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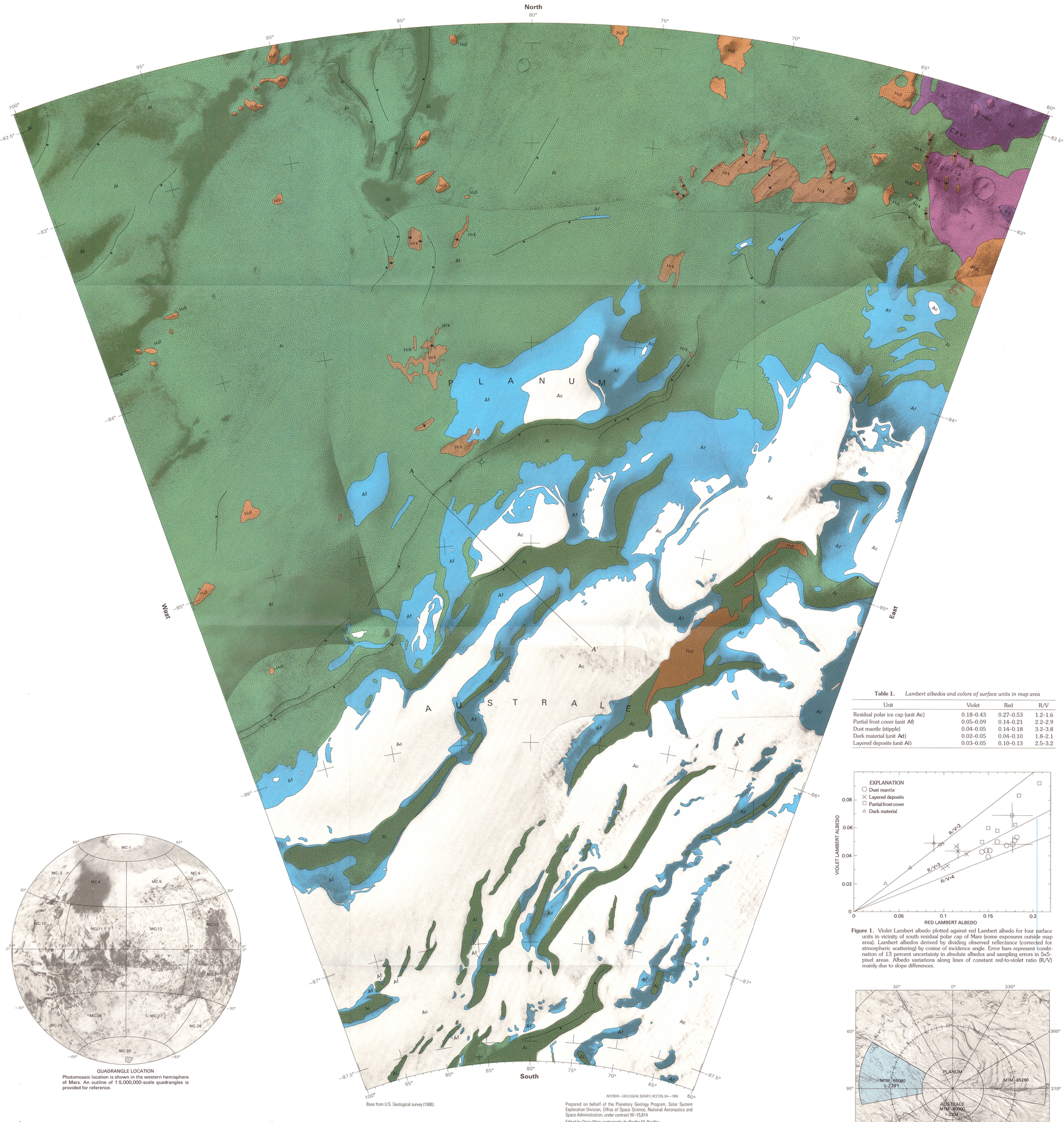
ATLAS OF MARS
1:500,000 GEOLOGIC SERIES
PLANUM AUSTRALE REGION
M 500 K –85/80 G, 1994
I–2391



