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
THARSIS QUADRANGLE
M 5M 15/112 G, 1975
I–893 (MC–9)

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 Patricia M. Bridges.

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) of 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, 1971) 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 source of data 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: Tractus Catena and Ulysses Patera.

MC-9: Abbreviation for Mars Chart 9

M 5M 15/112 G: Abbreviation for Mars 1:5,000,000 series; center of sheet, 15° latitude, 112° longitude; geologic map, G.

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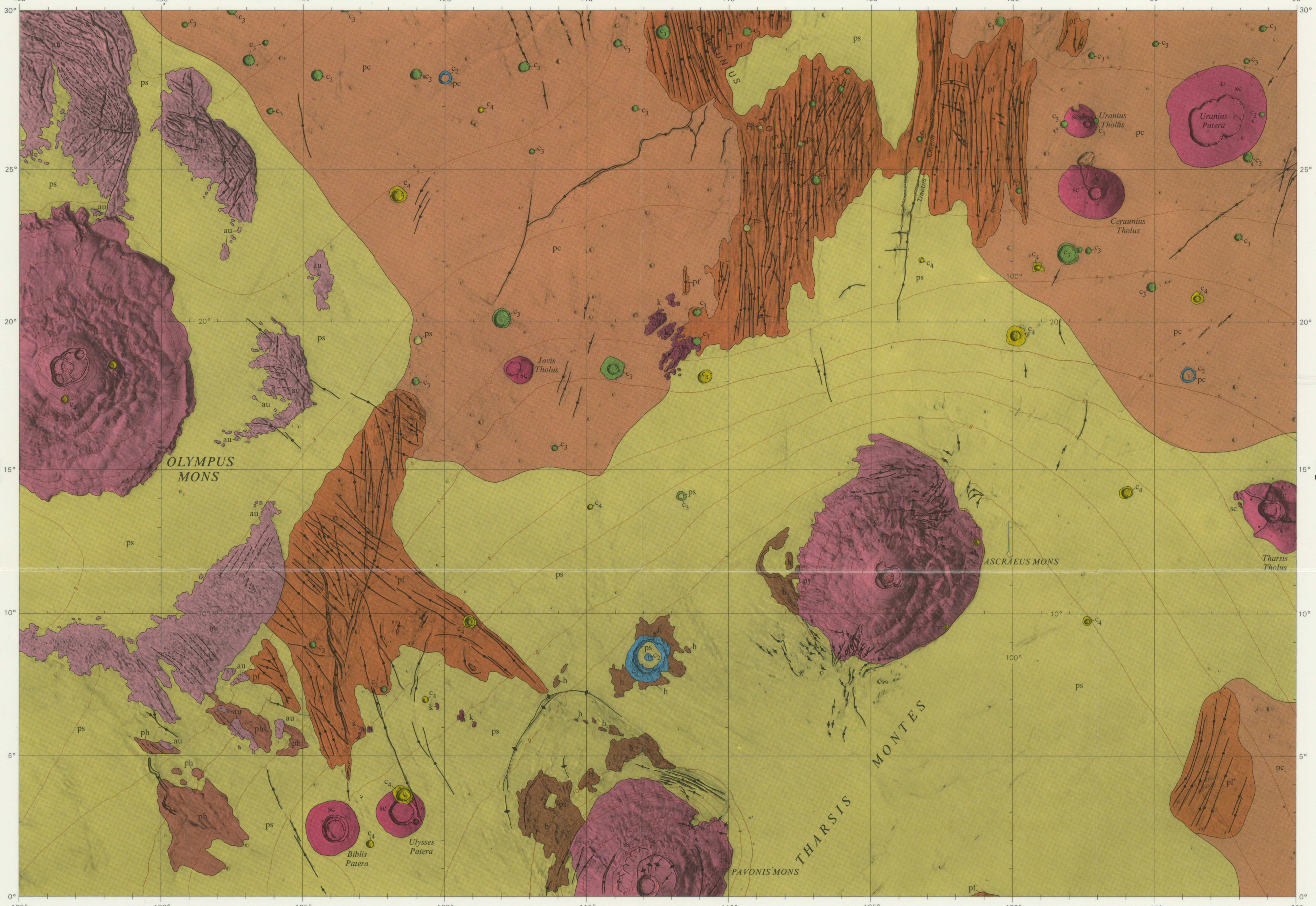
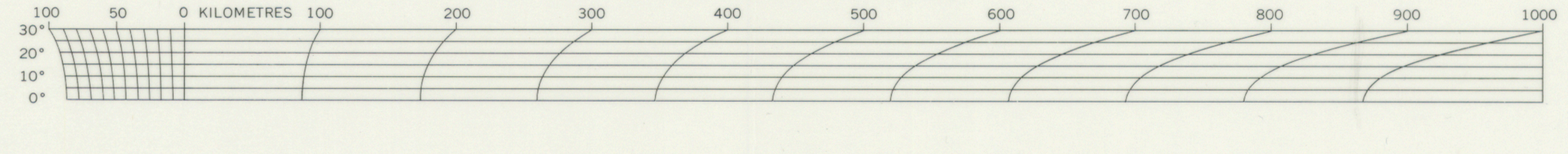
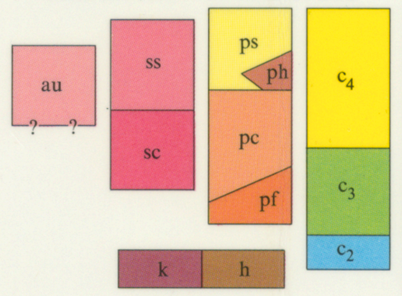


