation:* Thin (less than a few meters) dust layer covering underlying units without obscuring topographic features. Distribution ephemeral, transported by atmospheric suspension and deposited during major dust storms; partly removed and redistributed by winds at times.

Ad **Dark material**—Dark, reddish-gray material in Chasma Australe. *Interpretation:* Dark, saltating sand or agglomerates of dust formed upon erosion of layered deposits. Sand may be porous basalt grains eroded from thin layers or lenses within layered deposits. Agglomerates may be filamentary sublimation residue particles composed of magnetic dust grains (Herkenhoff and Murray,1990a)

Al **Layered deposits**—Widespread, horizontally layered unit having generally smooth surface at available image resolution. Color and albedo intermediate between those of dust mantle and dark material (table 1). *Interpretation:* Deposits of dust and water ice in unknown proportions, with lag or weathering rind probably covering surface. Unit extensively eroded in places; covered by dust mantle in many areas. Color and albedo suggest 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, marked by few sinuous ridges about 1 km wide and as much as 20 km long. Rough topographic grain terminates at contact with layered deposits. *Interpretation:* Volcanic plains exposed by erosion of overlying 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 approximately located or broadly gradational; queried where uncertain

Scarp base—Barb points downslope. Dashed where uncertain; forms contact in places

Ridge crest

Trough or groove

Crater rim—Showing crest

INTRODUCTION

The polar deposits on Mars are of great interest because they probably record martian climate variations (Thomas and others, 1992). The area shown on this map includes polar layered deposits with distinct low-albedo features and a sharp boundary between the layered deposits and the moderately cratered unit that forms the floor of Chasma Australe. Detailed mapping of this quadrangle was undertaken to further investigate the geologic relations between the albedo features and the layered deposits and to better constrain the recent geologic history of the south polar region. Dark dunes in the north polar region appear to be derived from erosion of the layered deposits, but the source of dark material in the south polar region is less clear (Thomas and Weitz, 1989). The presence of dark material in the brighter, redder layered deposits is paradoxical (Herkenhoff and Murray, 1990a); resolving this paradox is likely to result in a better understanding of the origin and evolution of the layered deposits and, therefore, the mechanisms by which global climate variations are recorded.

Published geologic maps of the south polar region of Mars have been based on images acquired by either Mariner 9 (Condit and Soderblom, 1978; Scott and Carr, 1978) or the Viking Orbiters (Tanaka and Scott, 1987). The extent of the layered deposits mapped previously from Mariner 9 data is different from that mapped using Viking Orbiter images, and the present map agrees with the map by Tanaka and Scott (1987): the floor of Chasma Australe is not mapped as layered deposits.

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 nonvolatile Amazonian units for this map and to test hypotheses for their origin and evolution. The colors and albedos of these units, as measured in places outside this map area, are presented in table 1 and figure 1. Accurately measuring the color and albedo of the units in this map area was not possible due to low signal/noise in the part of the red/violet mosaic (corrected for atmospheric scattering) that includes this area (Herkenhoff and Murray, 1990a). However, color/albedo unit boundaries in this area are visible in color mosaics that have not been corrected for atmospheric scattering effects. Therefore, while the color and albedo of various units on this map cannot be precisely quantified and compared with the values in table 1 and figure 1, color/albedo units can still be recognized. 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 slightly elongate rather than circular. One, 1.6 km in diameter at lat 86.6° S., long 268°, was recognized by Plaut and others (1988); the other, about 3 km in diameter, is at lat 82.8° 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 conclusions that the south polar layered deposits are Late Amazonian in age and that some areas have been exposed for at least 120 million years (Plaut and others, 1988; Herkenhoff and Murray, 1992, 1994). However, the recent cratering flux on Mars is poorly constrained, so inferred 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 about 1,600 km long and 1,200 km wide (U.S. Geological Survey, 1989, sheet 1). Its relief 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.