Base from U.S. Geological survey (1986)

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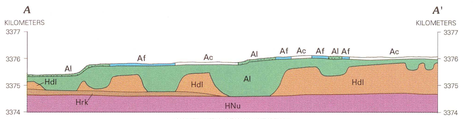
INTERIOR—GEOLOGICAL SURVEY, RESTON, VA—1994

SCALE 1:500 000 (1 mm = 500 m) AT –87.5° LATITUDE
POLAR STEROGRAPHIC 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. An 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

GEOLOGIC MAP OF THE MTM –85080 QUADRANGLE, PLANUM AUSTRALE REGION OF MARS

By
Ken Herkenhoff and Bruce Murray
1994

CORRELATION OF MAP UNITS

SYSTEM	HIGH-ALBEDO MATERIALS	LOW-ALBEDO MATERIALS	NUMBER OF CRATERS LARGER THAN 2 AND 5 KM IN DIAMETER PER MILLION SQUARE KILOMETERS*	
			2	5
AMAZONIAN	Ac Af	Ad	Less than 5	
		Al	7	
		Unconformity	10	
HESPERIAN		Hdl Hrk HNu	400	
			600	100
			1000	
			1200	200
NOACHIAN				400

*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 within cap 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 (table 1). 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

Ad **Dust mantle**—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. Dust possibly removed from surface of high-albedo units by solar heating and sinking of grains into frost (Paige, 1985), or during sublimation of seasonal CO_2 frost

Al **Dark material**—Dark, neutrally colored material in topographic depression in northeast corner of quadrangle. *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). Color and albedo of unit consistent with incomplete dune cover overlying brighter material

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). Unit thins and layering becomes less conspicuous toward margins. 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

Hdl **Lower member, Dorsa Argentea Formation**—Forms plains in northern part of quadrangle characterized by pits as much as 1 km deep (Tanaka and Scott, 1987) in otherwise smooth surface. Layered deposits partly bury unit in some places and are found within pits outside map area. Exposures are high standing except where indicated. *Interpretation:* Massive sedimentary unit eroded by wind, perhaps aided by sublimation of volatiles in some areas to form pits (Sharp, 1973). Erosion of pits completed before deposition of layered deposits over most of unit (Condit and Soderblom, 1978)

Hrk **Ridged and knobby material**—Scattered exposures in northern part of quadrangle. Marked by linear to gently curving, narrow, near-vertical ridges. Ridge heights of around 100 m estimated from shadow lengths; horizontal spacings typically a few kilometers. Representative area outside map area at lat 82° S., long 63° (Sharp, 1973). *Interpretation:* Ridges are resistant igneous dikes or ice wedges covered by dust mantle

HNu **Undivided material**—Rough material exposed in northeast corner of map area, where covered by bright, red dust mantle. Corresponds to undivided material mapped by Tanaka and Scott (1987). *Interpretation:* Basement rocks underlying all other units; landforms subdued by debris mantle (thicker than dust mantle) or degraded by ground ice (Squyres and Carr, 1986)

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—Only major, continuous ridges mapped

Crater rim crest—One, 7 km in diameter, recognized at lat 82.85° S., long 61.4°

Partly buried crater—One, 4 km in diameter, recognized at lat 82.6° S., long 80.3°

Dome or knob—Age and origin uncertain

Depression

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 mapped extent of the southern layered deposits differs in many places on these maps and on our map. These differences reflect the difficulty in accurately determining the location of the contact between the layered deposits and subjacent units. The polar layered deposits gradually thin toward their margin in many places, and the smooth surface features that characterize the layered deposits are also found on other sedimentary blankets in the south polar region (Murray and others, 1972; Sharp, 1973).

