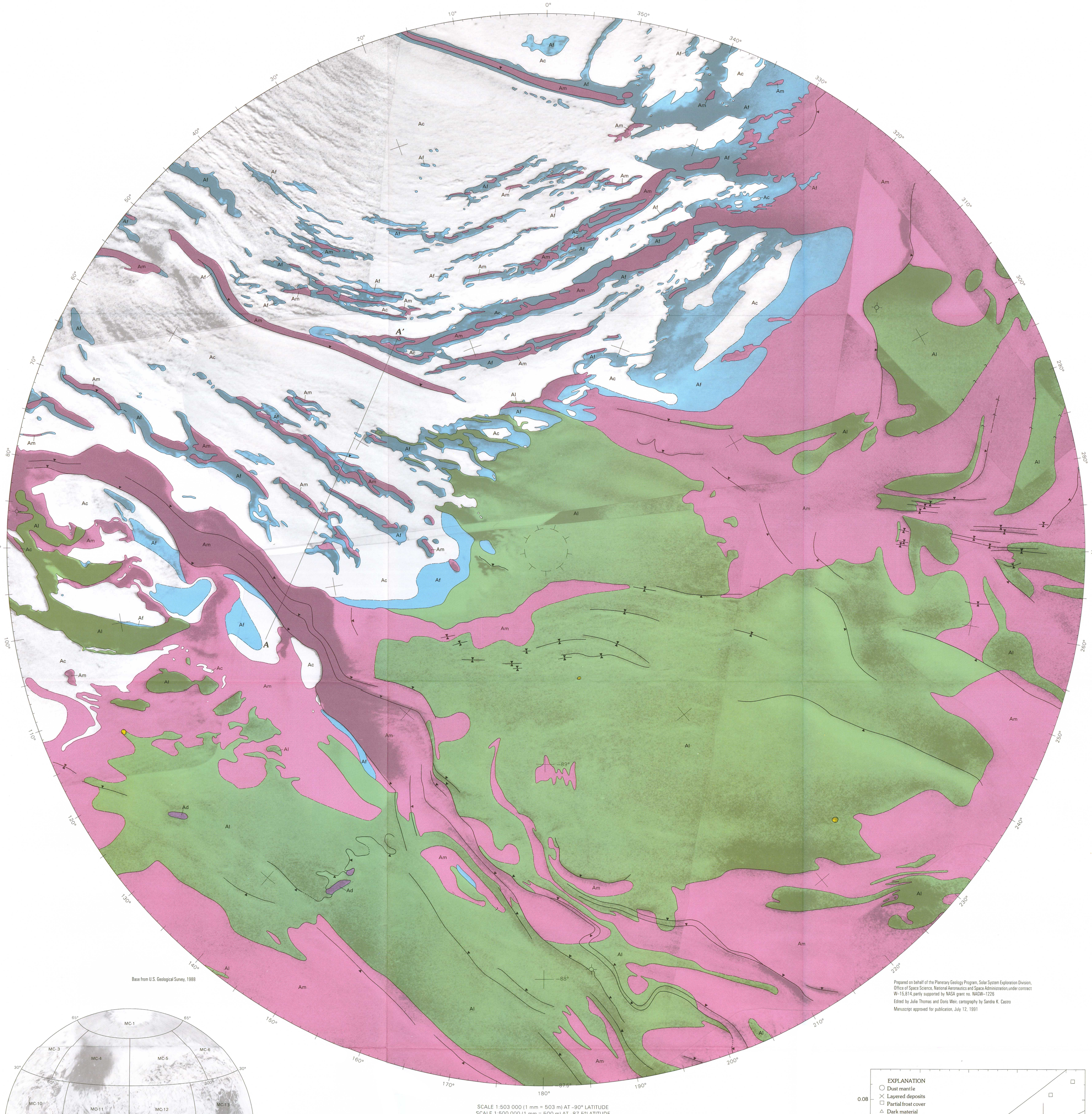
U.S. DEPARTMENT OF THE INTERIOR
U.S. GEOLOGICAL SURVEY

Prepared for the
NATIONAL AERONAUTICS AND SPACE ADMINISTRATION

ATLAS OF MARS
1:500,000 GEOLOGIC SERIES
MTM –90000 AREA, AUSTRALE REGION
M 500k 90/0 G, 1992
MAP I–2304



Base from U.S. Geological Survey, 1988

Prepared on behalf of the Planetary Geology Program, Solar System Exploration Division, Office of Space Science, National Aeronautics and Space Administration under contract W–15,814 partly supported by NASA grant no. NAGW-1226
