DEPARTMENT OF THE INTERIOR
UNITED STATES GEOLOGICAL SURVEY

Prepared In Cooperation With The
JET PROPULSION LABORATORY, CALIFORNIA INSTITUTE OF TECHNOLOGY
FOR THE NATIONAL AERONAUTICS AND SPACE ADMINISTRATION

ATLAS OF MARS
1:5,000,000 GEOLOGIC SERIES
LUNAE PALUS QUADRANGLE
M 5M 15/68 G, 1975
I-894 (MC-10)

NOTES ON BASE

This map sheet is one of a series covering the entire surface of Mars at nominal scales of 1:25,000,000 and 1:5,000,000 (Batson, 1973). The major source of map data was the Mariner 9 television experiment (Masursky and others, 1970).

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.

PROJECTION

The Mercator projection is used for this sheet, with a scale of 1:5,000,000 at the equator and 1:4,336,000 at 30° latitude. Longitudes are positive westward in accordance with usage of the International Astronomical Union (IAU, 1970). 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 first meridian passes through the crater Airy-0 (lat 5.19°S) within the crater Airy. No simple statement is possible for the precision, but local consistency is 5–10 km.

MAPPING TECHNIQUE

A series of mosaics of rectified and scaled Mariner 9 pictures was assembled at 1:5,000,000. In this context, rectification includes transformation to the Mercator projection.

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

Shaded relief analysis and representation were made by Susan L. Davis.

CONTOURS

Since Mars has no seas and hence no sea level, the datum for altitudes is defined (in part arbitrarily) by a surface that combines gravity-field determinations (Jordan and Lorell, 1973) with radio-occultation determinations (Kliore and others, 1973) and the 6.1-millibar surface of the Mars atmosphere (Christensen, 1974).

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

Formal analysis of contour-line accuracy has not been made. The estimated accuracy of each contour at this scale indicates a probable error of 1–2 km.

