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
AMAZONIS QUADRANGLE
M 5M 15/158 G, 1978
I-1049 (MC-8)

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; 1976). 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. This is not the height datum which is defined below under the heading "Contours".

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 lat 30°. Longitudes increase to the west in accordance with the usage of the International Astronomical Union (IAU, 1971). 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-O (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 Mercator projections of Mariner 9 pictures was assembled 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 besides those in the base mosaic were examined to improve the portrayal (Levinthal and others, 1973; Green and others, 1975; Inge and Bridges, 1976). The shading is not generalized and may be interpreted with nearly 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 (the 0 km contour line) for altitudes is defined by a gravity field described by spherical harmonics of fourth order and fourth degree (Jordan and Lorell, 1973) combined with a 6.1 millibar atmospheric pressure surface derived from radio-occultation data (Kliore and others, 1973; Christensen, 1975; Wu, 1975).

The contour lines on most of the Mars maps (Wu, 2975) 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 the accuracy of topographic elevation information has not been made. The estimated vertical accuracy of each source of data indicates a probable error 1-2 km.

NOMENCLATURE

All names on this sheet are approved by the International Astronomical Union (IAU, 1974; 1977).

MC-8: Abbreviation for Mars Chart 8.
M 5M 15/158 G: Abbreviation for Mars 1:5,000,000 series; center of sheet, 15° latitude, 158° longitude; geologic map G.

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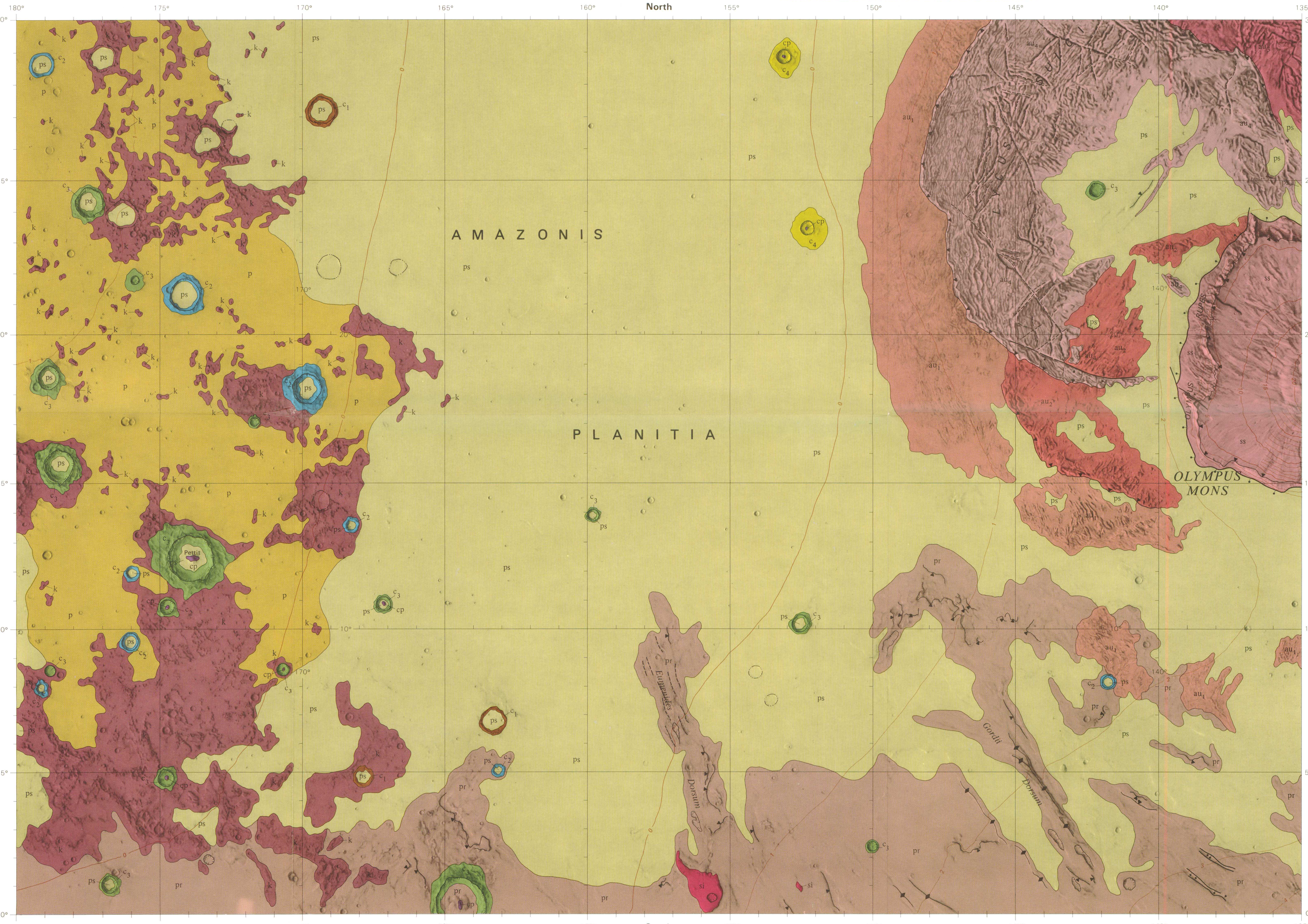