Edited by Julia Thomas and Doris Weir; cartography by Sandra K. Castro
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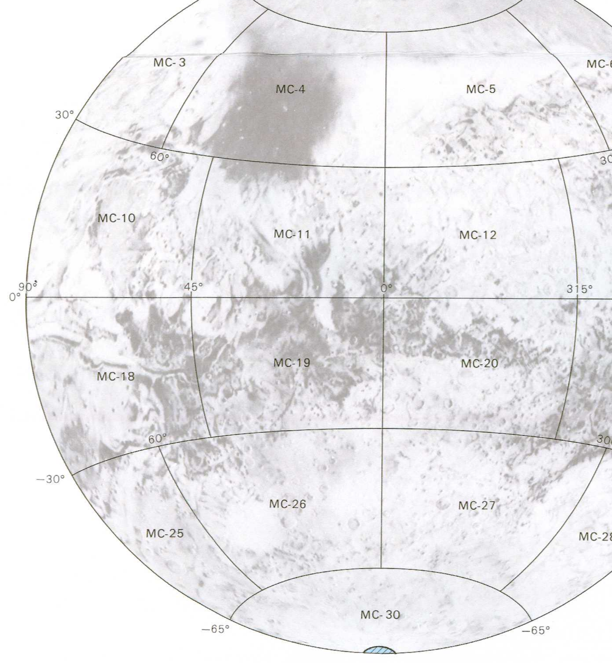
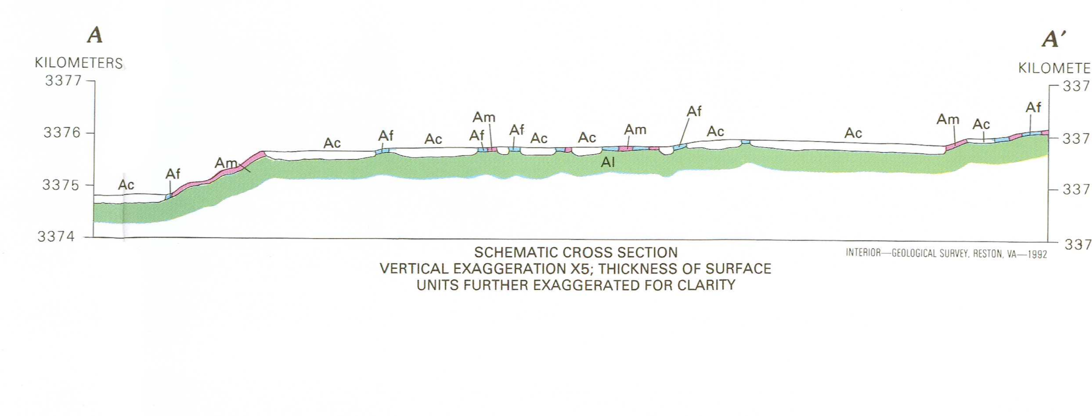
SCALE 1:503 000 (1 mm = 503 m) AT –90° LATITUDE
SCALE 1:500 000 (1 mm = 500 m) AT –87.5° LATITUDE
POLAR STEREOGRAPHIC PROJECTION

10 0 10 20 30 40 50 60 70 80 90 100
KILOMETERS



QUADRANGLE LOCATION
Photomosaic location is shown in the western hemisphere of Mars. The outline of 1:5,000,000-scale quadrangles is provided for reference.



