DEPARTMENT OF THE INTERIOR
UNITED STATES GEOLOGICAL SURVEY

Prepared for the
NATIONAL AERONAUTICS AND SPACE ADMINISTRATION

ATLAS OF MARS
1:5,000,000 GEOLOGIC SERIES
MARE AUSTRALE QUADRANGLE
M SM -90/0 G, 1978
I-1076 (MC-30)

NOTES ON BASE

This map sheet is one in a series covering the entire surface of Mars at nominal scales of 1:25,000,000 and 1:5,000,000 (Batson, 1973; 1976). The major source of map data was the Mariner 9 television experiment (Masursky and others, 1975).

ADOPTED FIGURE

The figure of Mars used for the computation of the map projection is an oblate spheroid (flattening of 1/192) with an equatorial radius of 3393.4 km and a polar radius of 3375.7 km. This is not the height datum which is defined below under the heading "Contours."

PROJECTION

The polar stereographic projection is used for this map between lat 65° and the pole (Snyder, 1978). Longitudes increase to the west in accordance with the usage of the International Astronomical Union (IAU, 1973). Latitudes are areographic (de Vaucouleurs and others, 1973).

CONTROL

Planimetric control is provided by photogrammetric triangulation using Mariner 9 pictures (Davies, 1973; Davies and Arthur, 1973) and the radio-tracked position of the spacecraft. The prime meridian passes through the crater Airy-O (lat 5.19° S) within the crater Airy. No simple statement is possible for the precision, but local consistency is 5–15 km.

MAPPING TECHNIQUE

Selected Mariner 9 pictures, transformed to the polar stereographic projection, were assembled in a mosaic at 1:5,000,000.

Shaded relief was copied from the mosaics and portrayed with uniform illumination with the sun to the west. Many Mariner 9 pictures beside those in the base mosaic were examined to improve the portrayal (Levinthal and others, 1973; Green and others, 1975; Wu and others, 1975). The lighting is not generalized and may be interpreted with nearly photographic reliability (Inge, 1972).

Shaded relief analysis and representation were made by Patricia M. Bridges.

CONTOURS

Since Mars has no sea and hence no sea level, the datum (the 0 km contour line) for altitudes is defined by a gravity field described by spherical harmonics of fourth order and fourth degree (Gildner and Lowell, 1973) combined with a 6.1 millibar atmospheric pressure surface derived from radio-occultation data (Kliore and others, 1973; Christensen, 1975; Wu, 1978).

The contour lines on most of the Mars maps (Wu, 1975) were compiled from Earth-based radar determinations (Downs and others, 1971; Pettengill and others, 1971) and measurements made by Mariner 9 instrumentation, including the ultraviolet photometer experiment (Hord, 1974), infrared interferometer spectrometer (Conrath and others, 1973), and stereoscopic Mariner 9 television pictures (Wu and others, 1973).

Formal analysis of the accuracy of topographic elevation information has not been made. The estimated vertical accuracy of each source of data indicates a probable error of 1–2 km.

NOMENCLATURE

All names on this sheet are approved by the International Astronomical Union (IAU), 1974; 1973.

MC-30: Abbreviation for Mare Chart 30.
M SM –00/0 G: Abbreviation for Mars 1:5,000,000 series; center of sheet, 90° S lat (lode, 0° longitude; geologic map.