Interior—Geological Survey, Reston, Va.—1975
Prepared on behalf of the Jet Propulsion Laboratory, California Institute of Technology under WO-8122

SCALE 1:5 000 000 AT 0° LATITUDE
MERCATOR PROJECTION
CONTOUR INTERVAL 1 AND 5 KILOMETRES



CORRELATION OF MAP UNITS



DESCRIPTION OF MAP UNITS

ss — SPARSELY CRATERED SHIELD MATERIAL—Forms the three large shields, Olympus Mons, Ascraeus Mons, and Pavonis Mons. Flanks of shields slope at 4°-5° and have fine radial patterns that terminate abruptly against surrounding plains or at scarp marking edge of shield. At high resolution, radial pattern is seen to result from elongate fingerlike structures, low ridges, and narrow channels. Coarse concentric pattern results from slight breaks in slope that divide shields into round, mutually intersecting, terracelike segments. Flanks of Pavonis Mons and Ascraeus Mons cut by concentric grabens; lines of rimless depressions or isolated pits common. Northeast and southwest edges of Ascraeus Mons deeply dissected by intersecting linear depressions. At summits of Olympus Mons and Ascraeus Mons several intersecting circular depressions form complex summit pit. Simple summit pit of Pavonis Mons connected to circular ridge and escarpment to north by several low ridges. *Interpretation*: Summit depressions, gentle slopes, elongate fingerlike structures, and narrow channels all suggest that the three features are shield volcanoes made up of low-viscosity, probably basaltic, lava. Landforms suggesting pyroclastic materials not in evidence. Small number of superposed craters suggests relatively young ages, approximately 400 m.y. for surfaces of Ascraeus Mons and Pavonis Mons (Soderblom and others, 1974) and approximately 200 m.y. for surface of Olympus Mons

sc — CRATERED SHIELD MATERIAL—Forms variety of domical or inverted saucer-shaped structures with central depressions. Tharsis Tholus has smooth, convex-upward, faulted flanks. Ceraunius Tholus has numerous channels with one large channel connecting central pit to depression in surrounding plains. Uranius, Pavonis, and Biblis Paterae all have central depressions that are large compared to total size of the feature, and their flanks are smooth with indistinct outer margins. Number of superposed craters on all the structures exceeds that on sparsely cratered shield material and is comparable to cratered plains material (unit pc, fig. 1). *Interpretation*: Volcanic deposits, probably of basaltic composition. Channels on Ceraunius Tholus indicate low-viscosity lava but evidence from other features is less convincing of basaltic composition, and materials of other compositions may be present. Number of superposed craters suggests an age in the 1.5-2.0-b.y. range (Soderblom and others, 1974)