Interior—Geological Survey, Reston, Va.—1978—G77025
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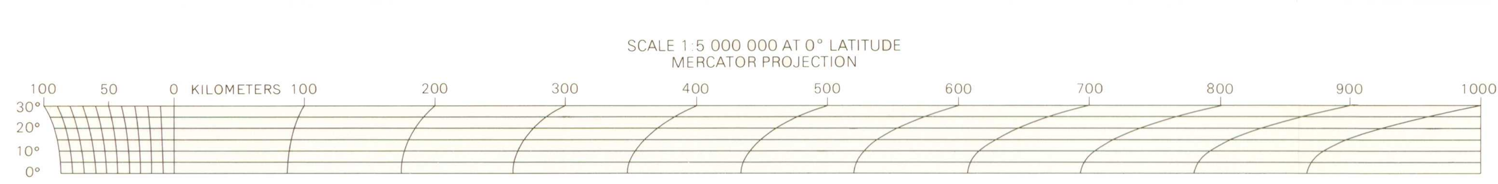
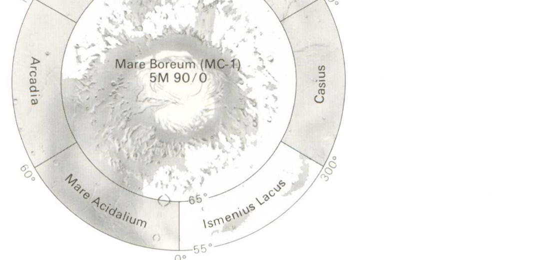
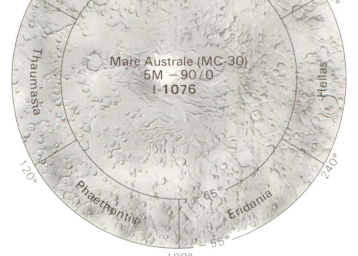
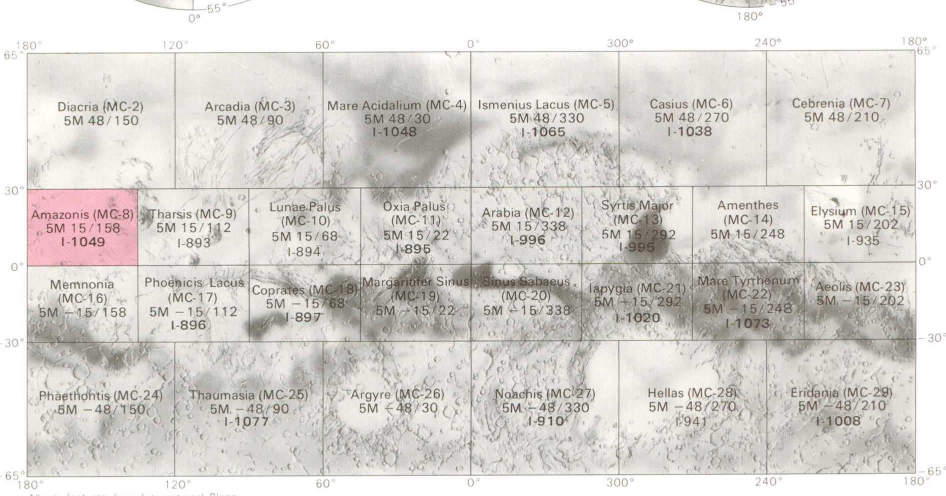
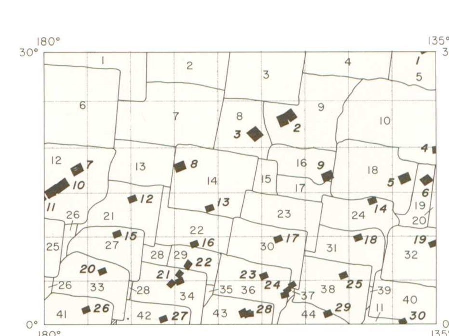








QUADRANGLE LOCATION
Number preceded by I refers to published geologic map



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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. Useful coverage is not available in cross-hatched area. Also shown (by solid black rectangles) are the high-resolution B-camera pictures, identified by italic numbers. The DAS numbers may differ slightly (usually by 5) among various versions of the same picture.