The topography of the south polar layered deposits has been studied only in the vicinity of the residual polar cap, so it is difficult to estimate the total thickness of the layered deposits. Dzurisin and Blasius (1975) combined Mariner 9 radio-occultation and stereophotogrammetric data and found that the region covered by the residual south polar ice cap is 1 to 2 km higher than the surrounding layered deposits. Areas of relatively complete frost cover are typically level, while defrosted scarps slope 1° to 5° overall. In some cases, the scarps form low-relief troughs that are asymmetrical in cross section. While photogrammetric data are lacking in this map area, brightness variations in several images of the layered deposits suggest that similar topographic relations exist here and in other areas of layered terrain outside the region studied by Dzurisin and Blasius (1975).

STRATIGRAPHY AND STRUCTURE

The oldest unit on this map is the upper member of the Hesperian-age Dorsa Argentea Formation (unit Hdu), which forms the floor of Chasma Australe in the northeast corner of the map area. The upper member is distinguished from the layered deposits by its numerous impact craters, mountains, and sinuous ridges. Tanaka and Scott (1987) used Viking Orbiter images to recognize flow fronts in the member outside this map area, 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, but their occurrence near the south pole suggests that ice has been involved in their formation. Better understanding of these features will require higher resolution imaging from future spacecraft. The sharp boundary between the upper member and the layered deposits at the base of scarps shows that the layered deposits overlie the upper member. Layering in the walls of Chasma Australe suggests that it was formed by erosion of the layered deposits and that the surface of the upper member has been exhumed in the chasma.

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 (Herkenhoff and Murray, 1992, 1994). 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 because of their terraced topography, especially 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 (Herkenhoff and Murray, 1992, 1994), 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.

Structural deformation in this area and in nearby quadrangles (Herkenhoff and Murray, 1992, 1994) appears to be minimal or absent, as no faulting or folding has been observed. The scarps and troughs in the layered deposits are interpreted as erosional rather than structural features because of the lack of folded or offset layers. An unusually steep, irregular scarp is present in the layered deposits at lat 83.3° S., long 297°, near the upper edge of the flank of a low-relief trough. The scarp appears to be fluted, with individual flutes as much as 1 km across, in a Mariner 9 image with 91 m/pixel resolution. This scarp is barely visible as a bright line in the best Viking Orbiter image of this area (383B27). Similar bright lines that are visible in other parts of this Viking image are mapped as scarps, but in most cases they cannot be seen in Mariner 9 images of the same area, perhaps due to greater atmospheric opacity. Such steep scarps were not found in either MTM –90000 (Herkenhoff and Murray, 1992) or MTM –85080 (Herkenhoff and Murray, 1994). 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. Either the dark material has been removed from the area by winds since the last episode of scarp retreat or erosion is continuing and dark material is simply not exposed in these scarps. 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 other map units, 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; Herkenhoff and Murray, 1994), but image resolution is insufficient to resolve dune forms. Deposition or redistribution of this unit may be continuing. 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 Paige and Keegan (1994) indicate that solid sand grains are not abundant in the map area. The dark material is therefore more likely composed of low-density aggregates of dust particles or very porous grains of basalt. We cannot distinguish between these two hypotheses using the available data in the map area. 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 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 (Herkenhoff and Murray, 1992, 1994). 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 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 boundary between the dust mantle and the layered deposits in the northwest corner of the map appears streaked in many cases. These streaks may be unique to this area, as they have not been seen in nearby quadrangles (Herkenhoff and Murray, 1992, 1994). The direction of the streaks is roughly parallel to the dip of the flanks of the large troughs in the layered deposits, suggesting that gravity has played a role in their formation. However, 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.

The differing crater densities and the contact relations between the layered deposits and the upper member of the Dorsa Argentea Formation seen in this quadrangle indicate that the layered deposits postdate the upper member. 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 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 great 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 dark residue particles. The streaks observed in the northwest corner 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 CO_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 future exploration.

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