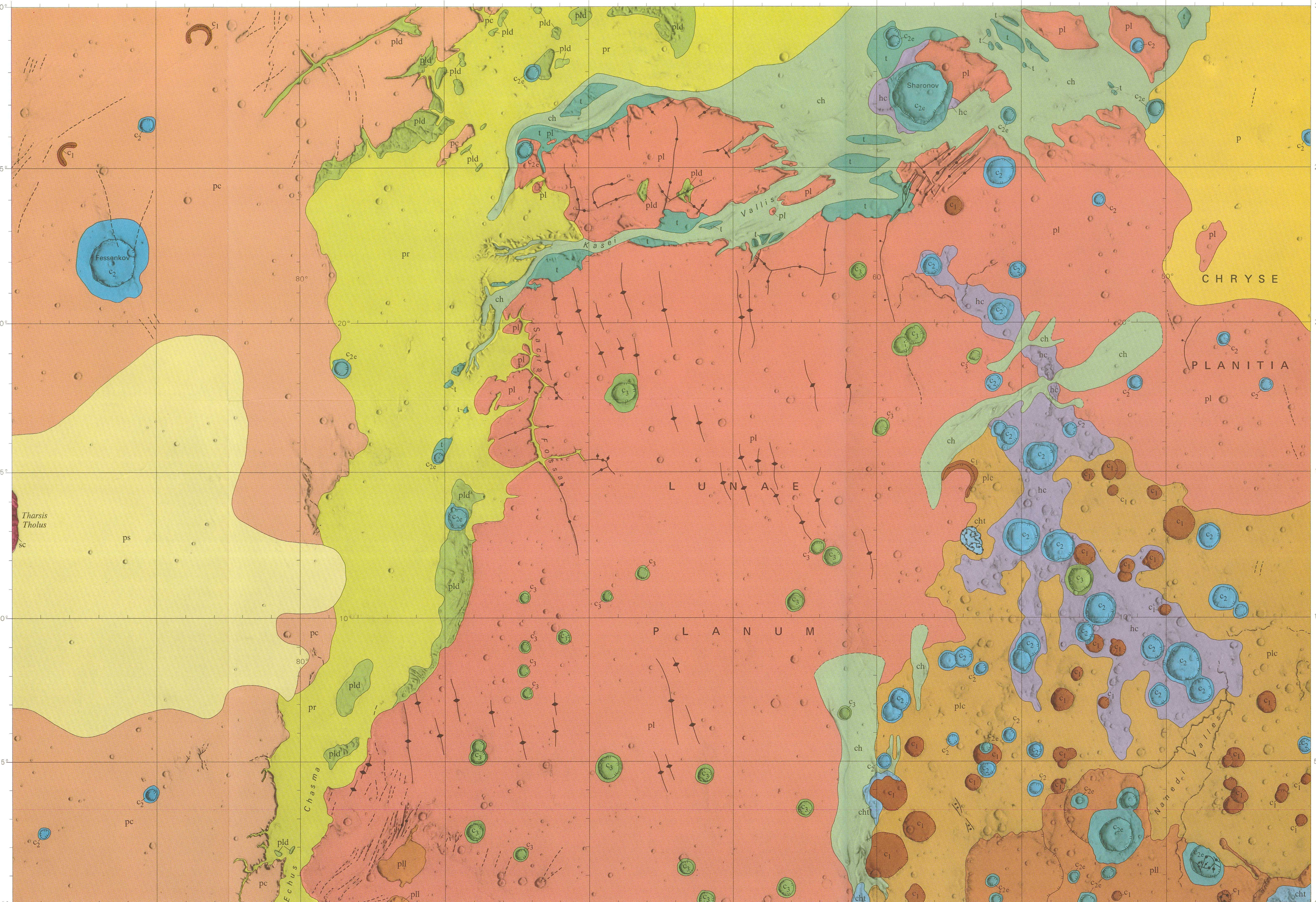
NOMENCLATURE

All names on this sheet are authorized by the International Astronomical Union (IAU, 1970), except the following names which are provisional: Echus Chasma, Nanedi Valles and Sacra Fossa.

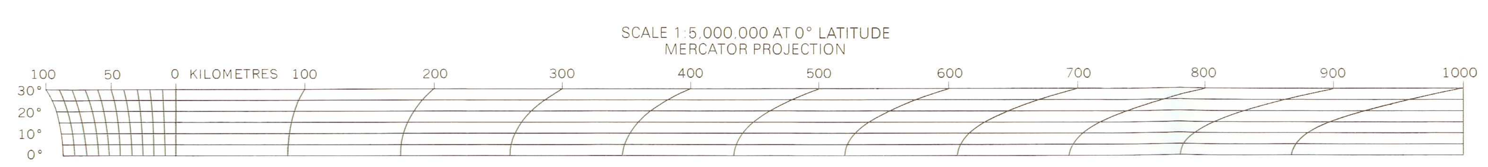
MC-10: Abbreviation for Mars Chart 10

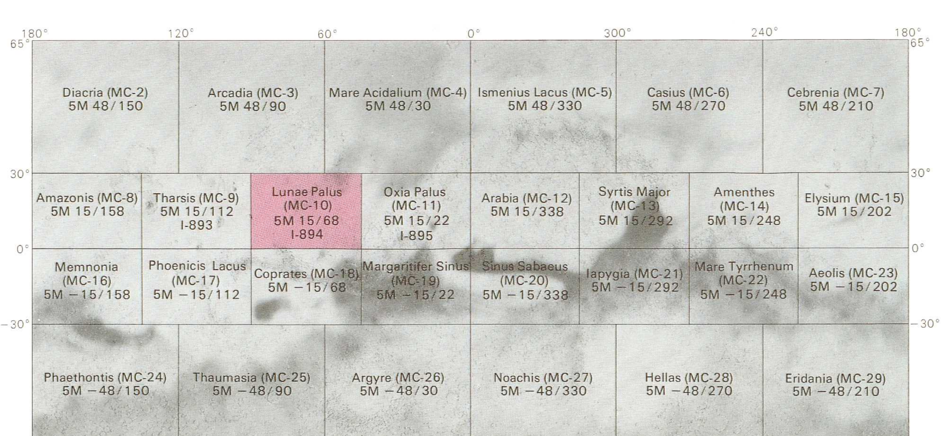
M 5M 15/68 G: Abbreviation for Mars 1:5,000,000 series; center of sheet, 15° latitude, 68° longitude; geologic map, G.

