DEPARTMENT OF THE INTERIOR
UNITED STATES GEOLOGICAL SURVEY

Prepared for the
NATIONAL AERONAUTICS AND SPACE ADMINISTRATION

ATLAS OF MARS
1:5000000 GEOLOGIC SERIES
MARGARITIFER SINUS QUADRANGLE
M 5M –15/22 G, 1979
I-1144 (MC-19)

NOTES ON BASE

This map sheet is one of a series covering the entire surface of Mars at nominal scales of 1:25000000 and 1:5000000 (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 1:5000000 at the equator and 1:4336000 at lat 30°. Longitude increases 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 10-15 km, except along the southern edge where inconsistencies as large as 20 km exist.

MAPPING TECHNIQUES

A series of mosaics of Mercator projections of Mariner 9 pictures was assembled at 1:5000000.

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 Patricia M. Bridges.

CONTOURS

Because 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, 1978).

The contour lines on most of the Mars maps (Wu, 1975, 1978) 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 of 1-2 km.

NOMENCLATURE

All names on this sheet are approved by the International Astronomical Union (IAU, 1974, 1977, 1980).

MC-19: Abbreviation for Mars Chart 19.
M 5M –15/22 G: Abbreviation for Mars 1:5000000 series; center of sheet, lat –15°, long 22°; geologic map, G.

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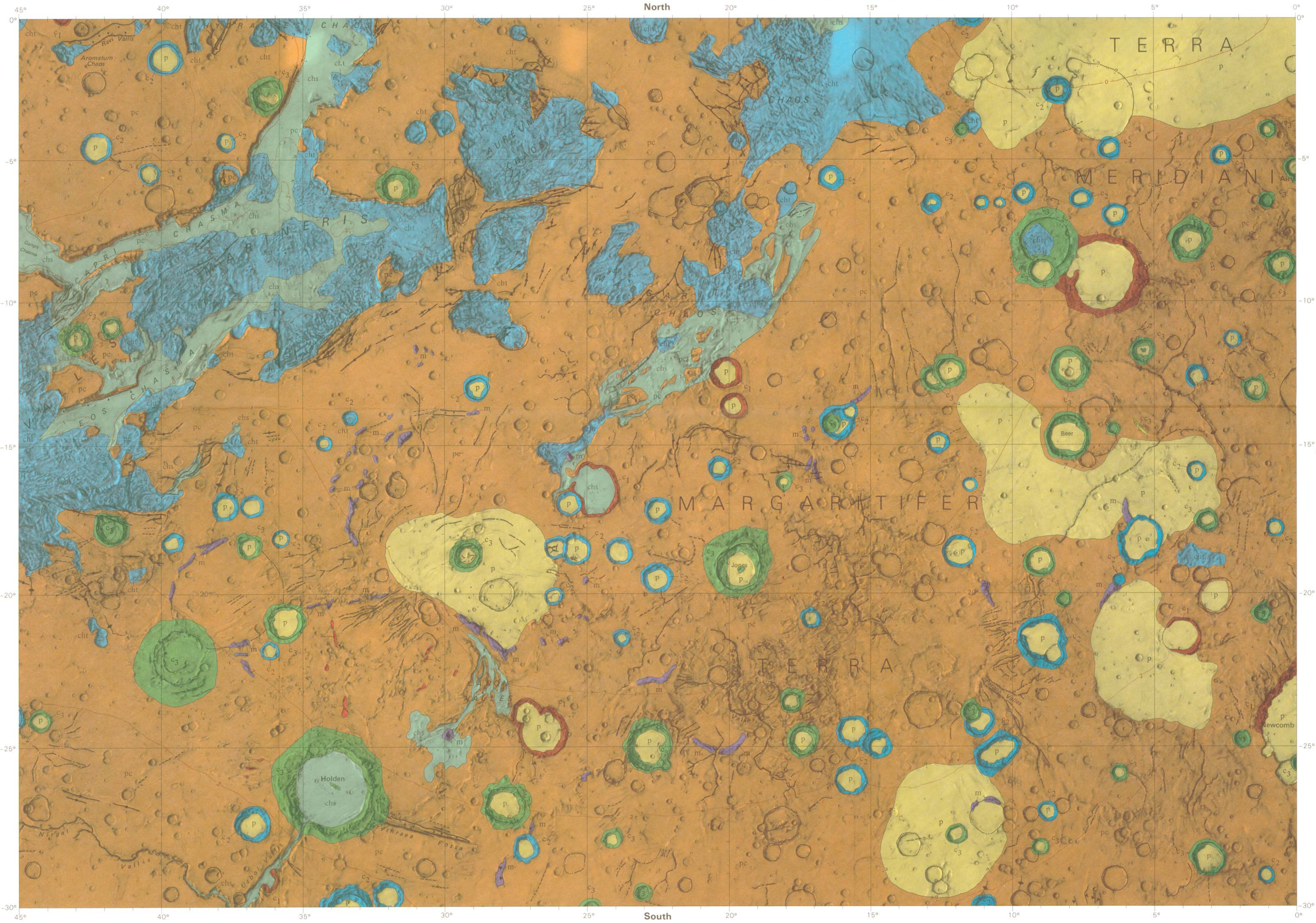