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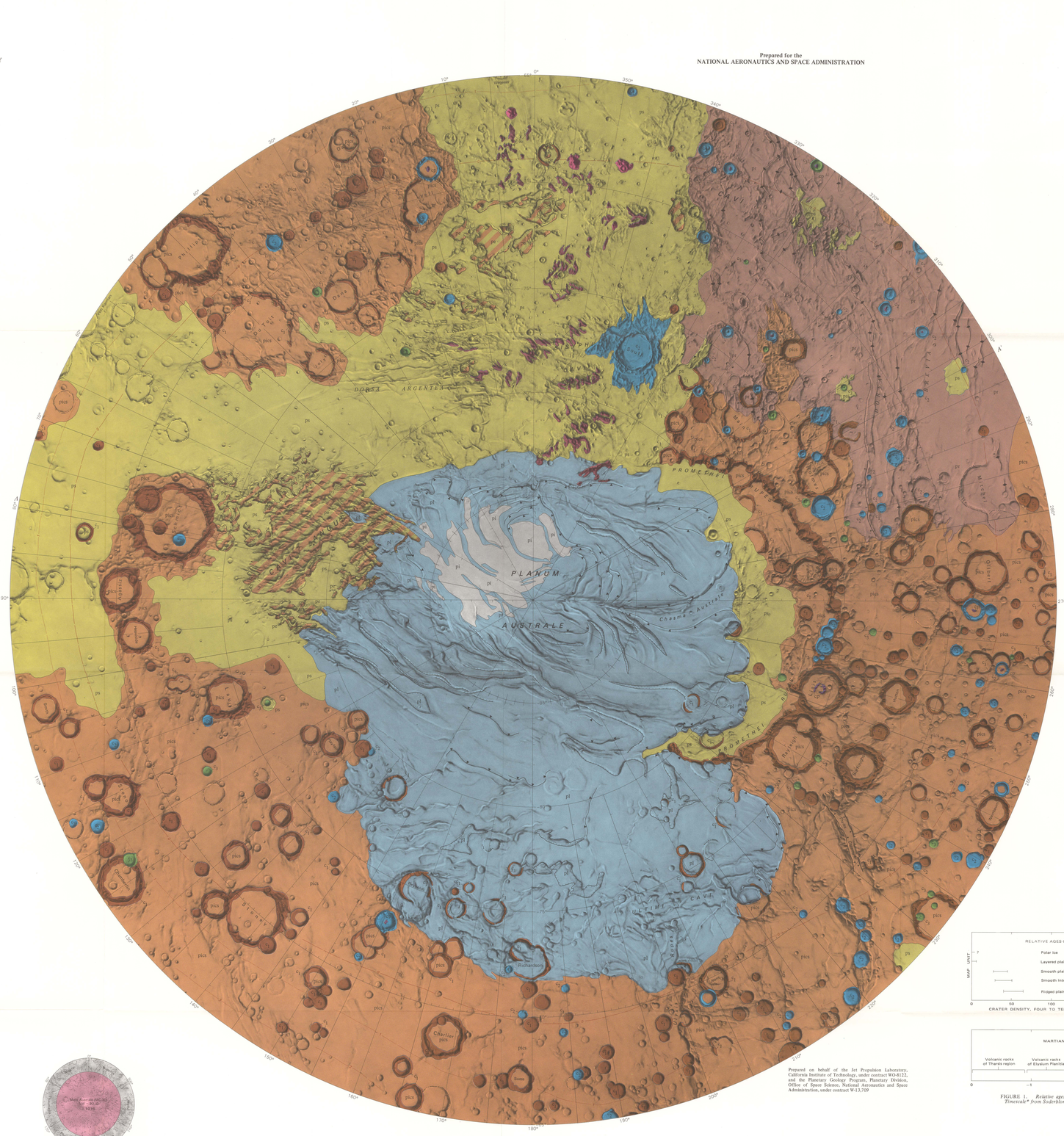
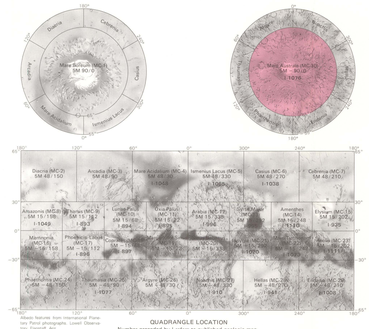


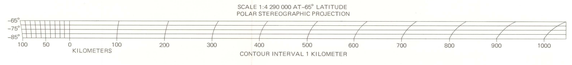
Prepared on behalf of the Jet Propulsion Laboratory, California Institute of Technology, under contract WO-8122, and the Planetary Geology Program, Planetary Division, Office of Space Science, National Aeronautics and Space Administration, under contract W-13,709



Albedo features from International Flamsteed Period photographs, Lowell Observatory, Flagstaff, Ariz.