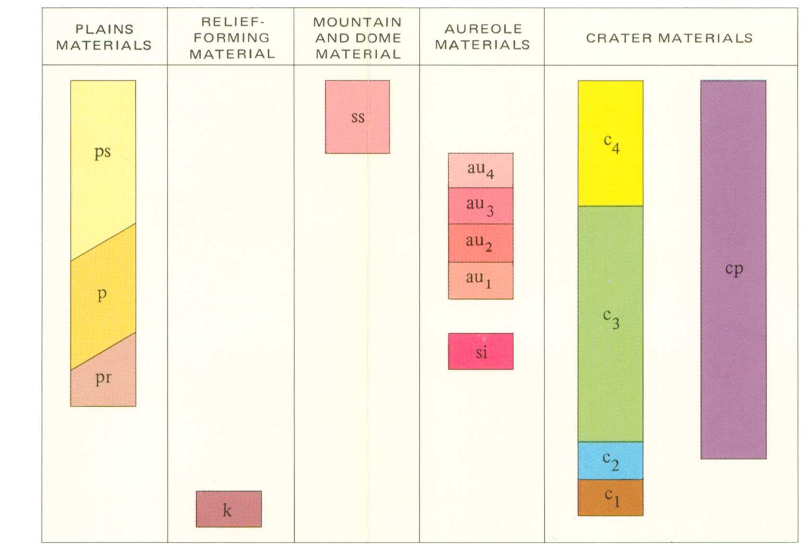
GEOLOGIC MAP OF THE AMAZONIS QUADRANGLE OF MARS

By

E. C. Morris and S. E. Dwornik

1978

CORRELATION OF MAP UNITS



DESCRIPTION OF MAP UNITS

PLAINS MATERIALS

ps — SMOOTH PLAINS MATERIAL—Covers almost 50 percent of the quadrangle; flat, light, featureless surface at high and low resolution. Frequency distribution of craters > 3 km diameter less than $100/10^6$ km^2; crater density least in central part of quadrangle. *Interpretation:* Relatively thick volcanic and eolian deposits; probably thickest in central part of quadrangle. Extreme youth indicated by low crater population

p — PLAINS MATERIAL—Resembles smooth plains material (unit ps) but has greater crater population ranging from about 100-$200/10^6$ km^2. In places subjacent topography, including hills and fractures, visible on high-resolution photographs. *Interpretation:* Volcanic and eolian deposits, older and/or thinner than unit ps

pr — ROLLING PLAINS MATERIAL—Occurs mostly on the margin of the southern part of the Amazonis plains; smooth, uneven, moderately cratered, mottled appearance. Lobate overlapping scarps. Crater density less than plains material in Amazonis quadrangle but similar to plains material in other areas. *Interpretation:* Mostly lava flows thinly covered by eolian deposits

RELIEF FORMING MATERIAL

k — KNOBBY MATERIAL—Consists of rounded to subangular, generally equidimensional hills forming rugged upland terrain. Forms part of rims and walls of craters older than c_2. High-resolution photographs show triangular faceted faces and elongate shapes resembling yardangs as well as conical forms. Summit craters on conical forms rare. Highest crater density of any unit in quadrangle, ranges from about 200-$300/10^6$ km^2. *Interpretation:* Remnants of ancient cratered terrain; dissected by faults and fractures and embayed by all plains units

MOUNTAIN AND DOME MATERIAL

ss — SPARSELY CRATERED SHIELD MATERIAL—Forms the large shield volcano, Olympus Mons. The flanks of the shield slope 4°-5° and have a fine radial pattern of grooves and ridges that terminate abruptly at the scarp marking the edge of the shield. High-resolution pictures show the radial pattern to be composed of a network of intersecting and anastomosing low ridges, narrow channels, and elongate fingerlike structures. Some of the larger ridges have sinuous channels along their apex. Slight breaks in the slope of the flanks of the volcano form a pattern of rounded terracelike segments. A summit crater marks the crest. *Interpretation:* The elongate fingerlike structures and narrow channels on the flanks of the shield are made by lava flows; the summit crater is a caldera. Olympus Mons is a shield volcano made up of low-viscosity, probably basaltic lava. The small number of superimposed craters on the flanks of the volcano suggests a relatively young age, possibly 200 million years (Carr, 1975) if lunar and Martian rates of crater accumulation are comparable

