DEPARTMENT OF THE INTERIOR
UNITED STATES GEOLOGICAL SURVEY

Prepared in Cooperation with the
JET PROPULSION LABORATORY, CALIFORNIA INSTITUTE OF TECHNOLOGY
FOR THE LANGLEY RESEARCH CENTER
NATIONAL AERONAUTICS AND SPACE ADMINISTRATION

ATLAS OF MARS
1:5,000,000 GEOLOGIC SERIES
OXIA PALUS QUADRANGLE
M 5M 15/22 G, 1976
I-895 (MC-11)

NOTES ON BASE

The base map is one in a series of topographic map sheets 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 lat 30°. Longitudes increase to the west in accordance with 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 (latitude 5.19°S) within the crater Airy. No simple statement is possible for the precision, but local consistency is 5-15 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). 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 (the 0 km contour line) for altitudes is defined by a gravity field described by spherical hormonics 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). This datum is a triaxial ellipsoid with semi-major axes of A=3394.6 km, B=3393.3 km, and a semi-minor axis of C=3376.3 km. The semi-major axis A intersects the Martian surface at long 105°.

The contour lines (Wu, 1975) were compiled from Earth-based radar determinations (Downs and others, 1971; Pettengill and others, 1971) and measurements made by Mariner 9 instrumentation, including the ultraviolet 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 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; Millman written communication, 1975).

MC-11: Abbreviation for Mars Chart 11.
M 5M 15/22 G: Abbreviation for Mars 1:5,000,000 series; center of sheet, 15° latitude, 22° longitude; geologic map, G.