Previous workers have also reached different conclusions regarding the origin of the lower member of the Dorsa Argentea Formation, which was named by Tanaka and Scott (1987) and interpreted by them as volcanic in origin (based on the observation of flow fronts in areas far outside this quadrangle). The lower member, previously called pitted material, and other sedimentary units were recognized in Mariner 9 images and described by Murray and others (1972), Sharp (1973), and Cutts (1973b). Sharp (1973) argued for exhumation of pits by wind, perhaps aided by sublimation of volatiles. He concluded that the massive pitted sediments of the lower member unconformably overlie older massive units. We have mapped one of these older units as ridged and knobby material. Condit and Soderblom (1978) found some layered deposits within pits, which indicates that erosion of the pits was completed before accumulation of the layered deposits commenced. Howard's (1981) suggestion that the pits may be formed by basal melting of ground ice is consistent with either a volcanic or sedimentary origin for the lower (pitted) member. Plaut and others (1988) mapped the extent of the pitted material and found that it overlies volcanic plains wherever the contact is visible. They concluded that the pitted material is no more than about 1 km thick and is about 3.3 billion years old (Late Hesperian).

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 Amazonian units for this map and to test hypotheses for their origin and evolution. 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.

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 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 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 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). A small part of the Cavi Frigoris, characterized by steep-sided hollows or pits in the lower member of the Dorsa Argentea Formation, appears along the north edge of the map area.

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. This slope may be due to the regional slope of underlying units (shown in the cross section), as indicated by the exposure of the lower member of the Dorsa Argentea Formation near the center of the quadrangle. 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. We have used a stereopair of Mariner 9 images to derive detailed photogrammetric data across scarps and troughs along the cross section; absolute elevation uncertainties are 100 to 200 m.

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° (Dzurisin and Blasius, 1975). However, these bands are not shown as scarps unless stereophotogrammetric data are available, because albedo contrasts within the cap obscure topographic shading. As shown in the cross section, the relief across some dark bands is less than the uncertainties in the stereogrammetric elevations. 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 than the irregular bands, whose relief is too low to resolve by photogrammetry.

STRATIGRAPHY AND STRUCTURE

The oldest mapped unit, unit HNu, is distinguished by its rough surface texture and an impact crater 7 km in diameter. The crater appears degraded, perhaps due to the presence of a debris mantle. Given the resolution of the Mariner 9 images of this area (90–100 m/pixel), the mantling deposit must be between a few hundred and a few tens of meters thick. Alternatively, the degradation of surface features may be due to the presence of ground ice, as suggested by Squyres and Carr (1986). The mantling or degradation occurred during Early Hesperian time, as indicated by crater counting in areas outside this quadrangle (Plaut and others, 1988).

The ridged and knobby material (unit Hrk) contains linear ridges similar in form to those near lat 82° S., long 63°, an area named "Inca City" by Sharp (1973) because of its regular geometric patterns. However, the rectilinear arrangement of these ridges is not as conspicuous as in the "Inca City." The stratigraphic relation between the ridged and knobby unit and the lower member of the Dorsa Argentea Formation is not clear in this quadrangle, so we adopt Sharp's (1973) inference that the lower member unconformably overlies the ridged and knobby unit. A less preferred interpretation is that the ridged and knobby unit may be large ice wedges within the layered deposits (unit Al).

The lower member of the Dorsa Argentea Formation (unit Hdl) does not show evidence of impacts in this map area, although a few impact craters are found on the member north of this quadrangle. Erosion of pits in the lower member appears to have preceded burial by the layered deposits (Condit and Soderblom, 1978), so that the initial deposition of the layered deposits was on the pitted surface of the member. The absence of impact craters on the lower member in this quadrangle suggests that it is mantled by layered deposits (not mapped); however, erosion of the layered deposits has apparently exhumed the member in many places. Exhumation may not be complete even where the member protrudes through the layered deposits, perhaps because the basal part of the layered deposits is more resistant than the rest of the unit. If so, the basal part must be thick enough to bury craters on the original surface of the lower member, but not so thick as to obscure the deeper erosional pits.

