

DESCRIPTION OF MAP UNITS

CORRELATION OF MAP UNITS

PLAINS-FORMING MATERIAL-Occurs as generally light, smoothappearing surface in low areas of plateau materials (units plc, pld, and pll) and as flat floors of intermediate- to large-size craters in western part of mapped area. Crater density very low (except for some very small bowl-shaped craters), similar to that of smooth plains-forming material (unit ps); small and local areal extent makes cratering characteristics uncertain. Interpretation: Eolian deposits; may be equivalent in age to smooth plains-forming material (unit ps)

SMOOTH PLAINS-FORMING MATERIAL-Occurs over wide areas in northeastern part of quadrangle, appearing to overlap subdued-plateau material (unit pls) and to grade into cratered-plateau material (unit plc). Fills very large circular basins or craters. Resembles plains-forming material (unit p), with very low crater density, but has numerous dark wind-plumes and streaks associated with craters. Interpretation: Widespread lava flows or ash flows from Tharsis Montes volcanic regions to northeast, subsequently smoothed by eolian erosion and deposition

KNOBBY AND SMOOTH PLAINS MATERIAL-Forms smooth plains in low area between two plateau terrains(units plc and pld) and surrounding one area of knob and mesa material (unit km). Only observable relief, except for small craters and gently undulating surface, consists of small (< I km), bright, isolated hills (B-frame DAS 05347233), which may be only of local extent. Interpretation: Composite unit; possibly blanket of colian debris lying on erosional surface, of which small bright hills may be erosional outliers of formerly more widespread planar unit, perhaps knob and mesa material (unit km). Alternately, bright hills may be volcanic domes or small plutonic masses within crust exposed by erosion ROLLING PLAINS MATERIAL-Forms gently rolling surfaces of very low relief. Moderately cratered; some small-scale, low, sinuous

covered by volcanic ash or lava flows to form present widespread unit; subsequently cratered by moderate meteorite influx, then modified by eolian activity LIGHTLY CRATERED PLAINS-FORMING MATERIAL-Moderately light tone, in some places mottled light and dark or with dark streaks. Generally smooth surface of low relief, although relief of underlying buried surface is apparent as faint crater outlines and gently hilly surface. On B-frame pictures, surface shows gentle. subdued hills. Forms extensive plains, probably covering low areas of crustal plateau materials (units pls and plc) and floors of large (> 100 km) craters. Small craters, commonly fresh in appearance,

ridges. Topographically lower than adjacent plateau material (units

pld, pll, and pls). Interpretation: Low areas of old cratered crust

moderately abundant; medium- and large-size craters lacking except

on underlying buried surface. Interpretation: Low-lying areas of

old, heavily impacted crust now buried beneath colian or volcanic ash-flow plains, subsequently lightly cratered and continually modified by eolian erosion and deposition MODERATELY CRATERED PLAINS-FORMING MATERIAL-Moderately light tone and smooth, level topography. Occurs in low areas of heavily cratered terrain and, in places, gradational with highly cratered uplands material (unit uhe). Population and size of craters larger than on lightly cratered plains-forming material (unit pel). Craters have flat floors and high walls, with rims very subdued and many nearly level with intercrater plain. Small craters (< 15 km) absent. Dark areas common on crater floors. Interpretation. Erosional or depositional plain, probably of eolian origin, which occupies and covers low-lying parts of primitive crust (unit uhc). Large craters may be remnants of highly cratered uplands material

(unit uhc) projecting upward through plains material (unit pcm) DARK PLAINS-FORMING MATERIAL - Dark, smooth, level surface that locally occupies low intercrater areas of highly cratered uplands material (terra unit uhc). Interpretation: Eolian deposits