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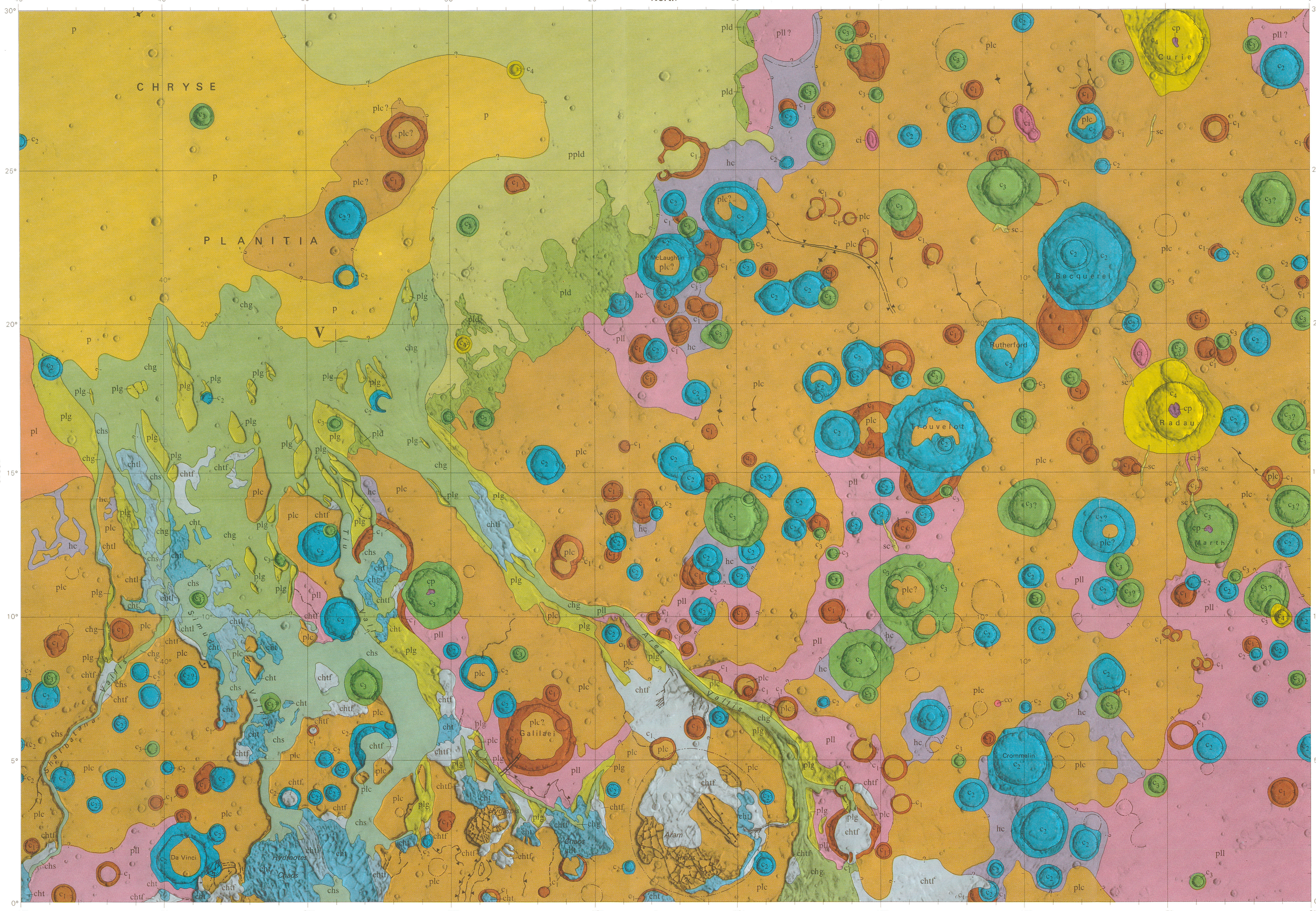
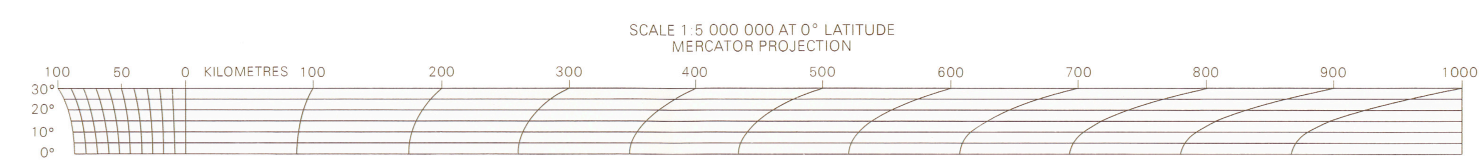
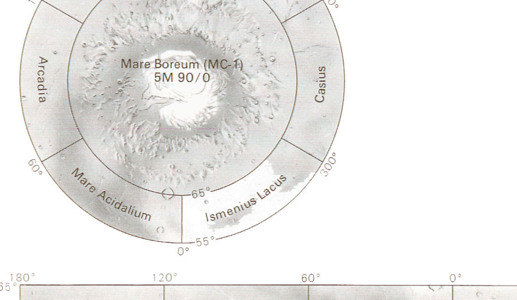
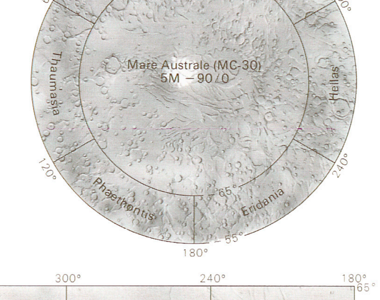


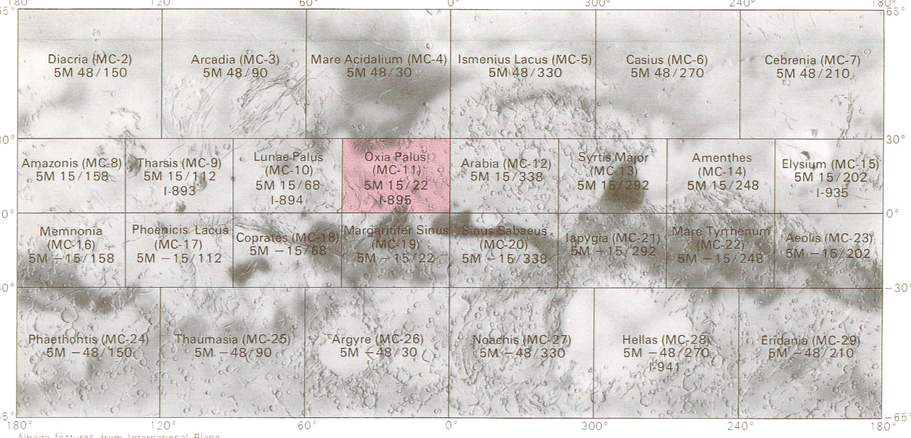
Interior—Geological Survey, Reston, VA—1976—G75122