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 exposed in defrosted scarps and troughs. Similar exposures have been recognized in the north polar layered deposits (Cutts, 1973a; 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, especially where accented by differential frost retention (Herkenhoff and Murray, 1990b). Several layers are visible in an erosional remnant of layered deposits at lat 82.6° S., long 85°. 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). No faulting or folding of the deposits has been observed. The basal part of the layered deposits appears to mantle much of the terrain in the northern part of the map. Layers cannot be seen in this mantle, but it is conformable with the layered deposits and is included in the unit. The basal part may contain less ice than the rest of the layered deposits, making it more resistant to sublimation and erosion. Alternatively, it may be debris eroded from the layered deposits and transported onto nearby terrains, or a lag deposit resulting from incomplete erosion of overlying layered deposits. In either case, the unit appears to decrease in thickness toward the north. 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.

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 residual polar ice cap (unit Ac) and partial frost cover (unit Af) also overlie the layered deposits (though the degree of conformity of their contacts is unknown) and may be sites of current layered-deposit formation.

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). 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. Where it occurs in the northeast corner of the quadrangle, it 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) layered deposits 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. Incomplete dune cover would decrease the apparent albedo and redness of the surface, as is observed in various parts of this quadrangle.

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 some areas during the 3 Mars years between the Mariner 9 and Viking Missions, indicating that it is ephemeral in those areas at least. Its boundary is mapped here as it appeared during the Viking Mission in 1977. Also evident are some changes in dust distribution during the 30 days between Viking Orbiter 2 orbits 390 and 421; we have mapped the distribution as it appeared in the images of highest quality. Dust on or near the surface of the residual polar cap may sink into the frost after individual grains are heated by insolation, effectively removing them from view (Paige, 1985). Alternatively, sublimation of seasonal CO_2 frost may entrain dust particles and remove them from the ice cap. In this case, dust could be retained on the cap only if it is deposited during the late summer, when the seasonal frost has completely sublimed. The slightly red color of the residual cap (table 1) indicates that red dust is mixed with the frost.

The partial frost cover generally has uniform albedo at the resolution of available images. This unit is interpreted as a mixture of seasonal frost and bare ground on the basis of 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 Mariner 9 images, but they 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 likely due (at least in part) to incomplete seasonal frost cover, perhaps caused by topographic roughness in the underlying layered deposits. In any case, areas of the highest albedos must be covered by nearly pure ice or frost (Clark and Lucey, 1984). Paige and others (1990) showed that seasonal CO_2 frost was present on the residual cap throughout the summer of 1972. 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 cap 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 thought to aid in the long-term retention of dust deposits (James and others, 1979), so that areas 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 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, for example, near lat 86.1° S., long 68°. It is not clear whether these curved features are due to underlying structures or erosional processes.

Three small domes or knobs, each 1 to 2 km across, occur within the layered deposits at lat 87.6° S., long 87° (also mapped by Herkenhoff and Murray, 1992), lat 84.6° S., long 83°, and lat 85.7° S., long 98°. 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 domes may be volcanic in origin or somehow related to the underlying units.

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, 1973a; 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 contrasting ages of the north and south polar layered deposits, as indicated by their different crater densities (Cutts and others, 1976; Plaut and others, 1988), are 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. Layers may be currently forming where frost remains on the surface throughout the year (Herkenhoff and Murray, 1990a).

Alternatively, the dark material (unit Ad) may be solid sand grains rather than sublimation residue particles (Thomas and Weitz, 1989). In this case, codeposition of dust and ice to form the layered deposits is implied. Saltating sand will eject dust into suspension, so that the dust must somehow be cemented to permit codeposition with sand (Herkenhoff and Murray, 1990a). We cannot distinguish between these two hypotheses using the available data in the map area.