DISSECTED PLATEAU MATERIAL-Planar unit, topographically higher than adjacent plains materials (units p, pr, psk, and pcl). Crater density lower, craters more subdued, and intercrater areas smoother than in cratered-plateau material (unit plc). Furrows common, some with branching patterns. Many areas dissected and with adjacent plains commonly an escarpment. Interpretation Ancient indurated ash-flow or colian deposits emplaced as widespread plateau-forming strata over low areas of cratered terrain. Lateral retreat to northeast has resulted in removal of material into plains material to west. Crenelated nature of scarp and dissection of plateau suggest scarp retreat by sapping, possibly by mass wasting and collapse accompanying release of entrapped volatiles to atmo-

LIGHT PLATEAU MATERIAL-Generally light tone. Plateau form results from accordance of summits and low relief of rolling or hummocky topography. Stands higher than surrounding regional plains materials (units pr and p) and abuts with steep escarpment against plains-forming material (unit p) that fills large craters. Interpretation: Localized unit within old crust, exposed by large, early impact events and subsequent erosion; absence of craters smaller than 30 km in diameter suggests extensive stripping of overlying material. May be equivalent in age to dissected and cratered plateau materials to north (units pld and plc)

KNOB AND MESA MATERIAL-Bright, rounded to flat-topped, steep hills, 1-4 km in diameter. Occurs as two clusters (lat 35°S., long 177°W., and lat 38°S., long 171°W.) of about 10,000 km<sup>2</sup> each, within and rising abruptly above plains (units p and psk). Interpretation: Localized unit within old crust, different in composition and erosional characteristics from nearby surrounding crustal materials (units pld and plc). Light tone, rounded nature of individual hills, and alinement of some valleys suggest silicic plutonic masses, regionally fractured and eroded by eolian activity

SUBDUED-PLATEAU MATERIAL-Mottled tone, intermediate to dark. Rough topography, but more subdued and with less relief than mountainous material (unit m). Locally shows quasi-parallel furrows, 1-3 km wide, branching and anastomosing; elsewhere, surface patterns are suggestive of sinuous and branching furrows. Many faintly outlined, moderate-size craters (<50 km); no small (<5 km) craters. In some areas, occurs as level surface cut by parallel grooves. Interpretation: Old crustal unit, possibly of lava-flow or ash-flow origin. Surface eroded and subdued, probably by eolian erosion and deposition

MATERIAL OF DARK PLATEAU-Forms moderately dark, rolling surface of gentle hills higher than adjacent plains; included some bright hills. Low to moderate crater density. Interpretation: Origin unknown; deposited on primitive crustal material (unit uhc); eroded by plains-forming processes and embayed by moderately cratered plains-forming material (unit pcm)

pic CRATERED-PLATEAU MATERIAL Forms rugged, irregular topography. High density of craters in all stages of degradation. Rough intercrater areas with ridges and troughs. Interpretation: Early crustal material subjected to impact by high-density meteorite influx. Ejecta and impact-produced crustal structures subsequently modified by wind erosion and also perhaps by eolian and volcanic

> MOUNTAINOUS MATERIAL-Light to moderate tone; irregular and large relief. Generally occurs peripheral to some large craters and to possible small basin (lat 45°S., long 170°W.). Moderately to sparsely cratered; craters highly degraded except for very small c3 craters. Interpretation: Upraised rim material, possibly with ejecta, formed by large impact HIGHLY CRATERED UPLANDS MATERIAL-Light to moderate

tone. Approximately 30- to 50-percent saturated with large- and medium-size craters. Hilly intercrater topography, rounded and subdued. Very few small (< 15 km) craters. Interpretation: Primitive crust redistributed by meteorite impact during early history of Mars. Crater rims contribute to rugged topography. Subsequently eroded by wind and blanketed with eolian debris, possibly from south polar region DOME AND CONE MATERIAL-Hilly terrain, including domelike, bulbous masses and small (≤ 1 km) cones with summit depression.