SCHEMATIC CROSS SECTION
VERTICAL EXAGGERATION X5; THICKNESS OF SURFACE UNITS FURTHER EXAGGERATED FOR CLARITY

CORRELATION OF MAP UNITS

SERIES	HIGH-ALBEDO MATERIALS	LOW-ALBEDO MATERIALS	NUMBER OF CRATERS LARGER THAN 2 KILOMETERS IN DIAMETER PER MILLION SQUARE KILOMETERS*
Upper Amazonian	Ac Af	Am Ad	Less than 5
		Al	7
			10

*Plaut and others, 1988

DESCRIPTION OF MAP UNITS

HIGH-ALBEDO MATERIALS

Ac **Residual polar ice cap**—Minimum extent as viewed by Mariner 9 in 1972. High to intermediate albedo, cover incomplete in many areas. Albedo patterns roughly parallel to dark bands of unfrosted ground, similar in both years of spacecraft observations (1972 and 1977). *Interpretation:* Water-ice residual cap covered by carbon dioxide (CO_2) frost. Seasonal CO_2 frost may completely sublime in some years, exposing water-ice cap (Jakosky and Barker, 1984). Incompleteness of cover due to topographic roughness of underlying surface: some areas receive greater insolation and are therefore defrosted during summer

Af **Partial frost cover**—Covers areas adjacent to residual polar ice cap. Both color and albedo intermediate between those of residual polar ice cap and dust mantle. Albedo gradually decreases throughout southern summer. Unit located in same areas during both years of spacecraft observations. *Interpretation:* Mixture of CO_2 frost and bare ground, commonly patchy at scales below resolution of available images. Surface roughness may allow frost to remain in topographic depressions while frost sublimes from sunward-facing slopes

LOW-ALBEDO MATERIALS

Am **Dust mantle**—Bright, red material covering layered deposits without obscuring topographic features. Interannually variable distribution. *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. Dust possibly removed from surface of high-albedo units by solar heating and sinking of grains into frost (Paige, 1985)

Ad **Dark material**—Dark, neutrally colored material in topographic depressions. Rare in map area but also found in nearby areas. *Interpretation:* Dark, saltating sand or agglomerates of dust formed upon erosion of layered deposits. Agglomerates may be filamentary sublimation residue particles composed of magnetic dust grains (Herkenhoff and Murray, 1990a)

Al **Layered deposits**—Horizontally layered unit with generally smooth surface at available image resolution. Both color and albedo intermediate between those of dust mantle (unit Am) and dark material (unit Ad). Grooves or troughs common in some areas. *Interpretation:* Deposits of dust and water ice in unknown proportions, believed to underlie all units described above. Ice not expected to be stable at surface, 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

Contact—Dashed where uncertain or broadly gradational, queried where doubtful

Scarp—Line marks bottom of slope, barb points downslope. Dashed where uncertain; dotted where covered; queried where doubtful. Used as contact in places

Trough or groove

Crater—Total of three recognized, between 0.9 and 1.5 km in diameter

Dome or knob—Age and origin uncertain

INTRODUCTION

Published geologic maps of the south polar region of Mars, made using either Mariner 9 (Condit and Soderblom, 1978) or Viking Orbiter (Tanaka and Scott, 1987) images, identified only layered deposits and polar ice within this map area. Layered deposits probably underlie all of the other units shown on this map. The residual polar ice cap, partial frost cover, and two low-albedo units are also mapped here. These units were first recognized and 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 five mapped color/albedo units. The 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 three impact craters, all in the layered deposits, have been found in the area mapped. Two craters were recognized by Plaut and others (1988); the third, about 0.9 km in diameter, is at lat 87.9° S., long 113.6° in an area that was not studied by them. Although the crater statistics are poor (only 16 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 on 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 135 m/pixel. (The "less than 100 m per picture element" in Notes on Base of the controlled photomosaic (U.S. Geological Survey, 1988) 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 80 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 covers only a small part of 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 figure 2).