Prepared on behalf of the Viking Project Office, National Aeronautics and Space Administration under contract L-55232, and the Jet Propulsion Laboratory, California Institute of Technology under contract WO-8122



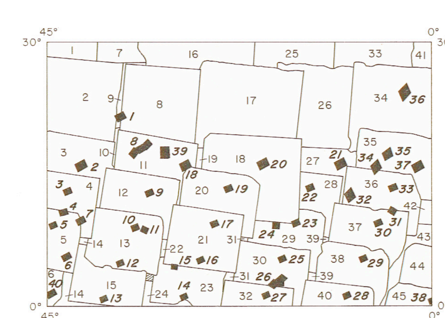






QUADRANGLE LOCATION
Number preceded by I refers to published geologic map

CONTOURS
Contour interval 0.5 and 1 kilometres. Surface markings derived from selected Mariner 9 photographs



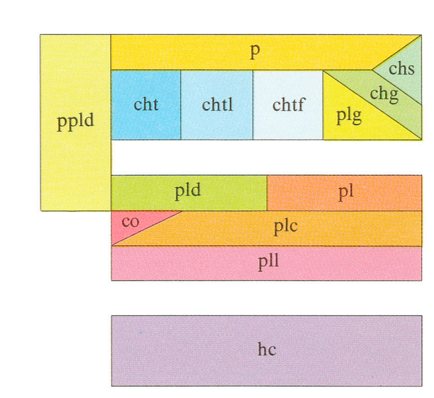
A-camera pictures				High-resolution B-camera pictures			
Index No.	DAS No.	Index No.	DAS No.	Index No.	DAS No.	Index No.	DAS No.
1	8946674	24	7758628	*1*	*10493079*	*20*	*7759218*
2	7615478	25	9162344	*2*	*7615438*	*21*	*7831108*
3	7615123	26	7831148	*3*	*7615088*	*22*	*7830758*
4	9089819	27	7830798	*4*	*9089784*	*23*	*7830688*
5	7614983	28	7830728	*5*	*7615018*	*24*	*6427328*
6	7614913	29	7830658	*6*	*10492794*	*25*	*7830618*
7	9018564	30	7759118	*7*	*10492864*	*26*	*12362246*
8	7687368	31	7783058	*8*	*12186872*		*9233284*
9	10493114	32	7830518		*12187012*		*12362176*
10	7615408	33	9234234		*12186802*	*27*	*7830548*
11	7687018	34	7903038	*9*	*7686978*	*28*	*7902438*
12	7686943	35	7902688	*10*	*7686908*	*29*	*7902508*
13	7686878	36	7902518	*11*	*9089504*	*30*	*7902578*
14	7615338	37	7902548	*12*	*7686838*	*31*	*9305174*
15	7686808	38	7902478	*13*	*7686768*	*32*	*13021508*
16	9090449	39	7831008	*14*	*7758658*	*33*	*7902648*
17	7759258	40	7902408	*15*	*9161394*	*34*	*13021578*
18	7759188	41	9306124	*16*	*7758728*	*35*	*13021648*
19	7758903	42	7902963	*17*	*7758798*	*36*	*13021718*
20	7758833	43	7902898	*18*	*7687333*	*37*	*7902998*
21	7758768	44	6571423	*19*	*7758868*	*38*	*6571388*
22	7687228	45	6571358			*39*	*13460108*
23	7758698					*40*	*10492724*

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.

GEOLOGIC MAP OF THE OXIA PALUS QUADRANGLE OF MARS

By
Don E. Wilhelms
1976

CORRELATION OF MAP UNITS



DESCRIPTION OF MAP UNITS

p PLAINS MATERIAL OF CHRYSE PLANITIA—Appears little cratered and otherwise smooth but photographic coverage poor. Lobelike features in north. *Interpretation:* May include water-laid sediments in south, volcanic rocks in north

cht CHAOTIC MATERIAL—Peaked and flat-topped blocks arranged chaotically. *Interpretation:* Derived from adjacent units, especially plc, by collapse

chtl CHAOTIC MATERIAL(?), LINEATED—Similar to unit cht but peaks and blocks distinctly parallel giving lineated appearance. *Interpretation:* Chaotic or plateau materials eroded by flowing water