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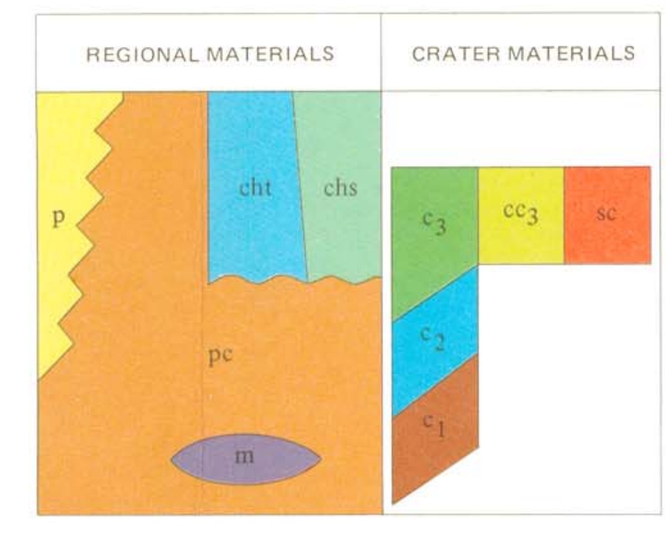
SCALE 1:5 000 000 AT 0° LATITUDE
MERCATOR PROJECTION

100 50 0 KILOMETERS 100 200 300 400 500 600 700 800 900 1000

CONTOUR INTERVAL 1 KILOMETER

CORRELATION OF MAP UNITS



DESCRIPTION OF MAP UNITS

REGIONAL MATERIALS

p SMOOTH-PLAINS MATERIAL—Forms smooth and gently undulating surface occupying crater floors and large expanses in northeastern and southeastern parts of quadrangle; some areas have isolated, low, irregular hills. Few channels occur in unit. Density of fresh craters is same or slightly less than in cratered-plateau material (unit pc) but with fewer modified craters. *Interpretation:* Larger expanses outside of craters may be eolian or volcanic material. Material within craters is locally derived from crater walls. Surficial material in all occurrences is fine-grained material deposited by wind

chs CHANNEL DEPOSITS—Form smooth surfaces in valley floors and contiguous areas. *Interpretation:* Material transported by moving water. Surface modified by wind, producing erosional landforms in places

cht CHAOTIC MATERIAL—Forms flat-topped to rounded blocks within scarpbounded depressions. In places structurally gradational with cratered-plateau material (unit pc), but defined as chaotic material where faulting and slumping have reoriented individual blocks of adjoining unit. *Interpretation:* Material of cratered plains chaotically disrupted and redeposited by downslope movement. Movement initiated in part by channel formation and by removal of support by flow of subsurface material, probably ice

pc CRATERED-PLATEAU MATERIAL—Forms smooth and gently undulating surfaces, occupied by craters of all morphologies. Contains numerous sinuous channels. Locally has scarps and ridges. *Interpretation:* Complex unit of diverse origins; major part consists of crustal material approximately 1 km thick, shattered and brecciated by early saturation impact-crater bombardment extending back to earliest recognizable events on Mars. Local, more recently formed surficial deposits not saturated with impact craters include volcanic materials, flows and ash, eolian deposits, and water-laid sediment

m MOUNT MATERIAL—Forms smooth, rounded, and generally isolated, elongated hills 10-100 km in greatest dimension, some in arcuate clusters, *Interpretation:* Remnants of eroded craters

CRATER MATERIALS

Craters are classified on basis of morphologic characteristics. Generally, most degraded craters are older. Craters smaller than 20 km in diameter are not mapped. *Interpretation:* Craters mapped in following classifications are of impact origin.