AUREOLE MATERIALS

Occur as several overlapping sheets of distinctly textured and lineated terrain that form an asymmetric apron or aureole around Olympus Mons. They extend more than 1500 km northwest from the center of Olympus Mons but only 500 km east. Four separate deposits have been recognized in the Amazonis quadrangle, but additional ones may be present. Each deposit can be distinguished from adjacent ones by the length and width of the ridges and the orientation of the surface features. The absence of small superimposed craters suggests a very young age, perhaps only slightly older than Olympus Mons. *Interpretation:* A series of overlapping, very fluid lava flows extruded prior to the construction of Olympus Mons but associated with the volcanism that produced the large shield volcano. Subsequent eolian erosion has modified the surface forms of the deposits and in places has stripped an overlying deposit to expose the underlying one

au_4 — AUREOLE DEPOSIT UNIT 4—Lies on and overlaps all other aureole deposits; partly buried by the smooth plains material. The central and southeastern parts of the nearly circular deposit form a shallow basin filled with smooth plains material. The surface is characterized by a series of ridges and grooves that roughly parallel the outer boundary of the deposit. Individual ridge segments are from 10 to 50 km long and form an anastomosing pattern that varies in length and width over different parts of the deposit. The ridges are closely spaced in the western and northwestern areas (32 ridges per 100 km) and further apart in southwestern exposures (16 ridges per 100 km). The ridges are estimated to be as much as 1 km high. Their pattern is broken by several sets of intersecting long linear grooves that may be grabens or possibly fractures with little displacement. Two major sets of grooves trend between N 20° W to N 30° W and N 65° W to N 70° W, and a minor set trends N 35° E

au_3 — AUREOLE DEPOSIT UNIT 3—Occurs in northeast corner of the quadrangle where it is covered by unit au_4 and rests upon unit au_1. At the contact of unit au_3 with unit au_4 the ridges of unit au_4 trend generally N 60° W whereas the ridges of unit au_3 trend N 10° E to N 20° E. The surface characteristics of unit au_3 are similar to those of unit au_4 in magnitude, and except for the difference in trend of the ridges at the contact of the two units, they are difficult to differentiate

au_2 — AUREOLE DEPOSIT UNIT 2—Occurs west of Olympus Mons and is covered in part by unit au_4 and overlaps unit au_1. The age relation between au_3 and au_2 is not known as a contact between the two units is not exposed. Both deposits (units au_2 and au_3) are partly covered by unit au_4, and both rest on unit au_1. However, the surface features of unit au_2 show a greater amount of degradation and are of a smaller scale than those of unit au_3, therefore, unit au_2 is considered an older deposit than unit au_3. The south half of unit au_2 is mostly buried by plains material, but the terminal edge of the deposit stands out in clear relief. The ridges that form the edge of the deposit are at an acute angle to the trend of ridges of the underlying unit au_1 deposit. The north half of unit au_3 is partly covered by au_4, but an expression of the terminal edge of au_2 can be seen in the au_4 deposit as a slight crescentic ridge and valley

au_1 — AUREOLE DEPOSIT UNIT 1—The oldest and most extensive of the aureole deposits and is overlain by all other aureole deposits. The full extent of unit au_1 is not known as smooth plains material laps upon and buries the outer reaches of the deposit. Surface features differ from overlying deposits mainly in scale and are characterized by sets of anastomosing ridges and alined hills and knobs as much as 10 km long; these features are alined roughly with the trace of the outer edge of the deposit. Where well exposed, the ridges are closely spaced, approximately 30 to 40 ridges per 100 km. High-resolution pictures (DAS 6823393) of the ridges show aerodynamic shapes similar in form to terrestrial yardangs

si — IRREGULAR SHIELD MATERIAL—Forms irregular shaped, convex upward structures with summit craters. Occurs in the rolling plains material in the southern part of the quadrangle. In high-resolution pictures surface appears rough with small knobs and grooves along the margins. *Interpretation:* Volcanic deposits, probably basaltic lavas. May be one of many vents or sources of the rolling plains material