chtf CHAOTIC MATERIAL, FINE—Undulatory or hummocky surface with small blocks or only a faint roughish texture. *Interpretation:* Various collapsed, slumped, and water-eroded materials

ppld PLAINS AND DISSECTED PLATEAU MATERIAL, UNDIVIDED—Small sharp hills surrounded by extensive plains. *Interpretation:* Outliers of dissected plateau material isolated by plains deposition. Plains could be different unit (older and higher-lying?) than unit p

chs CHANNEL DEPOSITS, SMOOTH—Apparently smooth at best available resolution. *Interpretation:* Sediments deposited in waning stages of stream flow

chg CHANNEL DEPOSITS, GROOVED—Narrow, curved or linear channels and ridges in channel bottoms. Queried where texture very faint. *Interpretation:* Sediments or eroded surfaces of older units; formed in later stages of stream flow

plg PLATEAU DEPOSITS, GROOVED—Narrow, curved or linear channels and ridges on terrain elevated above channels, including islands and shelves along banks; coarser texture than in unit chg. *Interpretation:* Sediments or eroded surfaces of older units; formed in earlier, "high-water" stages of stream flow

pld DISSECTED PLATEAU MATERIAL—Small, closely spaced peaks and mesas; randomly oriented or alined NW-SE. *Interpretation:* Derived from plateau materials by erosion caused by sapping or undermining

pl MATERIAL OF LUNAE PLANUM—Level and smooth or faintly textured. Few craters visible. *Interpretation:* Volcanic or water-laid sediments

plc CRATERED PLATEAU MATERIAL—Smooth and level on most photos except for craters and wrinkle ridges; gentle swells or small hillocks locally. Sharply embays c_1 and most c_2 materials. Queried where could be units hc, pll, ppld, or, in craters, material younger than these units. *Interpretation:* Layered rocks; in some craters could be debris from crater walls. Type area: 15°-18°N, 18.5-21°, covered by A-frame 7758903; especially area covered by B-frame 7759218, centered at 16.7°N, 19.6°

co CONE MATERIAL—Single apparent cone with summit crater, 7°N., 11°W. *Interpretation:* Volcano related in origin to cratered plateau material

pll LOWER PLATEAU MATERIAL—Surface mostly level but some small hills and circular forms. Queried where could be unit hc or ppld. *Interpretation:* Lithology variable; in places stripped by erosion and present surface geomorphically young

hc HILLY AND CRATERED MATERIAL—Rugged topography apparently consisting mostly of parts of craters; western third of quadrangle, small rugged peaks isolated by plateau materials. *Interpretation:* Ancient heavily cratered terrain

c_4 CRATER MATERIAL—Sharply textured rim, wall, and floor; extensive ejecta blankets. *Interpretation:* Formed by impact; younger than all units except perhaps some plains material

c_3 CRATER MATERIAL—Sharply textured rim flank, less extensive relative to rimcrest diameter than in unit c_4; sharply textured, high walls; most floors rough and apparently below level of surroundings. Queried where could be unit c_2. *Interpretation:* Formed by impact; contemporaneous with or younger than unit plc

cp CRATER PEAK MATERIAL—Rugged irregular peaks centrally situated in two large craters mapped as unit c_3 and two as c_4; also may occur in a few smaller craters. *Interpretation:* Formed by rebound following impact

c_2 CRATER MATERIAL—In large craters, considerable rugged topography on rim flanks, walls, and some floors. In smallest mapped craters (20-30 km), sharp rim crest and smooth rim flanks and walls. Many floors flat, probably filled by younger plateau materials (mapped separately in craters larger than 40 km). Queried where could be unit c_3. *Interpretation:* Probably formed by impact; mostly or entirely older than unit plc

c_1 CRATER MATERIAL—For large craters, subdued terraces and rim-flank hummocks. For small craters, mostly narrow, knicked or subdued rim crest. Floors mostly flat, probably filled by younger plateau materials (mapped separately in craters larger than 40 km); no central peaks exposed. *Interpretation:* Large craters formed by impact, small ones by impact or volcanism

sc SATELLITIC CRATER MATERIAL—Crater chains and grooves subradial to large c_3 and c_4 crater materials. *Interpretation:* Secondary impact craters

ci IRREGULAR-CRATER MATERIAL—Elliptical outline. Rim morphology like that of c_1 or c_2 materials. Central ridge at 26°N., 15½°. *Interpretation:* Formed by volcanism or multiple impacts