Batson, R. M., 1973, Cartographic products from the Mariner 9 mission: Jour. Geophys. Research, v. 78, p. 4424–4435.
Christensen, E. J., 1974, Martian topography derived from occultation, radar, spectral, and optical measurements: Jour. Geophys. Research (in press).
Conrath, B., Curran, R., Hanel, R., Kunde, V., Maguire, W., Pearl, J., Pirraglia, J., Welker, J., and Burke, T., 1973, Atmospheric and surface properties of Mars obtained by infrared spectroscopy on Mariner 9: Jour. Geophys. Research, v. 78, p. 4267–4278.
Davies, M. E., 1973, Mariner 9—Primary control net: Photogram. Eng., v. 39, no. 12, p. 1297–1302.
Davies, M. E., and Arthur, D. W. G., 1973, Martian surface coordinates: Jour. Geophys. Research, v. 78, p. 4355–4394.
Downs, G., Goldstein, R. M., Green, R. R., and Morris, G. A., 1971, Mars radar observations: A preliminary report: Science, v. 174, p. 1324.
Hord, C. W., Simmons, K. E., and McLaughlin, L. K., 1974, Mariner 9 ultraviolet spectrometer experiment—Pressure-altitude measurements on Mars: Icarus, v. 21, p. 292–302.
Inge, J. L., 1972, Principles of lunar illustration: Aeronaut. Chart and Inf. Center Ref. Pub. RP-72-1, 60 p.
International Astronomical Union, Commission 16, 1970, Physical study of planets and satellites, *in* Proceedings 14th Gen. Assembly 1970: Trans. Intl. Astron. Union, v. 14B, p. 128.
Jordan, J. F., and Lorell, J., 1973, Mariner 9: an instrument of dynamical science: Presented at AAS/AIAA Astrodynamics Conf., Vail, Colo., July 16–18, 1973.
Kliore, A. J., Fjeldbo, G., Seidel, B. L., Sykes, M. J., Woiceshyn, P. M., 1973, S-band radio occultation measurements of the atmosphere and topography of Mars with Mariner 9—Extended mission coverage of polar and intermediate latitudes: Jour. Geophys. Research, v. 78, p. 4331–4351.
Levinthal, E. C., Green, W. B., Cutts, J. A., Jahelka, E. D., Johansen, R. A., Sander, M. J., Seidman, J. B., Young, A. T., and Soderblom, L. A., 1973, Mariner 9 image processing and products: Icarus, v. 18, p. 75–101.
Masursky, H., Batson, R., Borgeson, W., Carr, M., McCauley, J., Milton, D., Wildey, R., Wilhelms, D., Murray, B., Horowitz, N., Leighton, R., Sharp, R., Thompson, W., Briggs, G., Chandeysson, P., Shipley, E., Sagan, C., Pollack, J., Lederberg, J., Levinthal, E., Hartmann, W., McCord, T., Smith, B., Davies, M., de Vaucouleurs, G., and Leovy, C., 1970, Television experiment for Mariner Mars 1971: Icarus, v. 12, p. 10–45.
Pettengill, G. H., Rogers, A. E., Shapiro, I. I., 1971, Martian craters and a scarp seen by radar: Science, v. 174, p. 1321.
de Vaucouleurs, Gerard, Davies, M. E., Sturms, F. M., 1973, The Mariner 9 areographic coordinate system: Jour. Geophys. Research, v. 78, p. 4395–4404.
Wu, S. S. C., 1974, Topographic Mapping of Mars. U.S. Geol. Surv. Interagency Rept. 63.
Wu, S. S. C., Schafer, F. J., Nakata, G. M., Jordan, Raymond, and Blasius, K. R., 1973, Photogrammetric evaluation of Mariner 9 photography: Jour. Geophys. Research, v. 78, p. 4405–4410.