c_3 MATERIAL OF SUBDUED CRATERS—Rims sharp and complete but narrow; distinctly elevated above surrounding terrain

cc_3 MATERIAL OF SUBDUED CRATER CLUSTERS—Small crater clusters with same morphology as c_3 craters

c_2 MATERIAL OF DEGRADED CRATERS—Shallow, pan-shaped craters; rim not elevated distinctly above level of surrounding terrain

c_1 MATERIAL OF HIGHLY DEGRADED CRATERS—Rims incomplete and floor at or near elevation of surrounding terrain

sc SATELLITIC-CRATER MATERIAL—Forms crater chains and depressions subradial to crater Holden. *Interpretation:* Secondary impact craters

Contact—Queried where uncertain or gradational

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 tract along crest

Escarpment—Line drawn at base; triangle points downslope

Shallow trough

Crater rim crest—May represent contact in places. Queried where uncertain or gradational

Buried or highly subdued crater rim

Crest-line of crater ring in crater with concentric multiple rings

Depression

INTRODUCTION

The Margaritifer Sinus quadrangle lies within a broad north-sloping trough, the Chryse lowland, between the elevated Tharsis plateau to the west and the cratered upland to the east.

The rugged, uniquely martian chaotic terrain is best developed in this quadrangle. Sinuous furrows a few kilometers wide and as much as several hundred kilometers long cover most of the quadrangle; in several places are broad regions many tens of kilometers wide that appear to be complex channel systems. None of these features can be correlated with markings seen from the Earth.

The major part of the quadrangle consists of moderately cratered material containing craters of different morphologic types. This region is typical of the most cratered regions of Mars (Jones, 1974), having been previously mapped as cratered terrain, undivided (Carr and others, 1973), as moderately cratered terrain (McCauley and others, 1972), and as plateau plains (Wilhelms, 1974).

PHYSIOGRAPHY

At the resolution of the available data, major clues to the important geologic processes and the nature of the surface materials must come from the gross morphology of the terrain. The entire quadrangle lies within a broad north-trending trough (Christensen, 1975) called the Chryse lowland, which contains nearly all the major channels on Mars and almost all the chaotic material. All major channels are concordant with regional slopes within the Chryse lowland; small channels are apparently controlled more by local slopes, particularly by the shallow depressions of large, ancient impact craters. These craters are now marked by the isolated remnants of rim materials, and local channels tend to form radial patterns. The largest example is a 500-km-diameter depression, with radial channels and remnants of rim material, that occurs at lat 18° S. and long 29° W.

In the northwest corner of the quadrangle, the major rift zone that formed Valles Marineris apparently ends. The straight scarps that bound the great canyons to the west give way to irregular scarps, except in parts of Capri and Eos Chasmata, and to large expanses of chaotic terrain. The nature of the surface material apparently controls the form of the canyons to a great extent. To the west of the quadrangle, nearer Tharsis Montes, the surface material may consist of relatively hard volcanic flows or indurated breccias, where rifting produces sharp linear fractures. In the Margaritifer Sinus quadrangle, the surface is not capped by rigid cohesive material but rather is made up of inhomogeneous, unconsolidated rubble produced by impact events. This material forms irregular scarps and may also contain large quantities of water ice. The east-west rifting may have initiated a process of melting or release of water from the subsurface that formed the chaotic terrain and created broad channels as water and debris flowed to the north down the slopes of the Chryse lowland.

The physiography of the chaotic material has been described elsewhere (Sharp and others, 1971; Sharp, 1973). The type area is within this quadrangle at lat 0° to 10° S. and long 15° to 35° W. The description of the unit by Sharp (1973, table 1) summarizes the data: "Jumbled chaos of slump and collapse blocks in lowland depressions bounded by steep walls with arcuate fractures."

GEOLOGY

Stratigraphy

The cratered-plateau material underlies most units of the quadrangle. This material is composed of impact debris of varying thickness but probably at least 1 km thick. The total volume of craters can be obtained from detailed crater counts (Jones, 1974). Using the relation between crater radius and volume given by McGetchin and others (1973), the thickness of ejecta on the cratered terrains of Mars is calculated from observed craters to be about 500 m. This is a conservative estimate because it ignores the contribution of large eroded craters and the Argyre, Isidis, and Hellas basins. The surface consists of reworked material deposited widely by wind, as evidenced by wind streaks and splotches, and locally by water, as evidenced by channels at all scales. Evidence for fluid reworking is much more ambiguous.