Contact—Queried where extrapolated on basis of albedo or uncertain topographic criteria

Probable fault (including slump)—Ball and bar on downthrown side

Narrow linear grove—Interpreted as tension fracture in plateau units; elsewhere same or unknown origin

Narrow sinuous groove—Interpreted as formed by flowing fluid

Narrow ridge—Dashed where inferred from A-frame

Gentle scarp—Line marks base of scarp; barb points downslope; dashed where inferred

Crater rim crest—Hachures point down crater wall; geologic contact in some craters. Craters 20 km or larger are mapped

Buried or highly degraded crater rim crest

V Prime proposed Viking landing site (lat 19½°N., long 34°)

INTRODUCTION

The Oxia Palus quadrangle contains three distinct geologic provinces: (1) an elevated cratered plateau that occupies three-fourths of the quadrangle and is similar to much of the southern hemisphere of Mars; (2) the low, relatively featureless Chryse Planitia in the northwest corner; and (3) a complex province of chaotic terrain and immense channels or valleys that divides the plateau and terminates at Chryse Planitia. Generally, the oldest geologic units occur in the plateau province and the youngest in Chryse Planitia. Discovery by Mariner 9 of the channels, the four largest of which are given names meaning "Mars" in Akkadian, Sumerian, Anglo-Saxon, and Greek (west to east), renews the possibility of water and therefore life on Mars. This possibility may be tested in July 1976 by a landing of the unmanned Viking spacecraft in Chryse Planitia at the mouths of the channels (lat 19½° N., long 34°).

The geologic mapping is based on Mariner 9 wide-angle (A-frame) photographs comparable in resolution (2 to 4 km) to average telescopic photographs of the Moon. Interpretations of unit origin and modifying processes rely partly on the 44 scattered narrow-angle (B-frame) photographs, whose resolution (200 to 400 m) compares with superior telescopic views of the Moon or with Lunar Orbiter IV high-resolution photographs. Before the Mariner 9 mission (1971-1972), some albedo features of the quadrangle and a few topographic features were photographed at low resolution by Mariners 6 and 7 (1969). Earlier the larger albedo features had been observed from Earth (see small-scale map). The most conspicuous of these is Oxia Palus, a small, irregular, seasonally variable dark spot centered at about lat 10°N., long 15° and covering about 10° of the surface. Chryse, for which the plains (planitia) in the northwest are named, is a distinctly brighter region with diffuse boundaries.

Mapping methods and principles are adapted from those developed for lunar photogeologic mapping (Wilhelms, 1970, 1972; Wilhelms and McCauley, 1971). Geologic units are mapped mostly on the basis of topography and albedo, and are ranked in order of relative age on the basis of superposition and transection relations, density of superposed craters, and crispness of topography. Regionally variable erosional processes have more severely affected the surface of Mars than that of the Moon. In addition, the effects of erosion cannot be completely distinguished from the effects of deposition. Therefore, as compared with the Moon, more of the map units may be geomorphic units rather than material depositional units (Milton, 1975a). Dating of rock units on the basis of crater density and of individual craters on the basis of topographic freshness is similarly less certain than on the Moon. Accordingly, the four morphologic categories of crater materials that are here assumed to have age significance (c_1-c_2-c_3-c_4) are subject to reinterpretation. Additionally, albedo is a less certain mapping criterion than on the Moon, where it is believed to have compositional significance. Many Martian albedo features obviously are surficial effects of wind action. However, where albedo is uniform over broad regions it may reflect bedrock lithology on Mars also, and is here used as an auxiliary criterion for mapping.

Elevation measurements (see small-scale map) confirm the visual impression that the channel and chaos province is depressed, and show that the southwest quadrangle corner is high. The extreme difference between these two areas is 3 to 4 km. The channel-and-chaos depression seems to slope towards the still-deeper Chryse Planitia. The entire depressed region of the channels, chaos, Chryse Planitia, and their continuations outside the quadrangle form a major, roughly north-south trending feature informally called the Chryse trough (R. S. Saunders, pers. commun.).