ps — SPARSELY CRATERED PLAINS MATERIAL—Occurs mainly around Olympus Mons and in Tharsis region. Featureless at 2-3-km resolution except for albedo markings; at 200-300-m resolution numerous low lobate escarpments visible, and crater density very low and very uneven. *Interpretation*: Lava plains, presumably of basaltic composition. Low, lobate escarpments, probably flow fronts, indicate low-viscosity lava. Average age approximately 100 m.y. (fig. 1), but uneven crater densities suggest wide spread in age or wide variation in rates of crater destruction

ph — HILLY PLAINS MATERIAL—Occurs only in small patches in southwest corner of quadrangle. Terrain consists largely of low, rounded, indistinct, and generally elongate highs with intervening subdued depressions. Crater density similar to sparsely cratered plains material (unit ps). *Interpretation*: Oldest part of unit ps, dissected and modified probably mostly by eolian action but also as result of some faulting

pc — CRATERED PLAINS MATERIAL—Forms cratered plains mainly in northern part of quadrangle. Surface featureless except for albedo markings and superposed craters. Lacks low, lobate escarpments that occur on sparsely cratered plains material (unit ps) at B-frame resolution. Widely spaced fractures and lines of small, rimless craters trend north-northwest–south-southeast in northwest part of quadrangle and northeast-southwest in northeast corner. *Interpretation*: Lava plains similar to units ps but older. Crater densities (fig. 1) suggest age in 1.5-2.0-b.y. range (Soderblom and others, 1974)

pf — FRACTURED PLAINS MATERIAL—Forms plains cut by numerous closely spaced fractures. Albedo lower than surrounding unfractured plains. At north edge of quadrangle trends of fractures mainly north-south and north-northeast–south-southwest; southeast of Olympus Mons they generally trend either northwest-southeast or north-northwest–south-southeast, and small area in southeast corner of quadrangle has north-northeast–south-southwest-trending fractures. Most fractures terminate abruptly against surrounding plains (unit ps and pc). Crater density suggests age similar to or slightly older than unit pc. Most fracturing appears to have occurred during relatively short period of time approximately 1.5 to 2.0 b.y. ago, probably concurrently with updoming of Tharsis region but prior to main period of shield building

k — KNOBBY MATERIAL—Occurs only in one small area of closely spaced, equidimensional, steep-sided hills close to center of quadrangle. Distinguished as separate unit because of close resemblance to knobby terrain (units kt and k of McCauley and others, 1972; Carr and others, 1973). *Interpretation*: Erosional remnant of primitive cratered terrain.

h — HILLY MATERIAL—Forms irregularly shaped, low hills, commonly elongate with no consistent orientation. Large craters and vague circular structures common. *Interpretation*: Remnants of primitive cratered terrain. Patches close to Pavonis Mons and Ascraeus Mons may be equivalents of the Olympus aureole material (unit au)

au — OLYMPUS AUREOLE MATERIAL—Occurs around Olympus Mons. Unit characterized by elongate hills typically 1-5 km wide, as much as 20 km long, and with accordant summits. Hills commonly separated by valleys with flat floors that commonly have fine striations parallel to length of valley. Parallelism of elongate hills commonly gives unit a marked linear texture. South of Olympus Mons individual hills more equidimensional than north, and linear texture correspondingly less pronounced. Unit appears to be broken into blocks along arcuate faults that tilt blocks gently inward toward Olympus Mons. *Interpretation*: Origin very uncertain. May be deeply eroded volcanic flows, the linear texture reflecting original flow structure. Implies that Olympus Mons or flows therefrom originally covered area where aureole materials presently exposed. Aureole perhaps made up of eroded ash-flow tuffs (King and Riehle, 1974) or formed by slump from central structure

CRATER MATERIALS—Divided into three categories according to supposed age. Only craters >20 km mapped

c_4 — Craters > 30 km have clearly identifiable, hummocky rim material, sharp rim crests, and steep, commonly terraced walls. Craters < 30 km have bowl shapes, sharp rim crests, and smooth rims

c_3 — Craters > 30 km have sharp rim crests, generally smooth but clearly identifiable rims, and bowl shapes. Craters < 30 km have bowl shapes with slightly subdued rims

c_2 — Partly buried craters with flat floors, resembling sparsely cratered plains material (unit ps). Rims partly buried by surrounding unit. Large (~60 km diameter) c_2 crater between Pavonis Mons and Ascraeus Mons has hummocky rim and central peak