Dzurisin and Blasius (1975) combined Mariner 9 radio occultation and stereophotogrammetric 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, but a slight (less than 1°) regional slope away from the residual cap within this map area is indicated. 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. The steepest scarp found by Dzurisin and Blasius (1975), at lat 88.8° S., long 100°, is about 1 km high and appears to extend outside the area of the residual cap. We have used the same stereopair of Mariner 9 images to derive detailed photogrammetric data across this and other scarps and troughs along the cross section *A–A′*. Absolute elevation uncertainties are generally a few hundred meters, except near the end of the section (*A′*), where uncertainties are as large as 1.8 km. Our results are similar to those of Dzurisin and Blasius (1975), and we note that the large scarp at lat 88.8° S., long 100° appears to be terraced. The local magnitudes of the slopes cannot be determined due to the lack of stereophotogrammetric control points, but they are probably greater than the 5° average slope of the entire scarp.

The defrosted bands within the residual cap shown on this map probably slope away from the regional high centered outside this map area near lat 86.5° S., long 10°. However, these bands are not mapped as scarps unless stereophotogrammetric data are available, because albedo contrasts within the cap obscure topographic shading. Defrosted bands that are either smooth or irregular in outline are apparent, but the origin of the different types is uncertain. Where stereophotogrammetric data are available, the smooth bands appear to slope more steeply (see cross section) than the irregular bands, whose relief is too low to resolve by photogrammetry.

STRATIGRAPHY AND STRUCTURE

The layered deposits (unit Al) are recognized by their intermediate color and albedo. They unconformably overlie Hesperian and Noachian units in the south polar region (Tanaka and Scott, 1987) and appear to be the oldest surface unit in the map area. The horizontal to subhorizontal beds that make up the layered deposits are exposed in defrosted scarps and troughs. Layers are recognizable due to their terraced topography, accented in places by differential frost retention. Photoclinometric analysis of an exposure of layered deposits just outside the map area (Herkenhoff and Murray, 1990b) indicates that layers are 100 to 300 m thick, but thinner layers, if present, cannot be detected due to limitations in image resolution. Thinner layers (14–46 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 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). No faulting or folding of the deposits has been observed.

The dust mantle (unit Am) and dark material (unit Ad) unconformably overlie the layered deposits, having been deposited from atmospheric suspension and by saltation, respectively. The residual polar ice cap (unit Ac) and partial frost cover (unit Af) may or may not lie conformably upon the layered deposits. Areas covered by these units may be sites of current layered-deposit formation. 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.

Dark, neutrally colored material (unit Ad) occurs in only three places in the map area, near lat 88.2° S., long 145°. The location of this material in topographic depressions here and elsewhere in the south polar region indicates that it is transported by saltation (Herkenhoff and Murray, 1990a). The unit may be composed of sand-size particles or low-density aggregates of dust grains, and it is more abundant in other parts of the layered terrain outside this map area. Dark material is found only on exposed layered deposits, which suggests that saltation of dark particles strips away the dust mantle. Local saltation of the dark particles in the unit would also be expected to eject dust grains into suspension or to allow them to trickle down between dark particles and out of sight. This unit may have been deposited recently, perhaps with partial mantle continuing until the present. Image resolution is insufficient to resolve dune forms, and there is no evidence of temporal variations in the extent or location of the dark material.

The bright, red dust mantle (unit Am) does not appear to obscure topography, and it is therefore probably no more than a few meters thick. The extent of the dust mantle changed in some areas during the 3 Mars years between the Mariner 9 and Viking Missions, indicating that it is ephemeral. Between lat 88.9° and 89.4° S. and long 170° and 250° the dust cover is patchy on a kilometer scale. Dust on or near the surface of the residual polar ice cap may sink into the frost after individual grains are heated by insolation, effectively removing them from view (Paige, 1985).