GEOLOGIC UNITS

Plateau Province

The elevated plateau contains the oldest materials in the area, those of degraded and partly buried craters (c_1) and of a few areas of hilly and cratered terrain (unit hc). The latter has a rough or undulatory topography that may consist of parts of degraded craters. The small exposures near the west map border consist of crude circles of small bright hills, probably degraded crater rims, that project above the plateau surfaces.

Much more abundant on the elevated plateau is flat intercrater and intracrater terrain (Murray and others, 1971; Wilhelms, 1974). Three units are mapped on this terrain. The most extensive is cratered plateau material (plc), which is flat and smooth even at B-frame resolution except for superposed craters and a few sinuous scarps and ridges. Because this flat material terminates abruptly at many crater rims and walls, apparently at the same elevation inside and outside some craters, the unit is believed to consist of deposits younger than the craters (Wilhelms, 1974). Strictly erosional levelling presumably would produce gentler contacts and more surface irregularities including bevelled roots of craters. Moreover, some channel scarps cut in this unit display indications of layering.

A second unit, lower plateau material (pll), is more uneven at B-frame resolution and in some areas at A-frame resolution. Roughness elements include small closely spaced hills and degraded crater rims like those in parts of unit hc. Unit pll has fewer craters smaller than 20 km (and therefore not mapped here) than unit hc, but more large craters, including the degraded rings, than unit plc. Therefore unit pll may consist of deposits older or thinner than those of unit plc. Its surface may not be primary, however. In several places it appears to be old material—unit hc or unmapped units—re-exposed by erosion. In the southeast corner, unit pll has few small craters (Soderblom and others, 1974). Here, one jagged contact, covered by a B-frame (lat 11°N., long 4½°), seems to have been produced by stripping away of unit plc. Lower plateau material is also mapped in several places along the channels where stripping has likely occurred, although the layers exposed here (mostly from beneath a cover of unit plc) might well be different from those in other lower plateau material. Unit pll may also be exposed in other, steeper scarps under unit plc but the latter unit is mapped to the scarp base except where stripping is evident. Thus unit pll is interpreted as old material but its present surface may be either old or young geomorphically.

A third unit, plains material of Lunae Planum (pl), occurs in one patch at the western map boundary in continuity with extensive deposits in the type area (Milton, 1975a). This unit has fewer superposed craters than units plc and pll and is believed to consist of younger deposits.

A belt of terrain along the boundary between the plateau and Chryse Planitia is mapped as dissected plateau material (pld). This unit consists of small peaks and mesas whose tops are at about the same elevation and seem to have once formed a continuous plateau. This is more clearly the case just north of the quadrangle and elsewhere along the boundary of the elevated, cratered hemisphere, where the peaks and mesas appear to have been isolated and cut back by some undermining or sapping process (Sharp, 1973). Therefore the geomorphic form that defines this unit is younger than its constituent material.

The lithology of the plateau deposits is unknown. In B-frames showing unit plc, wrinkle ridges like those of the lunar maria are visible, and other such ridges are inferred from faint sinuous light lines on the A-frames. Thus, the plateau materials may consist of marelike basalts, although the origin and lithologic significance of lunar wrinkle ridges is by no means certain. Alternatively, the deposits could be other volcanic lavas or tuffs, water-laid sediments, eolian debris, or different materials in different areas. The presence of a feature resembling a volcanic cone (unit co) supports a volcanic origin at least in its vicinity (lat 7°N., long 11°).

Chaos and Channel Province

The elevated plateau is interrupted by chaotic terrain and large channels or valleys. The two are intimately associated; the chaotic terrain occurs within the channels, along their banks, and, especially, at their heads. Extensive chaotic terrain also occurs south of the quadrangle, in and near the continuation of Chryse trough (R.S. Saunders, pers. commun.). The chaotic terrain and channels are part of an extensive arcuate disrupted zone which includes the great Valles Marineris canyons southwest of the quadrangle (Carr and others, 1973).