Generally bright tone. Restricted to one small area in southwestern part of map. Interpretation: Volcanic domes, pyroclastic cones, and perhaps viscous flows or pyroclastic ejecta HILLY MATERIAL-Hilly unit of small areal extent, restricted to one locality in north-central part of map area, where it seems to be superposed on c2 crater. Interpretation: Volcanic extrusive material CRATER MATERIALS-Occur as circular or arcuate forms elevated above central depressed area. Classified by morphologic character-

istics that probably reflect relative age. Only craters 20 km in diameter or larger are mapped. Interpretation: Most craters believed formed by impact Crater material-Complete, sharp and distinct rim crest raised above

surrounding terrain and bowl-shaped interior. Material of irregular topography surrounds rim crest and extends to about one crater diameter beyond rim crest. Superposed on underlying material Crater material -Rim crest complete and high, raised above surrounding terrain and interior, which lies below level of surrounding area and may be uneven to smooth. Central peak sometimes present (unit cp3). Material surrounding rim crest irregular, less than one crater diameter from rim crest Crater material Rim crest rounded, low, and usually complete.

Rim narrow and smooth; texturally distinct material only rarely present outside narrow rim. Interior flat and shallow, lying at or slightly below level of adjacent terrain.

rater material - Gentle depression with very low, incomplete rim crest. Rim narrow or absent, wall low and narrow. Interior smooth

CENTRAL PEAK MATERIALS-Individual hill or, in larger craters, cluster of hills near center of crater interior. Interpretation: Brecciated material of crater interior elevated by rebound following compression produced by impact shock wave Central peak material-Near center of c3 crater

entral peak material Near center of c2 crater

Shallow depression

Central peak material - Near center of c1 crater

IRREGULAR CRATER MATERIAL-Single elongate depression (lat 38°S., long 174°W.) with sharp rim crest raised above surroundding terrain. Resembles overlapped or coalesced crater forms. Interior lower than adjacent terrain, smooth, and uninterrupted by septa along length of depression. Interpretation: Endogenic origin, either volcanic or gas vented along fracture

INTRODUCTION The Phaethontis quadrangle of Mars is dominated by densely cratered uplands and plateaus which form some of the oldest surfaces on the planet. Extensive low-lying areas within the cratered terrains, including the floors of large craters, are covered to different degrees by plains-forming material. The youngest plains units surround Tharsis Montes to the north. Various erosional processes, including eolian scour and possibly scarp retreat through volatile-release sapping and mass wasting, have modified martian terrains in the northwestern part of the quadrangle, producing several distinctive physiographic features: knob and mesa terrains, plains with small knobs, and plateaus dissected by furrows, steep-walled gorges, and pits.

ATLAS OF MARS

I-1145 (MC-24)

above the adopted datum. Mariner 9 UVS altimetry shows some craters (Hussey and several unnamed craters) to have depths of 1 to 3 km (Burt and others, 1976). Features of less relief include broad undulations in the cratered surface, knobs, mesas, steep-walled canyons, pits, and fault and erosional escarpments. Martian geologic units were delineated on Mariner 9 A-frame pictures, applying mapping methods and principles used for lunar geologic mapping (Wilhelms, 1972) to the interpretation of stratigraphic relations and geologic history. Higher resolution B-frame pictures of scattered small areas provided information about terrain characteristics and modification. As elsewhere on Mars (Milton, 1975; Wilhelms, 1976), units are mapped on the basis of geometry, spatial relations, and tonal and textural characteristics resulting from their emplacement as geologic bodies. The geomorphology reflects the initial form, structure, and lithology of the units, as well as their subsequent modification by erosional and depositional processes. The relative age assigned to each unit (for example, the knob and mesa material) may reflect a long period of emplacement and geomorphic development. The assignment of stratigraphic ages to units on the basis of crater density or state of crater degradation cannot be done with any certainty because of the variable extent and nature of erosional and depositional modifying

The topographic map of Mars (U.S. Geological Survey, 1976) shows this region to be nearly level at the kilometer scale, standing as a plateau about 3 km

processes in this region.