Contact

Fault—Bar and ball on downthrown side. On narrow graben, ball either centered between faults or on single line representing both faults

Lineament—Linear ridge or valley

Low ridge showing trace along crest

Escarpment—Line drawn at base, hachures extend outward from steep face. May represent contact in places

Flow front—Arrow shows direction of flow

Crater rim crest—May represent contact in places

Rimless depression—May be superposed on fault

SUMMARY

The Tharsis quadrangle lies within the sparsely cratered hemisphere (Carr and others, 1973) of Mars. Its geology is dominated by young volcanic features, including both circular constructs and lava plains; little evidence of primitive densely cratered terrain remains. Included are three of the four largest shield volcanoes in the Tharsis province, Olympus Mons, Ascraeus Mons, and Pavonis Mons, together with several smaller shields. The fourth shield, Arsia Mons, lies to the south of the map area, as does Labyrinthus Noctis at the west end of the equatorial canyon system. The terrain within the quadrangle has approximately 25 km of relief with the three shield volcanoes standing 9 to 25 km above the plains, which slope 0.2° to 0.4° to the north-northwest.

The oldest materials in the area are the knobby and hilly materials (units k and h). Indistinct circular structures within the hilly material suggest old eroded craters. Such structures are common in a similar unit south of the map area in the Claritas Fossae region and suggest that this unit is a remnant of primitive cratered terrain. The knobby material is also believed to be a remnant of cratered terrain by analogy with similar material elsewhere, particularly at the boundary between the densely cratered terrain and the sparsely cratered plains (Carr and others, 1973). The nature of the difference between these units is not known, but they may be basically the same material and may differ only in degree of dissection. The presence of these isolated patches of cratered deposits implies that the volcanic plains are thin and that their relatively high elevation is due to upwarping of the crust and not to the thickness of volcanic deposits.

The fractured plains (unit pf) and the cratered plains (unit pc) are the next youngest units exposed in the quadrangle. The number of superposed craters suggests ages in the 1.5-2.0-b.y. range (Soderblom and others, 1974) for both units, so that a significant gap occurs in the local record between the formation of the cratered terrain, estimated at 3.5 to 4.5 b.y. ago, and the formation of the two plains units. This gap may merely reflect burial of units of intermediate age. Although these two plains units show no significant difference in the number of superposed craters, transection relations, which are particularly well developed at 17° N, 122° W, show that the fractured plains units is older than the cratered plains unit. Both units are believed to be of volcanic origin although they lack the long lobate escarpments that suggest flow on the younger plains units. Several circular volcanic structures (unit sc) formed at approximately the same time as the cratered plains. These include several shieldlike and domelike structures with central depressions and some low circular features that have central calderas encompassing as much as half the structure. All are more heavily cratered by what appear to be typical impact craters than the shield volcanoes. Significant by their absence are conical structures that might indicate pyroclastic activity. Such features may never have formed because magma composition was inappropriate or they may have been destroyed by wind. All the observed volcanic features are consistent with the quiet effusion of low-viscosity lava.

The small difference in age between the fractured and cratered plains, as indicated by the negligible difference in the number of craters, coupled with the enormous difference in the degree of fracturing suggest that most of the fracturing took place over a relatively short period of time (< 0.5 b.y.). Most fracturing occurred before the deposition of the cratered plains material so that it has relatively few fractures. Several closely spaced episodes of fracturing appear to have produced sets of fractures with slightly different orientations. North of Arsia Mons, the most recent fractures trend approximately north-northeast–south-southwest, commonly have numerous rimless depressions along their length, and terminate in lines of craters. Earlier fractures trend north-south and northeast-southwest. All appear to be part of a wide system that is roughly radial to Labyrinthus Noctis and may have formed as a result of broad updoming centered on that region.