Wilhelms (1974) has divided the cratered regions into two geologic provinces: the cratered province and the plateau plains province. The Margaritifer Sinus quadrangle lies within the plateau plains province; typically, this region has level intercrater areas, with a few smaller craters older than the intercrater plains. This is demonstrated by detailed crater counts: Jones (1974) has presented evidence for a period of crater obliteration on the basis of his interpretation of crater statistics. The obliteration episode and the creation of moderately cratered plains in the intercrater areas may be manifestations of the same erosion episode. Wilhelms suggests that the plains are the product of deposition rather than of erosion; candidate materials are eolian, fluviatile, and volcanic deposits. Jones argues further that the obliteration may not be directly related to volcanism because the most extensive, unquestionably volcanic deposits are much younger. The surface modification that created the smooth intercrater areas certainly predates the most recent extensive volcanism of the Tharsis Montes region. Wilhelms presents evidence that much intercrater material is volcanic cover.

Catastrophic changes accompanied formation of the chaotic material. This unit is much less cratered than the smooth intercrater areas of the cratered-plateau material and therefore was probably formed more recently. The most extensive regions of chaotic material merge with channel deposits reminiscent of dry channels in the arid regions on Earth. The chaotic material clearly formed by modification of the cratered-plateau material because the two units are morphologically gradational in many places. The smooth channels appear to drain the chaotic regions, and the dominant impression is that water has drained from beneath large regions, causing collapse.

None of the myriad small furrows are disrupted by the chaotic material and none appear to flow into it. In two instances broad channels with mappable smooth material on their floors appear to have drained into regions of chaotic terrain. These occurrences begin at lat 7° S., long 17° W., and lat 15° S., long 38° W. Thus channels may not always drain away from the chaotic terrain, as usually reported.

The primary requirement for formation of the chaotic material appears to have been the removal of support from below; this may have been accomplished by structural subsidence in some areas. The lateral extension of chaotic terrain may have been enhanced by the removal of trapped liquid water or by the melting of lenses of ice and the consequent formation of broad, sediment-choked runoff channels. Surface channels on the moderately cratered material that are not related to formation of the chaotic-terrain material, as well as many of the broad channels (such as the one that appears to flow into the crater Holden from Nirgal Vallis), may have formed in some other way. The most probable mechanism appears to have been surface runoff following torrential rains.

Within this quadrangle are numerous isolated mounds arranged in circular and semicircular arrays; these are almost certainly the eroded remnants of large craters. The distrubution, size, and number of these features indicate that the initial cratered surface of this region was similar to that of the lunar highlands. Erosion of these large craters could not have been accomplished solely by continuing impact up to the present because the surface is far from saturated (Jones, 1974). The coexistence of large, nearly destroyed craters with the present crater population suggests an early period of extensive erosion or burial by widespread lava flows. The incomplete rings of mound material are remnants of a population of craters as large as 500 km in diameter. If the present population of undestroyed large craters is ancient (> 3 b.y.), then nonimpact degradation processes must have been even more significant in early martian history.

The origin and nature of the material of the smooth plains are problematical. They are relatively young as they contain craters that postdate the resurfacing episode. None of the small sinuous channels cross the large expanses of smooth plains, although some channels may cross smaller occurrences in the smooth intercrater regions. There is no direct evidence that the smooth-plains material is volcanic. Rather, it appears of the same age as the most recent episode of intense erosion or resurfacing, and the material of the smooth plains may be related to this event. The argument against a volcanic origin is that other recent and more extensive volcanic deposits have not been accompanied by extensive regional crater degradation or obliteration and, as previously discussed, that the mechanical properties of the material seen in chaotic areas of this region are unlike those of the volcanic surfaces. A reasonable possibility is that the smooth intercrater plains in the cratered-plateau material are formed primarily of eolian material reworked from fluvial and impact-comminuted material.

Craters

Craters are mapped on the basis of their morphology. Although it is generally assumed that the more degraded craters are older, other effects such as burial or intense erosive processes may alter this criterion locally. The relative ages of surfaces within the Margaritifer Sinus quadrangle have been determined by crater density rather than by morphology. Other criteria, particularly superposition and transection, confirm the relative ages of cratered-plateau material, smooth-plains material, and chaotic material as determined by crater densities. Craters larger than about 20 km in diameter are mapped. The crater Holden (lat 34° W., long 26° S.) may be the youngest large (160 km diameter) impact crater within the quadrangle. Numerous subradial elongated craters as large as 20 km occur within about three crater radii of Holden to the north and west; these craters resemble the secondary craters occurring around young lunar craters. Holden has an indistinct rim that is much lower and more subdued than the rims of similar-size craters without secondaries in other areas of Mars. Although many small craters on Mars may have formed from secondary impacts, few can be attributed to a specific parent crater so certainly as these. If they are secondary impact craters, then Holden is probably younger than the plains material.