The partial frost cover (unit Af) generally has uniform albedo at the resolution of available images. This unit is interpreted as a mixture of seasonal frost and bare ground based upon its albedo, color, and temporal variability. Although patches of frost and bare ground can be distinguished in some places, the scale of mixing is commonly below the resolution of the images. Areas of this unit are observed to darken as summer progresses, which suggests that CO_2 frost is subliming throughout the season. Topographic roughness on centimeter to decameter scales may allow seasonal frost to remain in shadowed depressions, protected from solar heating (Herkenhoff and Murray, 1990a). Many of the boundaries between the partial frost cover and adjacent units are narrowly gradational at the resolution of the images but are drawn as solid lines for simplicity.

The albedo of the residual polar ice cap is highly variable, so that the contact with the partial frost cover unit is gradational in many areas. The albedo variations occur at many different spatial scales, probably extending below the resolution of the images. The variations in albedo are probably due (at least in part) to incomplete seasonal frost cover, perhaps caused by topographic roughness of the underlying layered deposits. Paige and others (1990) showed that the residual cap was cooled to the temperature of sublimating CO_2 during the summer of 1972, indicating that seasonal frost was present throughout that season. However, Jakosky and Barker (1984) have interpreted global water-vapor measurements made in 1969 by Barker and others (1970) as indicative of complete sublimation of the south polar seasonal CO_2 frost that year, exposing a residual water-ice cap. Some of the albedo variations within the residual polar ice cap observed in later years by orbiting spacecraft may therefore be caused by differences in the amount of dust in the water-ice cap. This exposed dirty water ice may actually be the top of the unweathered layered deposits. The presence of perennial frost is expected to aid in the retention of dust deposits (James and others, 1979), so that areas that are covered by frost all year are the most likely sites of layered deposit formation.

The summer albedo patterns within the south polar cap appeared in the same areas during both the Mariner 9 and Viking Missions, which suggests that they are caused by underlying topography. The albedo within the cap is complexly variegated, and only the contiguous defrosted areas have been mapped. Many of the elongate defrosted areas curve at their ends, some forming crescent-shaped bands. It is not clear whether these curved features are due to underlying sedimentary or impact structures or are formed by erosional processes.

Three small domes or knobs, each about 1 km across, occur within the exposed layered deposits at lat 87.6° S., long 87°, lat 88.1° S., long 307°, and lat 88.0° S., long 186°. These features may be the eroded remains of impact structures, but better image resolution is needed to test this hypothesis. A hypervelocity impact in the layered deposits would be expected to melt any water ice that is present at depth, perhaps forming a lens of debris and recrystallized ice below the crater upon cooling. This concentration of debris might be expected to be more resistant to weathering than the surrounding icy layered deposits and, when eroded, might form the positive features seen here. Alternatively, the knobs may be volcanic in origin.

GEOLOGIC PROCESSES AND HISTORY

The polar layered deposits (unit Al) 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 millions of 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, in press). In particular, the apparent contrasting ages of the north and south polar layered deposits, as indicated by their different crater statistics (Cutts and others, 1976; Plaut and others, 1988), are paradoxical. The geology of this map area illustrates some of the processes that are important in the evolution of the southern deposits.

With the exception of areas covered by perennial frost, the south polar layered deposits appear to have undergone net erosion in the recent geologic past. Solar heating of the 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 (unit Am) that covers much of the Martian surface. The magnetic dust may preferentially form filamentary sublimation residue particles (Storrs and others, 1988) that eventually erode and saltate, ejecting the remaining dust into suspension. Dark particles about 100 microns in size will continue to saltate until trapped by an obstacle or in a depression, forming isolated patches of 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 mantle 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. Layers may be currently forming where frost remains on the surface throughout the year (Herkenhoff and Murray, 1990a).