QUADRANGLE LOCATION
Number preceded by I refers to published geologic map

SCALE 1:4 290 000 AT–65° LATITUDE
POLAR STEREOGRAPHIC PROJECTION

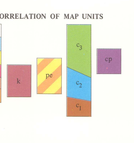


CONTOUR INTERVAL 1 KILOMETER

GEOLOGIC MAP OF THE MARE AUSTRALE AREA OF MARS

By
Christopher D. Condit and Laurence A. Soderblom
1978

CORRELATION OF MAP UNITS



DESCRIPTION OF MAP UNITS

pl — POLAR ICE MATERIAL—Centered 200 km from the pole; e^2; rotational axis at 87° S., 47° W. Permanent ice, at its farthest retreat during the Mariner 9 mission, measured approximately 300 X 350 km. Characterized by alternating high albedo and dark bands ranging from 5 to 15 km in width and to 300 km in length arranged concentrically around center of ice. *Interpretation:* Probably thin unit composed of water ice. Youngest unit in south polar region

ps — LAYERED PLAINS MATERIAL—Forms rolling plains characterized by regularly spaced arcuate scarps with rounded crests several hundred kilometers long, tens of kilometers wide, and averaging 300 m high (Malin and others, unpublished data). Finely divided into more than 40 layers, each estimated to be about 30 m ± 15 thick, with a maximum of 39 layers found at intersection of at least three scarps. High-resolution images show grooves near areas of topographic relief. Total thickness estimated to be 1.0 to 2.5 km (Druzhin and Blasius, 1974) *Interpretation:* Probably composed in part of reworked smooth plains material combined with water ice and eolian materials of global origin. Very young surface (as indicated by small number of 4– 10-km-diameter craters), probably undergoing erosion

pe — SMOOTH PLAINS MATERIAL—Features low-relief region at low-resolution. High-resolution images show surface scarred by parallel grooves to 0.5-km wide and several kilometers long (Sharp, 1973). *Interpretation:* Unit probably composed of fine particulate matter, possibly some of volcanic origin that fell from the atmosphere along with or alternating with particles of frozen volatiles, largely H_2O and CO_2 (Sharp, 1973; Murray and others, 1972; Cutts, 1973; Murray and Malin, 1973). Stratigraphic position, absence of large craters, and density of intermediate (4– 10-km diameter) craters ($38{\cdot}10^6$km^{-2}) suggest an intermediate to young age for surface of unit

pr — RIDGED PLAINS MATERIAL—Forms low-relief plains with linear ridges and scarps ranging from 20 to 200 km in length. Mesas, difficult to separate from scarps except in high-resolution images, are common. Edges of ridges, scarps, and mesas display high-albedo digitate and fluted patterns. Ejecta blankets of old and intermediate age large craters covered by ridged plains and material. *Interpretation:* Linear ridges and scarps are lava-flow features. Mesas are part of smooth plains material, now being removed by eolian processes. Absence of ejecta blankets on large (>20-km diameter) craters, density of intermediate (4–10-km diameter) craters ($54{\cdot}15/10^6$ km^2), and stratigraphic position beneath smooth plains material suggest an intermediate age for unit and a long period of formation

d — DOME MATERIAL—Forms small (10– 40-km) irregular rounded features located between 71–47° S., 34–003° W. *Interpretation:* Volcanic domes probably deposited before the smooth plains material

pics — SMOOTH INTERCRATER PLAINS MATERIAL—Smooth to locally hilly unit that surrounds material of old large (>20-km diameter) craters. Narrow-angle images show sharp, serrated edges and streamlined patterns on all scales that are locally parallel to contours between 270° W. and 100° W., where the plains smooth, there are fluted and digitate patterns that have no direct relation to topographic features. *Interpretation:* Hilly areas probably represent old debris of crater material resulting from erosive regime associated with accretional bombardment of planet. Smooth areas are depositional blanket now in a predominately erosive period. Intermediate-size (4–10-km diameter) crater density (39±10 craters/10^6km^2) indicates depositional blanket has a geologic history similar to smooth plains material

k — KNOBBY MATERIAL—Small irregular knobs or hills, many arranged in roughly circular patterns. *Interpretation:* Knobs either combination of ejecta material of polar impact basin and (or) rims of old crater material

pc — ETCHED PLAINS MATERIAL—Forms smooth to rough surfaces in depressions more than 400 m deep within smooth plains material. Smooth surfaces show a few fresh bowl-shaped craters. Rough surfaces display knobs, ridges, some small bowl-shaped craters, larger deteriorated craters, and, locally, strongly developed marvertical to gently curving intersecting sets of crescents (Sharp, 1973). *Interpretation:* Erosional window into smooth plains material down to old crater material. Knobs attributed to ablation and deflation (Sharp, 1973)