The main building period of the large shield volcanoes probably postdates deposition of the cratered plains; however, this is uncertain because only the present surfaces can be dated. The number of impact craters on the shields suggests that approximate ages for their surfaces are 800 m.y. for Arsia Mons, south of the quadrangle, 400 m.y. for Ascraeus Mons and Pavonis Mons, and 200 m.y. for Olympus Mons (Soderblom and others, 1974). Thus about 1 b.y. ago, the style of volcanism changed from numerous small shields to fewer but substantially larger features. Each shield is slightly different. Ascraeus Mons has a complex summit crater, numerous rimless depressions on its flanks, and intersecting crevasselike depressions on its northeast and southwest edges. The summit depression of Pavonis Mons is simple, and on the flanks are several concentric fractures. The surface texture of Olympus Mons is crisper than that of the other two shields, with elongate flow lobes and narrow lava channels clearly visible. The aureole of Olympus Mons is very sparsely cratered, suggesting a relatively young age, which is consistent with transection relations at 10°N, 126°W that clearly show the aureole to be younger than the fractured plains. The large size of the shields implies that they were built over a long period of time, probably several tens to possibly a few hundred million years. Their extreme height suggests a deep source of lava, probably in the 150-200-km range (Carr, 1973). Earlier shields do not appear to be as high. If the present heights of the old shields (unit sc) are the same as their original heights, then the magma originated at a shallower depth than that of the later shields (unit ss).

The origin of the aureole and escarpment of Olympus Mons is uncertain. The aureole may be the eroded remnants of the former outer parts of Olympus Mons, the cliff being a receding boundary between the eroded and noneroded parts. The linear texture of the aureole could then represent etched fossil flow structures. However this theory fails to explain why erosion should be so selective—active at the cliff face and negligible on the flanks where very fine structures are preserved. It also fails to explain why cliffs are not so well established on the other shields. Other alternatives are that the aureole is etched and compacted ash-flow tuffs or that it is the eroded remnants of flows from the central structure that were emplaced either by volcanic activity or by some process of mass wasting. Whatever its origin, the aureole appears to have been subsequently fractured along arcuate faults, concave toward Olympus Mons, that divide the aureole into gently inward dipping blocks.

The youngest unit in the area is the sparsely cratered plains material (unit ps). In general it occurs around the large shield volcanoes and is distinguished by its lack of craters. The number of superposed craters gives an average age of 10^8 years (Soderblom and others, 1974). However, the average age is somewhat deceptive in that at B-frame resolution the number of craters varies greatly; many B-frames have no discernible craters, while others have several tens of craters. This variation suggests that the unit has a wide range of age, with parts as young as 10^7 years. All B-frames show long, low, lobate flow fronts, which suggest that the unit is made up largely of basaltic flows, although a thin veneer of eolian debris is almost certainly present in places. The unit represents the final volcanic episode in the area.

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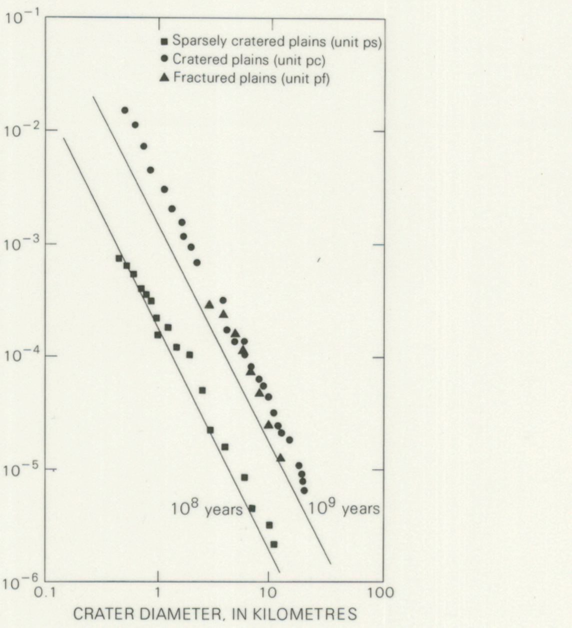
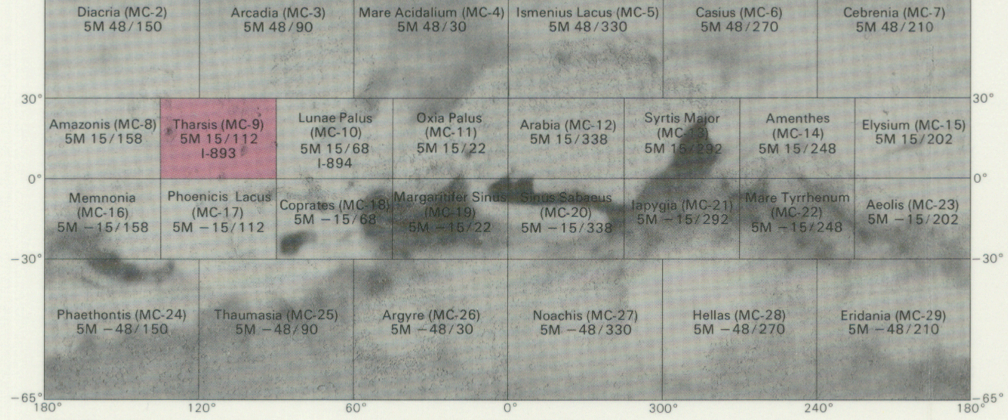
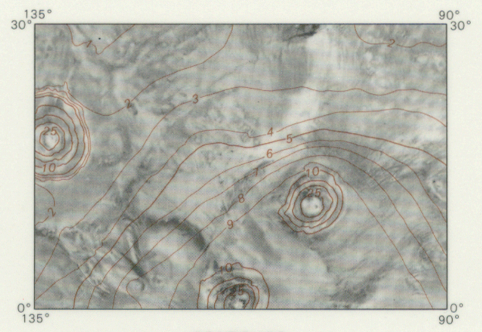