Prepared on behalf of the Jet Propulsion Laboratory, California Institute of Technology under WO-8122





QUADRANGLE LOCATION

Number preceded by I refers to published geologic map

CONTOURS

Contour interval 1 kilometre

INDEX TO MARINER 9 PICTURES

The mosaic used to control the positioning of features on this map was made with the Mariner 9 A-camera pictures outlined above, identified by vertical numbers. Also shown (by solid black rectangles) are the high-resolution B-camera pictures, identified by italic numbers.

A-camera pictures: Index No.	DAS No.	Index No.	DAS No.	High-resolution B-camera pictures: Index No.	DAS No.	Index No.	DAS No.
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]

GEOLOGIC MAP OF THE LUNAE PALUS QUADRANGLE OF MARS

By
Daniel J. Milton
1975

CORRELATION OF MAP UNITS

AGE	DEVELOPMENT OF SURFACE CHARACTERISTICS			EMPLACEMENT OF MATERIALS
Years	Primarily depositional	Depositional and erosional	Primarily erosional	
<1·10⁹	ps, p		ch, t, cht	ps, p
1-2·10⁹	sc		pld, pr, pll	sc
2-3·10⁹		pl, pc		pl, pld, pc, pr, t, ch
>3·10⁹	plc	hc		plc, hc, pll, cht

A double columnar legend is used rather than the usual single column because the erosional episodes responsible for the characteristics of some units occurred at a much later period than the original emplacement of the material. Ages of crater materials are relative to surrounding units and hence are not shown in this column.

DESCRIPTION OF MAP UNITS

ps SPARSELY CRATERED PLAINS MATERIAL—Forms plains with very few small craters, almost featureless in wide-angle frames. Narrow-angle frames show multiple levels separated by jagged low scarps. *Interpreted* as lava flows, probably composed of basalt. Scarps resemble presumed flow fronts of lunar mare basalts, but their greater angularity suggests minor erosional modification

p MATERIAL OF CHRYSE PLANITIA—Forms plain in sparsely cratered low area, Chryse Planitia. *Interpreted* as alluvial fill, thin on western margin, thickening eastward

ch CHANNEL MATERIAL—Occupies elongate depressions with streamlined internal landforms. Entire channel may be deeply entrenched or almost at level of neighboring surfaces. *Interpreted* as the former site of running water. Erosional landforms dominate; depositional landforms occur

t TERRACE MATERIAL—Occurs as small patches at elevations intermediate between floor of Kasei Vallis and surface of Lunae Planum. Edge of patches generally smoothly convex in profile rather than sharply cliffed. *Interpreted* as remnants of lower, possibly sedimentary, levels of Lunae Planum material exposed and eroded by fluvial action

cht CHAOTIC MATERIAL—Occurs as irregular angular blocks and small hills in depressed terrain. *Interpreted* as material fractured and slumped, possibly as a result of ground-ice decay

sc CRATERED SHIELD MATERIAL—Forms smooth convex dome with a summit crater. *Interpreted* as a shield volcano. Probably composed mostly of basaltic lava flows by analogy with terrestrial shield volcanoes; viscosity must be greater than that of flows of the sparsely cratered plains material

pld DISSECTED PLATEAU MATERIAL—Forms very irregular surface with relief elements several kilometres across. Occurs at contact of units at higher elevation (units pl and pc) and ribbed plain. *Interpreted* as remnants of plateau material dissected by erosion along joints and locally displaced by slumping. May be correlative in part with chaotic material in quadrangles to the east