The rim of Holden appears to be breached in the southwest by a broad channel (Uzboi Vallis). Extending eastward is a straight-walled structural feature, Erythraea Fossa. Because the crater Holden differs so markedly from most morphologically younger impact craters of similar size on Mars, it is postulated either to differ in origin or to consist of different target material. There is no evidence that the crater was not produced by impact. Although one might argue that a cometary impact could produce a crater with subdued morphology, evidence for the cometary origin of subdued young lunar craters is lacking, and it appears likely that any object possessing the requisite kinetic energy to form Holden would produce a crater with normal geometry whatever the nature of the impacting substance. Therefore, we must consider a local difference in target material. From the existence of large expanses of chaotic terrain in the region, one would suspect that at some time the upper few kilometers of surface was of different material, perhaps containing considerable ground ice and trapped water. Possibly the object that created the crater impacted this region just after formation of the plains and after the proposed obliteration event.

Structural geology

Most structural features of the Margaritifer Sinus quadrangle are related to the chaotic material. Series of fractures unlike those of Thaumasia Fossae or Claritas Fossae in the Phoenicis Lacus and Thaumasia quadrangles of Mars parallel the scarps that bound regions of chaotic material.

Near the east-central margin of the quadrangle are irregular ridges, resembling somewhat those of the lunar maria, which may be structural features or possibly volcanic forms. No systematic regional pattern of structural features seems to occur within the quadrangle.

Geophysics

The Chryse lowland is the site of a large negative free-air gravity anomaly (Sjogren and others, 1975). The Bouguer anomaly is strongly positive for a reasonable range of density (Phillips and others, 1973), and a negative isostatic anomaly also occurs (Phillips and Saunders, 1975). The positive Bouguer anomaly indicates that the density of rock beneath the Chryse lowland is greater than that beneath surrounding regions. This anomaly can be interpreted in two ways: (1) Less likely is that the density of surface materials is higher in the Chryse region. There is no geologic evidence that the cratered-plateau material of the Chryse region is different from that of adjacent regions to the east. (2) The alternative is that the upper part of the planet is density stratified and that the uppermost lower density layer, the crust, is thinner beneath the Chryse lowland. The Chryse lowland is not isostatically compensated (Phillips and Saunders). A crustal thickness model that satisfies the Bouguer anomaly is not in isostatic equilibrium. Because of similar correlations between gravity and topography at the Tharsis plateau to the west and at the Chryse lowland, these regional features are probably associated and may, therefore, be of the same age (Phillips and Saunders). The age of uplift of the Tharsis plateau and of accompanying depression of the Chryse lowland is somewhat greater than that of the oldest plains (cratered plains of Carr and others, 1973) to the west. All the major channels are concordant with the regional slopes, and it is likely that they are consequent, that is, that the channels were formed more recently than the regional topography.

Geologic history

The Margaritifer Sinus quadrangle records some of the earliest events on Mars, as do all the regions of cratered terrains. These events comprise the ancient impact craters, now represented only by the scattered remnants of rim material. At about this time or slightly later, small furrows on the surface of the moderately cratered terrain formed from runoff of rain water. Rainy climate caused the erosion documented by the remnants of ancient craters. After this erosion event, the present population of craters developed. The next major event was regional crustal warping that resulted in uplift of the Tharsis plateau and contemporaneous downwarp of the flanking Chryse and Amazonis lowlands (Phillips and Saunders, 1975). Following downwarp of the Chryse lowland, the lower parts became the site of thick accumulations of ground ice and probably of liquid water at depth. A slight climate change or perhaps continued epeirogenic movement resulted in catastrophic release of the trapped ground water and formation of the chaotic terrain. The absence of craters on the terrain suggests that chaotic material still continues to form, perhaps by the melting of residual ground ice.