CRATER MATERIALS—Craters subdivided into morphologic categories believed to reflect approximate age. Craters less than 20 km in diameter not mapped. *Interpretation:* Most craters in these categories are believed to be of impact origin.

c_3 — Material of sharp-rimmed craters—Craters have sharp, raised complete rim crests, rough floors, central peak (if greater than 30-km diameter). Secondary craters common. Smaller craters bowl shaped. Some craters display ejecta blankets

c_2 — Material of subdued craters—Craters have rounded, raised complete rim crests. Rough floor may be partially filled. May have central peak. Craters less than 30 km may be rimless

c_1 — Material of highly degraded craters—Craters have rounded, commonly incomplete rim crests, or may be rimless. Shallow flat interiors generally level with adjacent terrain

up — CENTRAL PEAK MATERIAL—Central peak of craters. Forms one or more mountains near center of c_3 and some c_2 craters. *Interpretation:* Brecciated crater floor uplifted by rebound during shock decomposition following compressive stage of impact

Contact

Fault—Ball and bar on downthrown side

Depression—Hachures point downslope

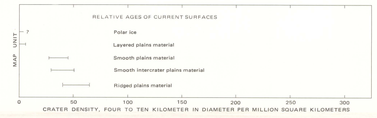
Scarp—Line at base of scarp; barb points downslope

Ridge—Barbs point downslope

Crater rim crest—May be used as contact on rimless c_1 and c_2 craters

Remnant or buried crater rim crest

Erosional scarp defining rim crest of south polar basin



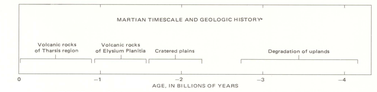


FIGURE 1. *Relative ages of surfaces based on crater density and martian timescale. Timescale* from Soderblom and others (1974, fig. 14).*

GENERAL INFORMATION

The south polar region of Mars is among the most geologically diverse on the planet. The area is within the heavily cratered hemisphere of Mars but is distinguished by a variety of younger, regionally extensive deposits and an assemblage of unique erosional forms. The spectrum of units varies from the oldest to the youngest on the planet. The oldest unit, typifying the cratered hemisphere, is the material of ancient large craters, most of which have undergone advanced degradation. These ancient crater materials are overlain by a variety of regional deposits, including extensive intercrater debris blankets, ridged volcanic flows, and massive eolian deposits that eroded to form complex cliff-rimmed pits. In the central zone of the polar region, south of roughly 75° S., these depositional units are, in turn, unconformably overlain by a tremendous sedimentary complex 1,500–2,000 km in diameter, consisting of 40 or more regularly spaced horizontal strata. Each stratum retains apparently uniform thickness (several tens of meters) over hundreds of kilometers; erosional unconformities between strata have not as yet been identified. Resting on the uppermost surface of this layered terrain is the permanent residual polar ice cap. This complex stratigraphic record may ultimately hold the keys to the initial atmospheric evolution, climatological fluctuations, and the history, budget, and mobility of water on the planet.

REGIONAL TOPOGRAPHY AND PHYSIOGRAPHY

Mariner 9 ultraviolet spectrometer (UVS) data, when combined with the S-band occultation data indicate topography relief within the south polar region exceeding 5 km (Druzhin and Blasius, 1974). The crater materials and smooth intercrater plains material are relatively high units, ranging from 3–4 km above the 6.1 millibar atmospheric pressure level. The smooth plains material, which stratigraphically underlies the layered terrains, is a regionally lower unit (<1 km in elevation). Across the central polar layered terrains, from the pole northward along meridian 270°, the UVS data indicate a drop in elevation from 3 km to less than 1 km. Druzhin and Blasius (1974) suggest that this gentle slope (about 0.5°) may be in fact the point of minimum annual solar insolation off the pole, thereby accounting for the position of the residual polar cap.