pr RIBBED PLAIN MATERIAL—Forms smooth plain with few small craters, which have narrow raised rims with a steep outer slope. Narrow-angle frames show close-set ridges and furrows in various directions. *Interpreted* as an eroded plain probably stripped to a resistant level. Final erosional process was wind scour that etched surface along joints. Extension along narrow angular canyons into higher terrain suggests aqueous erosion or sapping as an earlier process

pll LOWER PLATEAU MATERIAL—Forms plain, generally sloping, with fine irregularities on surface. Moderately abundant craters of all sizes to 150 km diameter, most rimless, some with scalloped outlines and "chaotic" floors. Albedo high. *Interpreted* as a surface lowered by erosion. Craters rejuvenated by collapse, resulting from melting of ground ice or from solution

pl MATERIAL OF LUNAE PLANUM—Forms smooth plain with scattered craters, most less than 20 km in diameter. Ridges resembling lunar mare ridges seen in narrow-angle frames. Cliff edges at margin sharp, upper slopes steep, lower slopes less steep and talus covered, but where free of talus show stratification in narrow-angle frames. *Interpreted* as thick mantling material. Upper level is well consolidated, perhaps basaltic lava flows; lower levels less consolidated, perhaps sedimentary. Erosional modification minor

pc CRATERED PLAINS MATERIAL—Forms smooth plains with few craters, most less than 10 km in diameter. Unit forms cliff at margin. *Interpreted* as probably equivalent to material of Lunae Planum. Partly preserved craters suggest that the unit may be thinner or more deeply eroded than Lunae Planum

plc CRATERED PLATEAU MATERIAL—Forms plain with craters to 20 km in diameter moderately abundant, craters 20–40 km in diameter scarce. Larger craters have smooth exteriors, some have raised rim crests, others appear to be rimless depressions. *Interpreted* as mantling deposit, thinner than materials of Lunae Planum, with older impact craters partly exposed. Some collapse of mantling material into subjacent craters has occurred

hc HILLY AND CRATERED MATERIAL—Characterized by abundant craters to 40 km in diameter with raised rims and rough exteriors and small hills and ridges between craters. *Interpreted* as impact craters and crater ejecta with mantling material thin, absent near rim crests. Some rimless and low-rimmed craters may have been rejuvenated by collapse of mantling material, but most craters have existed at surface since formation

CRATER MATERIALS—Form circular or near-circular areas depressed relative to rim

c_3 Crater younger than surface—Rim raised above surrounding terrain. Broad outer rim of rough-textured material with a gradational outer limit

c_2 Partly buried crater—Rim raised above surrounding terrain, may be incomplete circle. Narrow outer rim of rough-textured material with a relatively abrupt outer limit

c_{2e} Exhumed crater—Occurs in low area and has a generally steep outer slope but may have adjacent patches of elevated terrain

c_1 Rimless crater—Rim smooth textured and not elevated above surrounding terrain

Interpreted as impact craters. Classification of types only approximates classification of other workers by apparent age or degree of preservation. Partly buried craters formed before, or more commonly during, the deposition of the surrounding unit. Rimless craters were completely buried by the surrounding deposit but have reappeared after material filling the crater was removed by an undetermined process, perhaps solution, ground-ice decay, or eolian erosion. Exhumed craters were completely buried but have reappeared by removal of material less resistant than the rim material by flood erosion, eolian erosion, or in the southeast lowland, the same process that led to rimless craters

Contact—Dashed where gradational at end of channel

Narrow Depression—*Interpreted* as product of erosion along fault or fracture trace

Lineament—Linear feature too small or too poorly observed for classification

Scarp—*Interpreted* as fault, locally modified by erosion. Bar and ball on downthrown side