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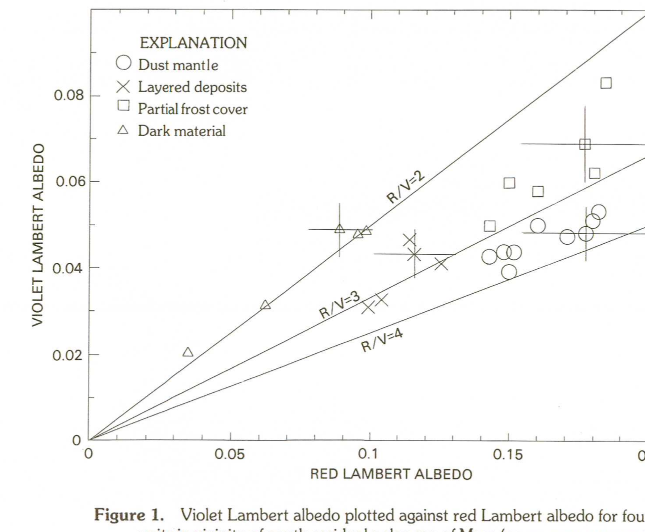

Figure 1. Violet Lambert albedo plotted against red Lambert albedo for four surface units in vicinity of south residual polar cap of Mars (some exposures outside this map area). Lambert albedos derived by dividing observed reflectance (corrected for atmospheric scattering) by cosine of incidence angle. 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.

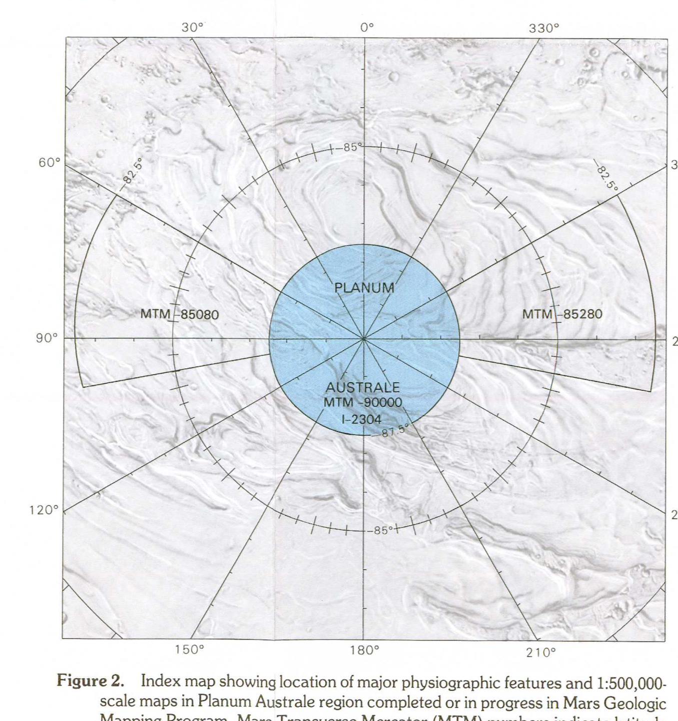

Figure 2. Index map showing location of major physiographic features and 1:500,000-scale maps in Planum Australe region completed or in progress in Mars Geologic Mapping Program. Mars Transverse Mercator (MTM) numbers indicate latitude and longitude of center of maps. I-number indicates published geologic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

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

Unit	Violet	Red	R/V
Residual polar ice cap	0.18-0.43	0.27-0.53	1.2-1.6
Partial frost cover	0.05-0.09	0.14-0.21	2.2-2.9
Dust mantle	0.04-0.05	0.14-0.18	3.2-3.8
Dark material	0.02-0.05	0.04-0.10	1.8-2.1
Layered deposits	0.03-0.05	0.10-0.13	2.5-3.2

GEOLOGIC MAP OF THE MTM –90000 AREA, PLANUM AUSTRALE REGION OF MARS

By

Ken Herkenhoff and Bruce Murray

1992

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