CRATER MATERIALS

Craters are classified according to relative age on the basis of their morphologic characteristics. Craters less than 20 km diameter were not mapped. Most craters in the following categories are believed to be of impact origin

c_4 — MATERIALS OF SHARP-RIMMED CRATERS—Rims complete, raised and clearly identifiable hummocky rim material extending at least one crater diameter from center of crater. Central peaks present and conspicuous

c_3 — MATERIALS OF RIMMED CRATERS—Rims complete, raised and rough appearing where diameter is >30 km. Floors lower than adjacent terrain; rough in craters <30 km, otherwise bowl shaped. Central Peaks present and conspicuous

c_2 — MATERIAL OF SUBDUED CRATERS—Rims similar to c_3 craters but partly consist of knobby material (unit k). Floors smooth, flat, lower than adjacent terrain. Central peaks small to absent

c_1 — MATERIAL OF HIGHLY DEGRADED CRATERS—Rims incomplete; consist in large part of unit k. Floors like those of c_2 craters but about same elevation as adjacent terrain. Central peaks absent

cp — CENTRAL PEAK MATERIAL—Prominent hill near centers of c_4 and c_3 age craters and some c_2 age craters. *Interpretation:* Brecciated crater floor uplifted by rebound during shock decompression following compressive stage of impact

SYMBOLS

Contact

Fault scarp—Ball on low side

Scarp—Line at base, barb points downdip. *Interpretation:* Flow front or fault scarp

Ridge

Crater rimcrest—Not shown around smaller craters or where indistinct

Remnant or buried crater rimcrest

Depression or caldera rim

Lineament

PHYSIOGRAPHIC SETTING

The Amazonis quadrangle lies within the northern sparsely cratered hemisphere of Mars (Carr and others, 1973). The dominant structural and physiographic features of the quadrangle are low featureless plains (Amazonis Planitia) in the center third of the quadrangle, the western flanks of the large volcanic construct, Olympus Mons, and its associated aureole deposits (Lycus Sulci), which lies on the eastern slopes of the plains, and an area of rough knobby terrain along the west edge of the quadrangle. The central plains descend northward into the circumpolar lowlands (Arcadia Planitia, Vastitas Borealis) and rise southward where they are bounded by the cratered terrains of the equatorial region of Mars.

GEOLOGIC SUMMARY

The oldest material exposed in the Amazonis quadrangle is rough knobby material that forms the west margin of the central plains. This material was included in the knobby terrain unit of McCauley and others (1972) and the fretted terrain unit of Sharp (1973). The exposures of the knobby terrain are a consequence of elevation and degree of burial by the various plains-forming materials that fill the central plains and cover its margins. The knobby material in the quadrangle is probably partly buried eroded remnants of primitive densely cratered terrain (Carr, 1975). Much of the knobby material is arranged in vague arcuate and circular outlines suggestive of old eroded craters. The small number of c_1 or c_2 class craters with coherent rims in the unit suggests that the knobby material had an intense erosional history that has mostly destroyed the older craters. However, the number of c_2 and c_3 class craters is the highest of all units within the quadrangle and their size frequency distribution indicates an age comparable to the cratered terrains in the equatorial regions of Mars (Hartmann, 1973). The northern exposures of knobby terrain are almost completely buried by plains material, and many islandlike knobs rise above the level plains. Rolling plains material encroaches upon and buries the south edge of the knobby terrain.

The next oldest material is the rolling plains unit that forms the southern margin of the basin. The topography of this material consists of low, rolling elongate highs and indistinct lows trending generally northwest. The highs in some local areas break up into very irregular trending scarps and fractures. The undulatory character of the rolling plains, its elongate highs, ridges and scarps suggest that the material is mostly volcanic plains formed from lavas, possibly basalts, with a thin covering of eolian deposits. The boundary of the rolling plains with younger plains material is gradational and in some areas arbitrarily placed. In these areas the boundary is determined mainly on the basis of albedo differences. The rolling plains for the most part are darker than the younger smooth plains.

High-resolution pictures reveal highly varied surface detail on the rolling plains unit. Most of the features seen in these pictures are probably due the erosive action of high-velocity winds. Lobate escarpments, possibly the terminal edges of lava flows, are strongly etched into streamlined forms similar to terrestrial "yardangs" (McCauley, 1973). Planar surfaces of the flows are eroded into numerous closely spaced parallel grooves and lineations. The ejecta blankets around a number of small craters appear to have formed a protective cover to the erosive processes that have lowered the surfaces upon which the craters lie. Thus, these craters and their ejecta are on elevated platforms.