Scarp and Flexure—Broad flexure, bounded on at least one side by a scarp. Similar to wrinkle ridges of lunar maria. *Interpreted* as monocline and fault, reflecting regional tectonic pattern

Sinuous Rille—Highly sinuous narrow depression, similar to lunar sinuous rilles. Origin unknown. Continuity of Nanedi Valles over a divide 2 or 3 km higher than either end makes any origin involving flow along rille implausible

Crater Rim Crest—Hachures toward center of depression

GENERAL INFORMATION

Mars presents two different terrains, a highly cratered surface that lies mostly in the southern hemisphere and sparsely cratered plains that lie mostly in the northern hemisphere. The cause of the dichotomy is a still unsolved fundamental problem of Martian geology, analogous to the problem of continents and ocean basins in terrestrial geology. The present features of the plains in particular reflect a varied history in which superficially similar landforms may have had very different origins. The Lunae Palus quadrangle is occupied mainly by plains and their variety is perhaps more evident than elsewhere. This map demarcates units inferred to have different geologic histories on the basis of their appearance in Mariner 9 wide- and narrow-angle television frames.

MAPPING PRINCIPLES

The processes that have shaped the surface of Mars, like those that have shaped the surface of the Earth, are either constructive or destructive. A purely constructive process yields a deposit, a volume of material of restricted lithologic composition that overlies any older deposit in the area it occupies. A series of volcanic flows, such as probably underlie much of the broad plains in the Lunae Palus quadrangle, would be such a deposit. A purely destructive process in a global view is not possible because eroded material must be deposited somewhere. Nonetheless, within a limited area a process can be purely erosive, and its product is a surface. An example would be the convoluted surface of a canyon system such as the tributaries to Kasei Vallis. The science of stratigraphy deals with formations or constructive deposits and unconformities or erosional surfaces. While the latter are no less important than the former, the three-dimensional forms naturally demand the bulk of attention. In another science, geomorphology, the primary concern is with surfaces, most of which are of erosional rather than depositional origin.

On Earth, stratigraphic and geomorphologic studies can be carried out to a large extent independently. Surface processes are so active and efficient that only rarely have surfaces older than Cenozoic resisted burial or erosion, so that while stratigraphy is a historical science, geomorphology is much less so. On a planet with very little surface activity, such as the Moon, and perhaps in some regions of Mars, erosional processes dwindle in importance so that surfaces are the expression of depositional processes, and geomorphology and stratigraphy coalesce. Over most of Mars, certainly in the Lunae Palus quadrangle, surface processes have been so intermittent or feeble that surfaces of many ages, reaching far back in planetary history, remain exposed. Martian history is thus written as much in exposed surfaces as in formations and unconformities, and stratigraphy and geomorphology are inextricably entangled.

The primary interpretation of orbital imagery must be geomorphic. The areas delineated during mapping ideally have stratigraphic significance also, but the degree of significance is variable and uncertain. Each surface developed its characteristic appearance at some specific time in Martian history. Depositional surfaces are underlain by materials that were emplaced at some earlier time. It is often difficult to distinguish the depositional and erosional components in the origin of surfaces. A knowledge of the third dimension would help, but is rarely available. Thus the assumed stratified nature of the most widespread unit, material of Lunae Planum, is confirmed only by a glimpse of a canyon wall at the edge of a single narrow-angle frame.

For primarily depositional units, the time of development of surface characteristics is equivalent or nearly equivalent to the time of emplacement of materials, but for primarily erosional units it can be much later. This difference is crudely illustrated in the double entry of units in the columnar legend. Quantification of the time coordinate is an important problem in Martian geology. A method based on the statistics of crater populations (Soderblom and others, 1974) suggests the time ranges indicated. This method yields the age of surface development rather than of emplacement, but geologic relations of units allow integration into a unified geologic history.