A major physiographic feature of the south polar region is a large circular scarp-and-ridge structure about 875 km in diameter that protrudes through a variety of young plains. This feature is interpreted as the rim of an ancient impact basin centered at 83° S., 266° W. The poleward side of the basin rim has been buried by layered plains material. The lowest point of the south polar region is in the floor of this giant basin. The topographic form of the basin probably controls the regional slope across the central polar layered terrains.

IMAGING DATA BASE AND MAPPING TECHNIQUE

The south polar region was repeatedly photographed during the Mariner 9 Mars 1971 Mission. The entire region was imaged at least twice (<3 km) with the 53-mm wide-angle camera, most regions several times. Additionally, for about 15 percent of the region, excellent high-resolution (<300 m) images were obtained with the 1500-mm narrow-angle camera. Owing to variations in dust range, emissions angle, atmospheric clarity, and lighting conditions, image quality for the low-resolution coverage ranges from average for about 80 percent of the area to poor for about 20 percent where there are no high-resolution images. Because of the large variation in image quality and resolution, there is high density of information in a few areas and very limited information in others. For this reason, boundaries of map units were based on the uniform low-resolution coverage; high-resolution images were used to define surface characteristics of the units.

Cratering statistics that have proved useful for relative age dating of geologic units elsewhere on Mars must be applied with care in the polar areas because: (1) the lifetime of craters subjected to the erosional conditions varies widely in this region; (2) the morphologic expression of craters on different geologic units may be quite varied; and (3) erosional and depositional rates appear to differ locally. Crater density statistics may thus reflect a surface age that differs greatly from the time of deposition of the original material. Alternative to criteria used in other regions, careful observation of the crater population has been used here to infer processes of continued local deposition and erosion. For example, the smooth intercrater plains material shows an abundance of 4– 10-km craters but a paucity of smaller craters. This implies to us a relatively thin surface unit that is undergoing contemporaneous erosion and deposition.

Crater density statistics in the south polar region were collected for craters within the 4 – 10-km diameter range. Smaller craters are a variable state of preservation and do not represent total accumulations on the surface. Craters (20- to 10-km diameter) predate most plains surfaces. Craters in the diameter range 4–10 km appear fresh; they post date the plains and best represent the net-accumulation of the last epoch. Densities of intermediate-size craters were counted for each geologic unit; this number was divided into the area of the unit and the result normalized to the number of craters per 10^6km^2. Because of the geologically dynamic environment of the south pole, we place greater significance in establishing relative ages of units on superposition and transection relations than on the interpretation of crater statistics. This is especially true when comparing units such as layered plains and smooth intercrater plains where materials of uncertain H_2O-CO_2 - ice-rock composition are subject to active reworking (and possibly greatly differing erosion and deposition rates), which radically affects the retention ages of small craters.

GEOLOGIC SUMMARY

The oldest materials in the south polar region of Mars are the rims of large degraded craters, which are surrounded and filled by smooth intercrater plains material. As developed below, these intercrater plains are inferred to be a complex of materials of widely varying age. Crater materials and smooth intercrater plains materials together occupy about 2.9 X 10^6km^2, occurring in a band north of about 75° S. Within this band, the smooth intercrater plains material and the south polar impact basin form about 10 percent of the surface area within the smooth intercrater plains material. The larger craters have undergone advanced erosion and burial as evidenced by their degraded forms. Blankets and ejecta of the smaller craters are well preserved and form a veneer on all other units of the south polar region with the exception of knobby material remnants that protrude through younger units. These knobs are in part a probable combination of ejecta materials of the polar impact basin and highly degraded crater rims.

The smooth intercrater plains material, which surrounds the majority of the degraded crater rims, is apparently a combination of debris eroded from the ancient craters combined with more recent eolian deposits and in an advanced state of reworking. Where large craters are most dense (around 68° S., 260° W.), the surface of the unit is hilly. The eolian depositional blanket is probably thin relative to the ridged plains and smooth plains materials, as evidenced by the large number of crater rims within the unit. The low crater density of this unit (fig. 1) may represent the age of recent reworking rather than the age of deposition, for the ridged plains material appears to overlap and be stratigraphically younger than the smooth intercrater plains material. The contact between the smooth intercrater plains and the smooth plains materials is gradational, reflecting possible interfingering of the more recent eolian depositional component of the intercrater plains. This inferred interfingering may be supported by similar crater densities of the smooth intercrater plains and the smooth plains materials (fig. 1). In some of the adjacent quadrangles (Eridania, Phaethontis, and Thaumasia), the smooth intercrater plains material has been further divided; because of the limitations imposed by the photographic data base, however, we have chosen not to subdivide the unit.