The smooth plains form the youngest plains-forming material within the quadrangle, overly and bury or embay all other units, and fill the interiors of many craters. At 2 to 3 km resolution the smooth plains material is nearly featureless and sparsely cratered, having very few craters larger than 20 km in diameter. At 200 to 300 m resolution, the smooth plains appear much the same except for a number of low, lobate escarpments. In general, the density of craters appears to increase westward with the least number of small craters (less than 20 km diameter) in the plains surrounding Olympus Mons. Because of the increase in crater density westward, an arbitrary division is made between the materials of smooth plains and plains. Plains material, in both high-and low-resolution pictures, appears identical to the smooth plains unit except for the greater number of small craters.

The plains and smooth plains materials probably include both aeolian and volcanic materials. Aeolian material may be interbedded with the lavas, and almost certainly the present surface is partially covered with wind blown debris. The presence of low, lobate scarps suggests, however, that the cover is discontinuous and that in places volcanic deposits are at the surface. Both plains materials appear to thin to the west and south.

The increase in the number of small craters westward on the smooth plains and plains materials implies that 1) either the surfaces of the plains material are older and thinner on the western flank of the basin and become younger and thicker towards the center of the basin and around the aureole of Olympus Mons, or 2) there was a layer of haze or windblown dust close to the ground in the center of the lowlands when the Mariner pictures were taken that obscured the small craters. The first interpretation is preferred.

Olympus Mons is the youngest feature within the quadrangle. However, the building of the large shield volcano and its associated aureole deposits probably was partly contemporaneous with the formation of the plains and smooth plains material. Olympus Mons rises from the smooth plains more than 23 km above the adjacent terrain (Carr, 1976) and is 500 to 600 km across at its base. High-resolution pictures reveal sharply defined flows and channels on its flanks. The scarcity of impact craters on its surface attests to a relatively youthful age, equivalent to 200 m.y. (Soderblom and others, 1974; Carr, 1976) if the crater accumulation rates on Mars are comparable to those on the Moon.

The large volcano is bounded at its base by a roughly circular scarp 1 to 4 km high. Several different origins for this scarp have been postulated; however, only two are considered here. King and Riehle (1974) postulate that the outer reaches of the slopes of Olympus Mons are dominantly ash-flow tuffs that eolian erosion has extensively modified from the scarp. This theory requires that the erosion be very selective, very active on the outer reaches but ineffective on the flanks where the fine details of lava flows and channels are preserved. Eolian erosion tends to streamline or aerodynamically shape obstacles being eroded. The highly irregular nature of the small elements of the scarp face do not suggest streamlining. Furthermore, the amount of erosion necessary to form a cliff 1 to 4 km high would have to be extreme and for Olympus Mons would have to be almost equally effective in all directions. An alternate hypothesis, which is favored here, is that the cliffs bounding Olympus Mons are fault scarps that have been slightly modified by eolian erosion (Carr, 1976).

The aureole deposits, because of the spatial arrangement surrounding Olympus Mons, are clearly associated with the volcano that produced the large shield volcano. The aureole is interpreted here to be a series of very fluid lava flows that were extruded during several episodes prior to the building of the main edifice of Olympus Mons.

It is not known whether the curvilinear ridges and troughs and lobate escarpments bounding the aureole deposits represent original flow structures or are subsequent erosional forms. However, the general parallelism of the ridges with the bounding scarps of each of the units strongly indicates that the location and orientation of the ridges are mostly from original flow structures and only subsequently have been modified by eolian erosion.

GEOLOGIC HISTORY

The geologic history of the Amazonis quadrangle, interpreted from the stratigraphic relations of the various mapped rock units, began with the erosion of ancient cratered terrain to form the knobby material. This material probably represents remnants of densely cratered and hilly terrain that developed early in the history of Mars during a period of intense meteorite bombardment. After the decline of the high impact flux, there was a long period of erosion and degradation of the cratered terrain, with subsequent development of the knobby terrain. The next major event was the flooding of the old cratered and knobby terrain in the southern regions of the map area by a thick series of basalts that form the rolling plains. The smooth plains and plains material filled the plains and buried the rolling plains and much of the knobby terrain. The youngest event recorded is the growth of Olympus Mons and the extrusion of its aureole deposits.

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For sale by Branch of Distribution, U.S. Geological Survey, 1200 South Eads Street, Arlington, VA 22202, and Branch of Distribution, U.S. Geological Survey, Box 25286, Federal Center, Denver, CO 80225.