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REFERENCES CITED

Barker, E.S., Schorn, R.A., Woszczyk, Andrzej, Tull, R.G., and Little, S.J., 1970, Mars: Detection of atmospheric water vapor during the southern hemisphere spring and summer season: Science, v. 170, p. 1308–1310.
Blasius, K.R., Cutts, J.A., and Howard, A.D., 1982, Topography and stratigraphy of Martian polar layered deposits: Icarus, v. 50, p. 140–160.
Carr, M.H., 1982, Periodic climate change on Mars: Review of evidence and effects on distribution of volatiles: Icarus, v. 50, p. 129–139.
Clark, R.N., and Lucey, P.G., 1984, Spectral properties of ice-particulate mixtures and implications for remote sensing 1. Intimate mixtures: Journal of Geophysical Research, v. 89, p. 6341–6348.
Condit, C.D., and Soderblom, L.A., 1978, Geologic map of the Mare Australe area of Mars: U.S. Geological Survey Miscellaneous Investigations Series Map I–1076, scale 1:5,000,000.
Cutts, J.A., 1973a, Nature and origin of layered deposits of the Martian polar regions: Journal of Geophysical Research, v. 78, p. 4231–4249.
———1973b, Wind erosion in the Martian polar regions: Journal of Geophysical Research, v. 78, p. 4211–4221.
Cutts, J.A., Blasius, K.R., Briggs, G.A., Carr, M.H., Greeley, Ronald, and Masursky, Harold, 1976, North polar region of Mars: Imaging results from Viking 2: Science, v. 194, p. 1329–1337.
Cutts, J.A., Blasius, K.R., and Roberts, W.J., 1979, Evolution of Martian polar landscapes: Interplay of long-term variations in perennial ice cover and dust storm intensity: Journal of Geophysical Research, v. 84, p. 2975–2994.
Dzurisin, Daniel, and Blasius, K.R., 1975, Topography of the polar layered deposits of Mars: Journal of Geophysical Research, v. 80, p. 3286–3306.
Herkenhoff, K.E., and Murray, B.C., 1990a, Color and albedo of the south polar layered deposits on Mars: Journal of Geophysical Research, v. 95, no. B2, p. 1343–1358.
———1990b, High resolution topography and albedo of the south polar layered deposits on Mars: Journal of Geophysical Research, v. 95, no. B9, p. 14,511–14,529.
———1992, Geologic map of the MTM –90000 area, Planum Australe region of Mars: U.S. Geological Survey Miscellaneous Investigations Series Map I–2304, scale 1:500,000.
Hofstadter, M.D., and Murray, B.C., 1990, Ice sublimation and rheology: Implications for the Martian polar layered deposits: Icarus, v. 84, p. 352–361.
Howard, A.D., 1981, Etched plains and braided ridges of the south polar region of Mars: Features produced by basal melting of ground ice? [abs.], *in* Reports of Planetary Geology Program—1981: National Aeronautics and Space Administration Technical Memorandum 84211, p. 286–288.
Howard, A.D., Cutts, J.A., and Blasius, K.R., 1982, Stratigraphic relationships within Martian polar cap deposits: Icarus, v. 50, p. 161–215.
Jakosky, B.M., and Barker, E.S., 1984, Comparison of ground-based and Viking Orbiter measurements of Martian water vapor: Variability of the seasonal cycle: Icarus, v. 57, p. 322–334.
James, P.B., Briggs, Geoffrey, Barnes, Jeffrey, and Spruck, Andrea, 1979, Seasonal recession of Mars' south polar cap as seen by Viking: Icarus, v. 68, p. 422–461.
Murray, B.C., Soderblom, L.A., Cutts, J.A., Sharp, R.P., Milton, D.J., and Leighton, R.B., 1972, Geological framework of the south polar region of Mars: Icarus, v. 17, p. 328–345.