The ridged plains material covers most 68° S., 310° W was emplaced after the development of the smooth intercrater plains material and before the smooth plains material was deposited. Only relatively fresh craters are seen on the ridged plains material; older crater forms visible have been covered by volcanic flows. The majority of large craters (average 25-km in diameter) on the ridged plains material have been modified to an intermediate in age. Because ejecta blankets and secondaries of these intermediate-age craters are not visible, we infer the ridged plains material to have been emplaced in multiple episodes over a long period of time, perhaps recently (<2 b.y. ago). In addition to mardike wrinkle ridges on the ridged plains material, cliff-rimmed mesas are superposed on the unit in several areas (see, for example 68° S., 123° W.). These mesas are interpreted to be erosional remnants of the smooth plains material that once covered the ridged plains material and has since been stripped back. The contact between the smooth plains and ridged plains materials is in places an erosional scarp, consistent with this interpretation. The ridged plains material, the most heavily cratered plains unit within the south polar region, has 4– 10-km diameter crater densities of $54{\pm}15/10^6$km^2 (fig. 1). The reason that this density indicates intermediate age (<2 b.y.) when compared with other martian regions (Soderblom and others, 1974) may be due to the depositional and erosional episodes during which the ridged plains were buried for long periods of time, any impacting bodies were not recorded on the surface of the deposit.

The smooth plains material, located between the 100° W. and 340° W. and north of 80° S., is a smooth featureless region of low relief. The unit thins northward where a few old crater rims protrude above the plains material (77° S., 30° W.). The contact between the smooth plains material and the ridged plains material (near 340° W.) ranges from an indistinct thinning of the smooth plains material to an abrupt erosional scarp. It appears that most of the smooth plains material was deposited later than the ridged plains material, although the possibility of an interfingering of lower parts of the smooth plains material with the ridged plains material cannot be ruled out.

Four small domical features 10– 40 km in diameter, interpreted as volcanic, occur near the prime meridian between 68° and 69° S. These features were probably emplaced before the smooth plains material, as no evidence of surrounding flows could be found.

Evidence for a major erosional period following the emplacement of the smooth plains material can be found in several areas. As stated, several isolated erosional remnants of smooth plains material occur as mesas standing above the ridged plains material, apparently the remains of a much more extensive deposit that once covered much of the ridged plains material. A pedestal crater, located within the smooth intercrater plains material at 76° S.,117° W.,provides additional evidence for this erosional period. McCauley (1973) proposed that the blankets of ejecta from an impact crater provide a protective armor that preserves the original depositional surface from deflation. Numerous cliff-rimmed depressions developed in the smooth plains material during this erosional period. The floors of these erosional pits, mapped as a mixture of materials of smooth plains and subjacent materials, contain a few exhumed remnants of old craters. Most of this erosion apparently predated the deposition of the layered terrains of the central polar region, unconformably emplaced within some of the pits.

The central polar layered plains material is composed of 40 or more layers each 10 to 50m thick. The individual layers, alternately high in competence and albedo, appear to maintain a uniform thickness for hundreds of kilometers. The entire complex has been eroded into several benches separated by rounded slopes on which the layers crop out. This extensive unit (centered at 84° S., 180° W. and covering 1.5 X 10^6km^2) is thought to consist of deposits of eolian debris of both global origin and reworked smooth plains material probably combined with water-ice. The layered terrain is transected by two major erosional remnants, one at 80° S., 230° W. the other in the center of the polar impact basin. Both are radial to the spin axis of the planet and are curved in a direction consistent with the direction of coriolis rotation of the wind flowing away from the pole. The layered plains material unconformably overlies the smooth plains, smooth intercrater plains, and the old crater materials. Intermediate-size craters are seen eroded remnants of lower units that protrude through the layered terrains. Intermediate-size craters (4–10 km) suggest a very young age for the surface of the layered plains, being about 4±5 craters/10^6km^2. Crater density reflects the age of the erosional surface, not the age of the deposit, and together with the common occurrence of linear grooves, indicates that the layered plains material is in a continuing erosional period (Soderblom and others, 1973).