Most of the chaotic terrain (unit cht) clearly consists of broken-up plateau deposits and craters, for it grades laterally into fractured but still generally coherent masses of these units. At this map scale, chaotic material is considered a separate deposit because the coherence of the older materials has been so thoroughly destroyed. Materials less blocky than this obviously chaotic terrain but which also have hummocky textures suggesting origin by disruption are designated fine chaotic material (chtf). Lineated chaotic material (chtl), more regularly grooved than the other two types, also lies in the channels and may have been scoured by fluid flow. Thus it is a geomorphic unit. At lat 1°N., long 33° this unit and adjacent smooth-appearing chaotic material (unit cht) seem to have been modified by flooding from Valles Marineris.

The channels and many of their banks contain curved and linear grooves that clearly were formed by fluid flow. Channels diverge and rejoin around midchannel bars and other obstacles. For mapping convenience, the many topographic levels of grooved terrain are grouped into two units, a higher grooved plateau material (plg) and a lower grooved channel material (chg). The largest grooves are mapped individually by dash-dot symbols, as are tributary channels in other units. The channel material truncates channels in the grooved plateau material, which presumably were formed at a higher, earlier stand of the fluid. The scale and apparent immaturity of the channels suggest to Baker and Milton (1974) that they were probably not formed by sedimentation in a long-lived, constantly shifting current as in terrestrial braided streams, but by erosion in a single massive flood like that which formed the channeled scablands of the Columbia Plateau.

Some channel floors are not visibly grooved and are mapped as smooth channel material (chs). Additional high-resolution photographs are necessary to show whether this unit is also grooved or smooth; perhaps it consists of sediment deposited as the flood subsided.

The intimate association of the chaotic terrain and channels indicates that they are related in origin: the fluid that excavated the channels must have flowed from the chaos. The chaos was probably formed by subsidence, fracturing, and slumping accompanied by removal of subsurface material (Sharp, 1973). This material was probably liquid water or some kind of ground ice whose melting produced the channel-cutting fluids. Milton (1974b) believes that the fluid was water released catastrophically from a carbon dioxide hydrate. Gradation of the chaos into more regularly fractured terrain suggests that chaos formation was initiated by crustal extension. Because the great arcuate disrupted zone that includes the Chryse trough, the chaos, the channels, and the great fractures to the southwest is peripheral to the Tharsis uplift (Carr, 1974), the uplift is a likely cause of the regional crustal extension.

The chaotic terrain was derived mainly from the plateau material, so the water, hydrate, or other fluid-bearing material presumably resided in that unit before the crustal extension. The water or fluid-bearing material may have accumulated in the plateau deposits as they were deposited early in martian history or may have emanated from the interior sometime later.

Chryse Planitia Province

The low-lying plains materials of Chryse Planitia (unit p) are relatively uncratered and presumably younger than most other units in the quadrangle except some of the youngest craters (c_4 and perhaps c_3). In the north-central part of the quadrangle, plains surround small peaks that seem to be outliers of the plateau, and, because of the small mapping scale, this area is mapped as plains and dissected plateau materials undivided (ppld). Because much of the contact between units p and ppld is sharp, unit ppld could be a distinct unit; where photographs are good it looks not unlike unit pl.

The origin of the plains is uncertain. Near the northern map boundary, faint lobate features that resemble flow fronts occur on the plains, suggesting a volcanic origin here. At the end of the channels, the plains could include water-laid sediments, but these may not be exposed at the surface. Local deposits of eolian dust are indicated by light-colored plumes, but the dust is probably thin and ephemeral. Thick young eolian deposits are unlikely because small unmantled craters are visible.

GEOLOGIC HISTORY

An early intense rain of impacting objects produced craters which are still partly preserved on the plateau that occupies three-fourths of the quadrangle. Deposition of extensive plains materials buried the smaller craters and embayed and filled the larger ones. Cratering continued after deposition of these plains materials, as demonstrated by numerous unburied c_3 craters. Comparisons with similarly cratered areas on the Moon suggest that the flat plateau materials were deposited about 4 billion years ago (Wilhelms, 1974), assuming similar cratering rates on the Moon and Mars as proposed by Soderblom and others (1974). Subsequently, perhaps in response to regional tectonic deformation, the plateau deposits were fractured and broken up chaotically, and their fluids released. Great channels were formed as the resulting floods flowed toward the low-lying Chryse Planitia. The floods may have deposited sediment at the mouths of the channels to form part of Chryse Planitia. Other materials in this plain may be volcanic in origin. Surficial eolian deposits still being redistributed cover many of the geologic units.

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