SUMMARY OF GEOLOGY The oldest units of the Phaethontis quadrangle are the highly cratered uplands material in the south and the cratered-plateau material, of similar high crater density, to the northwest. These materials may represent primitive Mars crust, reworked and partially emplaced during late stages of planetary accretional bombardment. The below-saturation density of large craters, lower than crater densities of lunar uplands, and the flat intercrater areas of these most densely cratered martian terrains may be the result of early erosional obliteration (Soderblom and others, 1974) or of depositional burial (Wilhelms, 1974). The nature of this modifying event cannot be determined from the Mariner 9 pictures in this area. The modified older crust, which can be seen or inferred from degraded or partially buried crater forms over most of the quadrangle, subsequently has been extensively buried by plains-forming deposits. Some topographically higher parts of the crust (the subdued-plateau material) are not covered with plainsforming deposits and are furrowed by small branching channels, 1-3 km wide, which may be either volcanic or fluvial in origin. The subdued irregular topography and, in some areas, a level surface cut by parallel grooves (lat 31°S., long 52°W.) probably resulted from wind erosion

The widespread plains-forming deposits derive from at least three major martian geologic provinces: (1) the south polar region, (2) the Tharsis region, and possibly (3) an area to the northwest of the quadrangle. Moderately cratered plains-forming material occurs in extensive low areas of highly cratered crust in the southern part of the quadrangle; it overlaps and embays the highly cratered uplands and subdued-plateau materials and covers floors of craters within these uplands. Rims of large craters project through the plains deposits; rims of other craters are nearly level with the plains, yet the flat crater floors lie at levels below the plains. The plains-forming material is within the southern mantled terrain (Soderblom and others, 1974) and may, at least in its upper part, be a blanket of eolian debris from the south polar region (Soderblom and others, 1974). The relative age of the moderately cratered plains-forming material is uncertain. Most of its features moderate-size class c2 craters predate the upper part of the plains-forming material, which may be a young, thin eolian mantle. The low density of small fresh craters may be real, or such craters may not be distinguishable on the lower esolution pictures available for this region. Lightly cratered plains-forming material overlies widespread low areas of the

subdued-plateau material and the floors of large craters in the north-central and northeastern parts of the quadrangle. Faint crater outlines within the plains and the gentle, hilly surface result from burial of the older cratered crust by this deposit. These plains-forming materials may be volcanic deposits-ash flow or lava or colian debris. In addition, smooth plains-forming material of very low crater density extends southwestward into the quadrangle from the elevated Tharsis plains. Burial of subdued plateau material is so extensive in the northeast corner of the quadrangle that only high islands of the plateau unit remain unburied. To the southwest the smooth plains-forming material apparently becomes thinner, embaying and overlapping the subdued-plateau material and merging gradationally with the lightly cratered plains-forming material. The smooth plains-forming material is the youngest in the quadrangle and is probably still being moved and deposited by winds. Wind directions of the 1971 dust storm, determined from dark wind-formed streaks, suggest that the material of the smooth plains-forming deposit, and perhaps of the lightly cratered plains, derives from the east or northeast.

The northwestern part of the Phaethontis quadrangle comprises several plains, plateau, and knob and mesa terrains that represent unique crustal units, erosional modification of old crustal material, and burial of low areas. The knob and mesa material is localized within the crust, occurring as two isolated, closely clustered and others, 1972; Carr and others, 1973, 1976; Scott and Carr, 1978). Possibly this knob and mesa material represents regionally fractured plutonic masses exposed by erosion and rounded by wind. Plateau-forming materials within this area exhibit various morphologies and are

thought to be old units superposed on or emplaced within older, densely cratered crustal material. The dissected plateau material, which may be composed of indurated ash flows or colian deposits, abuts the lower surrounding plains in many places with an escarpment. Sapping, possibly by mass wasting and collapse accompanying release of entrapped volatiles to the atmosphere, has produced crenation and lateral retreat of the escarpment and the formation of isolated pits and steep-walled gorges within the plateau. The scarp has retreated to the east, with the removal of material into the plains. Similarly, the light plateau material rises above surrounding plains along steep escarpments (lat 43°S., long 177°W.), some of which correspond to crater outlines. This plateau unit may be either strata superposed on, or a localized plutonic mass within, old crust. Subsequent erosion has removed plateau material brecciated by impacts.