FIGURE 1.—*Cumulative crater counts on three plains units. Solid line, isocrons showing estimated ages based on Soderblom and others (1974)*

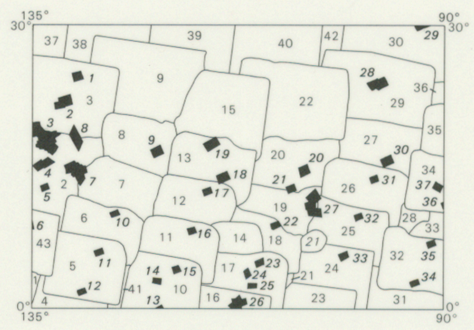


Albedo features from International Planetary Patrol photographs. Lowell Observatory, Flagstaff, Ariz.

QUADRANGLE LOCATION
Number preceded by I refers to published geologic map



CONTOURS
Contour interval 1 and 5 kilometers. Surface markings derived from selected Mariner 9 photographs



A-camera pictures

Index No.	DAS No.	Index No.	DAS No.
1	06895178	23	07183158
2	06895668	24	07183228
3	06895738	25	07183298
4	06967138	26	07183368
5	06967208	27	07183438
6	06967278	28	07183648
7	06967348	29	07183788
8	06967418	30	07183928
9	06967768	31	07255188
10	07039168	32	07255258
11	07039238	33	07255328
12	07039308	34	07255398
13	07039378	35	07255468
14	07039588	36	07255818
15	07039728	37	08226864
16	07111128	38	08298824
17	07111198	39	08370854
18	07111268	40	08442884
19	07111338	41	08513864
20	07111408	42	08514844
21	07111618	43	06895248
22	07111758		

High-resolution B-camera pictures

Index No.	DAS No.	Index No.	DAS No.	Index No.	DAS No.
1	*9701374*	*10*	*6967308*		*7111158*
2	*6823948*	*11*	*6967238*		*6779968*
	9701234	*12*	*6967168*	*27*	*8729914*
3	*12500485*	*13*	*7039128*		*5636468*
	5492408	*14*	*8513894*		*9917604*
	11656890	*15*	*7039198*	*28*	*10061454*
	11656960	*16*	*7039268*		*10061524*
	10686389	*17*	*7039338*	*29*	*7183958*
	11657030	*18*	*7039688*	*30*	*7183748*
	9845434	*19*	*9845574*	*31*	*7183398*
	8297874	*20*	*7111718*	*32*	*7183328*
4	*9557314*	*21*	*7111368*	*33*	*7183258*
	9557384	*22*	*7111298*	*34*	*7255218*
5	*6895348*	*23*	*7111228*	*35*	*7255288*
6	*6895278*	*24*	*9916624*	*36*	*7255358*
7	*6895698*	*25*	*8585924*	*37*	*8657884*
	9845364	*26*	*9917394*		
	9845294		*9917324*		
	9844594		*9916554*		
8	*9844664*		*9917254*		
9	*6967728*		*5563948*		

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

GEOLOGIC MAP OF THE THARSIS QUADRANGLE OF MARS

By
M.H. Carr
1975