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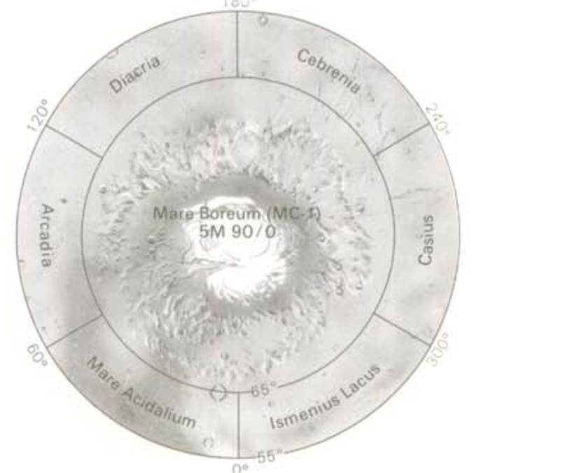
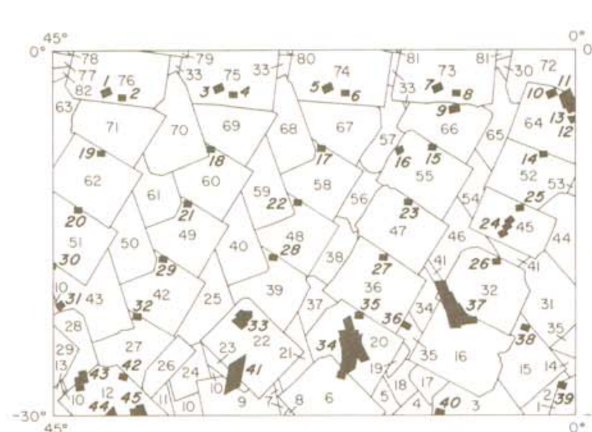
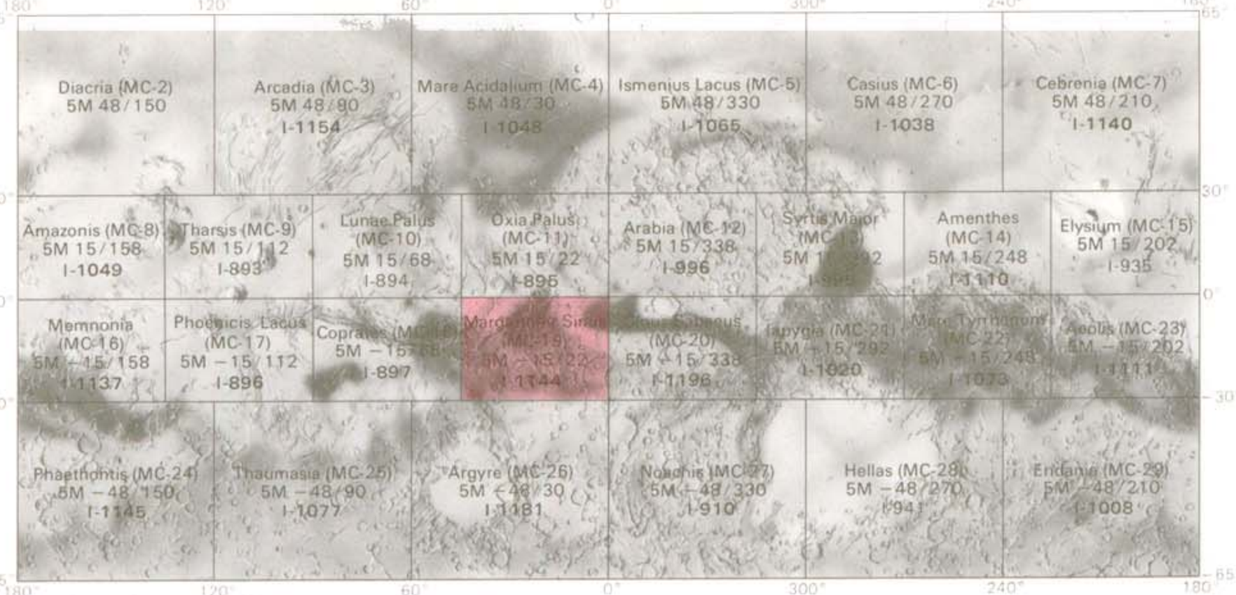


ALBEDO MARKINGS AND CONTOURS
Contour interval 1 kilometer. Surface markings derived from selected Mariner 9 photographs.



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. In three small areas (index no. 33) surface relief could not be portrayed because the only available picture lacks adequate photographic detail. 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.



QUADRANGLE LOCATION
Number preceded by I refers to published geologic map

GEOLOGIC MAP OF THE MARGARITIFER SINUS QUADRANGLE OF MARS

By
R. Stephen Saunders
1979

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.