SUMMARY OF GEOLOGY

The most primitive terrain on Mars, dating back probably to the late stage of planetary accretion, is characterized by closely spaced large impact craters and multiring basins. No such basin occurs in the Lunae Palus quadrangle, unless Chryse Planitia occupies a highly degraded basin with the hilly and cratered material (unit hc) marking part of its rim. The largest craters, 190 and 150 km in diameter (indicated by rim crest symbols in unit pll near the southeast corner), are irregular, partly rimless depressions whose present form may be a result of filling by younger deposits and their later incomplete removal. Whether material as old as the time of formation of these craters is exposed is uncertain. Two other large craters, Fessenkov and Sharonov, each about 90 km in diameter, are isolated in the northwestern and northeastern parts of the quadrangle, respectively. Fessenkov appears to emerge from deposits of younger cratered plains material (unit pc) lapping onto its flanks. Sharonov appears to be an exhumed crater, with part of its eastern rim still buried. These craters may have formed during the early period when most craters of their size formed, indicating that the mantle of later deposits in their vicinity is thin or absent. If so, other smaller craters must have been destroyed by the erosion that exposed Sharonov. Alternatively, these two craters may be random impact craters of younger age. If this is the case, older cratered terrain is buried to an unknown depth in the entire quadrangle, except where exposed in the southeast.

The approximately level Lunae Planum, which occupies most of the center of the quadrangle, clearly forms a surface distinct from the sloping surface in the western third of the quadrangle. The relation between these surfaces is an important geologic problem but is obscured by erosion near their junction in the lowland that extends from Echus Chasma to the head of Kasei Vallis. This lowland may reflect a relatively late disruption of a continuous surface, so that the materials of the western plateau correlate with the materials of Lunae Planum. Alternatively, Lunae Planum and the cratered plains to the west may have been structurally discontinuous from an early period, and the relative age of the principal plains-forming units is indeterminate.

Some of the material burying old cratered terrain is almost certainly volcanic. Tharsis Tholus, which barely extends across the west boundary of the quadrangle, is the only clearly volcanic form, one of the great volcanic constructs on the Tharsis Ridge. The sparsely cratered plains material (unit ps) that surrounds Tharsis Tholus (and the volcanoes to the west) in a wide area and locally appears to bury the scarp at the west edge of the ribbed plains material (unit pr), is characterized in narrow-angle frames by what appear to be flow fronts similar to those in the lunar maria. Such scarps are not seen in Lunae Planum, which is characterized by forms resembling the ridges of the lunar maria. In the face of the diversity of opinion as to the origin of mare ridges on the Moon, it is questionable whether their presence can be taken as evidence that Lunae Planum consists of volcanic flows. The sharp cliff edges of the margin of Lunae Planum suggest that at least the uppermost levels are composed of a resistant rock that may be basalt. At least the sparsely cratered plains and Tharsis Tholus are part of the Tharsis Ridge volcanic province. Lunae Planum may be a further extension; if it is, the Echus-Sacra line is a later feature.

Evidence for sedimentary deposits is less convincing. The island in the mouth of Kasei Valles, an outlier of Lunae Planum, shows a lower gentle slope beneath the basalt(?) cliffs. The material behind this slope is mostly concealed by talus, but in one small area a sequence of horizontally bedded strata is visible in a narrow-angle frame. The apparent rejuvenation of buried craters in the southeastern part of the quadrangle suggests they are covered by material that can be removed by the wind or by solution, perhaps fine-grained eolian sediments or volcanic ash. Distinguishable landforms associated with the channels are predominantly erosional, although low bars may occur on the channel floor. Presumably the debris was deposited in Chryse Planitia, but no diagnostic depositional features can be distinguished in the segment within the Lunae Palus quadrangle.

Eolian landforms are evident only in narrow-angle frames and prominent only in the ribbed plains material, where wind scour has etched joints to produce a ribbed bedrock surface. Pedestal craters formed where crater ejecta was more resistant to erosion than adjacent terrain, and their height suggests that the land surface has been lowered at most a few tens of metres by eolian erosion. Well-developed yardangs were not photographed, but carinate landforms appear to have been streamlined by the wind. Dark and light streaks extending from craters indicate contemporary wind transport of material in greatly different directions in different parts of the quadrangle.