Paige, D.A., 1985, The annual heat balance of the Martian polar caps from Viking observations: Ph.D. thesis, California Institute of Technology, Pasadena.
Paige, D.A., Herkenhoff, K.E., and Murray, B.C., 1990, Mariner 9 observations of the south polar cap of Mars: Evidence for residual CO_2 frost: Journal of Geophysical Research, v. 95, p. 1319–1335.
Plaut, J.J., Kahn, Ralph, Guinness, E.A., and Arvidson, R.E., 1988, Accumulation of sedimentary debris in the south polar region of Mars and implications for climate history: Icarus, v. 76, p. 357–377.
Pollack, J.B., and Toon, O.B., 1982, Quasi-periodic climate changes on Mars: A review: Icarus, v. 50, p. 259–287.
Scott, D.H., and Carr, M.H., 1978, Geologic map of Mars: U.S. Geological Survey Miscellaneous Investigations Series Map I–1083, scale 1:25,000,000.
Sharp, R.P., 1973, Mars: South polar pits and etched terrain: Journal of Geophysical Research, v. 78, p. 4222–4230.
Soderblom, L.A., Malin, M.C., Cutts, J.A., and Murray, B.C., 1973, Mariner 9 observations of the surface of Mars in the north polar region: Journal of Geophysical Research, v. 78, p. 4197–4210.
Squyres, S.W., 1979, The evolution of dust deposits in the Martian north polar region: Icarus, v. 40, p. 244–261.
Squyres, S.W., and Carr, M.H., 1986, Geomorphic evidence for the distribution of ground ice on Mars: Science, v. 231, p. 249–252.
Storrs, A.D., Fanale, F.P., Saunders, R.S., and Stephens, J.B., 1988, The formation of filamentary sublimate residues (FSR) from mineral grains: Icarus, v. 76, p. 493–512.
Tanaka, K.L., and Scott, D.H., 1987, Geologic map of the polar regions of Mars: U.S. Geological Survey Miscellaneous Investigations Series Map I–1802–C, scale 1:15,000,000.
Thomas, Peter, Herkenhoff, Ken, Howard, Alan, Murray, Bruce, and Squyres, Steven, 1992, Polar deposits on Mars, in Mars, Tucson, University of Arizona Press, p. 767–795.
Thomas, P.C., and Weitz, Catherine, 1989, Sand dune materials and polar layered deposits on Mars: Icarus, v. 81, p. 185–215.
Toon, O.B., Pollack, J.B., Ward, William, Burns, J.A., and Bilski, Kenneth, 1980, The astronomical theory of climatic change on Mars: Icarus, v. 44, p. 552–607.
U.S. Geological Survey, 1986, Controlled photomosaic of the MTM –85080 area, Planum Australe region of Mars: U.S. Geological Survey Miscellaneous Investigations Series Map I–1845, scale 1:500,000.
———1989, Topographic maps of the western, eastern equatorial, and polar regions of Mars: U.S. Geological Survey Miscellaneous Investigations Series Map I–2030, three sheets, scale 1:15,000,000.

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 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.

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

Unit	Violet	Red	R/V
Residual polar ice cap (unit Ac)	0.18–0.43	0.27–0.53	1.2–1.6
Partial frost cover (unit Af)	0.05–0.09	0.14–0.21	2.2–2.9
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

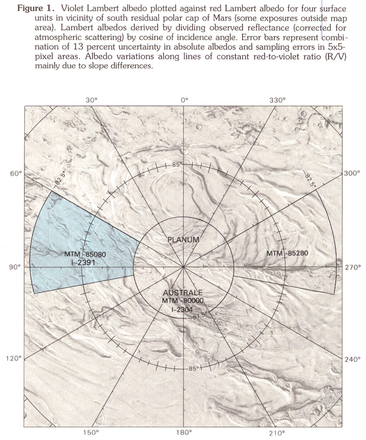

Figure 2. Index map showing location of major physiographic features and 1:500,000-scale maps in Planum Australe region completed or in progress in Mars Geologic Mapping Program. Mars Transverse Mercator (MTM) numbers indicate latitude and longitude of center of maps. I-number indicates published map.

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