The permanent polar ice cap is the youngest geologic unit in the south polar region. It is offset about 200 km from the rotation axis and is located on a topographic high (Druzhin and Blasius, 1974). Measured at its maximum retreat during the Mariner 9 mission, the ice cap covers about 68,000 km^2. On defrosted slopes, the ice cover is broken by dark bands, 5– 15 km in width and to 300 km in length, forming an irregular concentric pattern around the topographic high. Model studies by Druzhin and Blasius (1974) indicate that the south polar dark bands have slopes of 1 to 5° and range in height from 0.1 to 1 km. Constraints on the stability of CO_2 - ice dictated in the south polar region by altitude (and hence pressure) and solar insolation indicate that the permanent south polar ice cap is water-ice (Murray and Malin, 1973; Druzhin and Blasius, 1974). Observations of Mariner 9 B-frames by these four investigators indicate that the ice cap is sufficiently thin to allow the discernment of subjacent small-scale relief.

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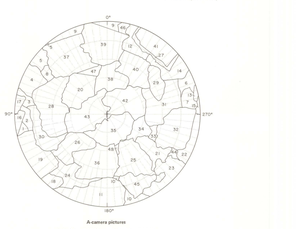

A-camera pictures

Index No.	DAS No.	Index No.	DAS No.
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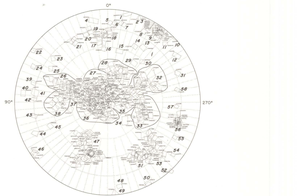
2	09094435	26	07488880
3	09094568	27	07546064
4	09094668	28	07746368
5	09094798	29	07792228
6	09094928	30	07792358
7	09095058	31	07864118
8	09453848	32	09008298
9	09453978	33	09108628
10	09621988	34	09123984
11	06136318	35	09295814
12	06136448	36	09295944
13	06137578	37	09295954
14	06245118	38	09851944
15	06245248	39	09853034
16	06262118	40	09853664
17	06262248	41	09853794
18	06422128	42	09051614
19	06425338	43	09371224
20	06425468	44	09371354
21	06740038	45	10884538
22	06820168	46	10729339
23	06820298	47	10729469
24	06984118	48	09851468

INDEX TO MARINER 9 A-CAMERA PICTURES

The mosaic used to control the positioning of features on this map was made with the Mariner 9 A-camera pictures outlined above. The DAS numbers may differ slightly (usually by 5) among various versions of the same picture.



High-resolution B-camera pictures

Index No.	DAS No.	Index No.	DAS No.	Index No.	DAS No.	Index No.	DAS No.
1	6928928	27	5498928	28	8091768	47	8988218
2	10729068		8734968		9123318		7538318
3	8091628		8734828		9123178		7538178
4	8317428		9010568		9123028		7538048
5	8323718		8618898		9195298		6904798
6	8323578		8618758		9195158		6904658
7	8323438		8618618		9195018		6904518
8	8494298		7619128		9195348		9637778
9	10729208		6207918		9195208		9637638
			6207778		9195068		8108628
			5741898		7999998		8439058
			5741758		7999858		8439198
			5741618		7999718		8439338
			5741478		7999578		8439478
			5741338		7999438		8439618
			5741198		7999298		8439758
			5741058		7999158		8439898
			5740918		7999018		8440038
			5740778		7998878		8440178
			5740638		7998738		8440318
			5740498		7998598		8440458
			5740358		7998458		8440598
			5740218		7998318		8440738
			5740078		7998178		8440878
			5739938		7998038		8441018
			5739798		7997898		8441158
			5739658		7997758		8441298
			5739518		7997618		8441438
			5739378		7997478		8441578
			5739238		7997338		8441718
			5739098		7997198		8441858
			5738958		7997058		8441998
			5738818		7996918		8442138
			5738678		7996778		8442278
			5738538		7996638		8442418
			5738398		7996498		8442558
			5738258		7996358		8442698
			5738118		7996218		8442838
			5737978		7996078		8442978
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			5737558		7995658		8443398
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			5736858		7994958		8444098
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			5736158		7994258		8444798
			5736018		7994118		8444938