Aqueous erosion is indicated in Kasei Vallis, the unnamed channel to the north, and the smaller channels at the east edge of Lunae Planum. Features seen in narrow-angle frames, including streamlined hills, longitudinal grooves, and inner channel cataracts, indicate that Kasei Vallis was the site of catastrophic floods of great depth and high velocity (Baker and Milton, 1974). The channels in Oxia Palus quadrangle to the east head in chaotic terrain and may have carried melt water from ground ice. Chaotic terrain is not associated with Kasei Vallis, although it may have once occupied the area of the ribbed plains and been removed by erosion. The small areas of dissected plateau material at the east edge have been massively slumped and may be the last remnants of chaotic material.

The extent to which aqueous erosion occurred elsewhere than in the major channels is uncertain. The labyrinthine canyons tributary to Kasei Vallis west of the great bend appear to have been eroded by water, and the same is probably true of the small canyon systems near Echus Chasma. Artesian sapping may have been a major factor in the growth of these canyons and may have been significant in the formation of the more straight-walled canyons, in particular those of the Sacra Fossa complex.

The processes that produced the rimless craters, the lower plateau in the southeast corner of the quadrangle, and the closed section of Hebes Chasma, which barely extends across the equator into the quadrangle near 77°W, are problematic. Decay of ground ice with subsequent eolian removal of finely particulate debris is a possibility, as is solution and collapse.

Fracture patterns are not strongly developed in the Lunae Palus quadrangle. The dominant lineaments, expressed particularly in Lunae Planum, trend north-south with a curvature to the northwest in the north and the southwest in the south. These directions would be normal to the compressional stress from a center of expansion in the Tharsis Ridge (Carr, 1974). Many, but not all, of the lineaments resemble lunar wrinkle ridges, which suggests that compressional forces were indeed responsible. Fractures in the direction of tensile stresses are less obvious in the Lunae Palus quadrangle than in other sectors around the Tharsis Ridge but do occur as the northeast-southwest lineaments in the northwest quarter of the quadrangle. Fractures of this set may be responsible for the course of Kasei Vallis, although erosion has destroyed any direct evidence for this.

GEOLOGIC HISTORY

The early history of the Lunae Palus quadrangle was dominated by impact cratering during a period of high cratering flux throughout the inner solar system. As this flux waned, plains formed that concealed most of the earlier craters. This process probably involved eolian and aqueous transport of sediments and perhaps volcanic ash; lava flows became the dominant component only later. Ground ice appears to have been incorporated in these deposits, either at the time of deposition or by subsequent cold trapping of volatiles. A period of disturbance associated with Tharsis uplift brought broad deformation of the surface with local faulting and minor folding, and effusion of lava. Melting of ground ice led to floods that eroded and redeposited older materials, probably late in this period. Thawing and flooding presumably reflect a short-lived warming of the climate which could have been brought about by either solar or Martian events. Volcanism ended earlier in the Lunae Palus quadrangle than in the Tharsis region to the west. At the present time, wind is the major geologic agent active at the surface.

REFERENCES

Baker, V. R. and Milton, D. J., 1974, Erosion by catastrophic floods on Mars and Earth: *Icarus*, v. 23, p. 27-41.
Carr, M. H., 1974, Tectonism and volcanism of the Tharsis region of Mars. *Jour. Geophys. Research*, v. 79, p. 3943-3949.
Soderblom, L. A., West, R. A., Herman, B. M., Kreidler, T. J., and Condit, C. D., 1974, Martian planetwide crater distributions: Implications for geologic history and surface processes. *Icarus*, 22, p. 1–25.

For sale by U.S. Geological Survey,
Denver, Colo. 80225, and Reston, Va. 22092, price $1.00