The subdued-plateau material bears, in this area, quasi-parallel and branching furrows, 1-3 km wide, and surface patterns suggestive of sinuous and branching furrows. In some areas a more planar surface, which abuts lower plains with a steep escarpment, is cut by parallel grooves (lat 34°S., long 148°W.). Either the escarpments, canyons, pits, and grooves of plateau terrains represent different types of erosional etching, stripping, or collapse processes, or they exhibit the various responses of different lithologies and structures to similar processes. Furrows may be primary features associated with the formation of the unit, such as lava channels or collapsed tubes, or they may be the result of erosion. Two units, the knobby and smooth plains material and the rolling plains material, which are adjacent to the plateau and knob and mesa materials, seem to be related geologically to the neighboring higher terrains. The knobby and smooth plains material, from the center of which rises a cluster of knob and mesa material, has as its only relief at B-frame resolution (except for small craters) small (< 1 km), bright, isolated hills (lat 36°S., long 171°W.); the hills may be volcanic domes or small plutonic masses exposed by erosional stripping of the overlying crustal material. The cluster of knobs and mesas may be a large remnant of this stripped unit. The rolling plains material, of greater area and extending into the Eridania quadrangle, surrounds the light plateau material and abuts the dissected plateau material. Low sinuous ridges on these plains may be indicative of lava sheets subsequently modified by cratering and wind activity.

VOLCANISM AND STRUCTURE

No features of certain volcanic origin have been identified in the Phaethontis quadrangle. Some lobate scarps seen in a few high-resolution frames of the smooth plains-forming material in the northeastern part of the map area may be the fronts of lava flows. Also, small branching furrows or channels on the subdued-plateau material and on adjacent low-lying plains may be lava channels or collapsed lava tubes. Two other small areas of volcanism may be the domelike hills and small cones (lat 60°S., long 179°W.) in the plains in the southwestern part of the quadrangle and the local hilly material (lat 32°S., long 145°W.) aperposed on a crater within the northern subdued-plateau material. The major tectonic feature in the quadrangle is Sirenum Fossae, a belt of narrow grabens and fault escarpments extending almost 2,000 km west-southwest across the cratered plains and plateaus from Tharsis Montes. The cratered plains and plateaus in the eastern part of the quadrangle are also transected by northeast-trending grabens and lineaments (interpreted as eroded or mantled grabens). All the grabens are components of the southern fan of fractures produced by crustal upwarp in the Labyrinthus-Tharsis region possibly 1 b.y. ago (Carr, 1974).

GEOLOGIC HISTORY Impact cratering dominated the early history of the Phaethontis quadrangle; the crater-saturated surface of early bombardment may have been removed by some late-contemporaneous obliterating process and repopulated with the presently observed crater density by a decreasing flux of late-accretionary bombardment (Soderblom and others, 1974). Successive, or perhaps coeval, plains-forming events have since filled low areas of the heavily cratered surface. The plains were probably formed by eolian and volcanic processes, although only the youngest smooth plains in the northeast show possible volcanic-flow features. The origin and time of formation of small furrows and channels that dissect some of the plateau terrains are uncertain; these channels may represent one or more volcanic or fluvial events. Tectonism, forming systems of extension fractures, has affected all but the smooth plains. Wind activity now predominates as the major geologic agent. Dark streaks

associated with small craters are common in the northeastern smooth plains, and dark patches occur on part of the floors of large craters throughout the area (lat 48°S., long 164°W.) and on plains at the base of adjoining uplands (lat 58°-61°S., long 167°-170°W.). At least some dark areas are dune fields (high-resolution B-frame DAS 05850743) that have accumulated in the lee of uplands. mountains, and crater walls, rims, and central peaks. REFERENCES CITED

Burt, Judith, Veverka, Joseph, and Cook, Kevin, 1976, Depth-diameter relation for large martian craters determined from Mariner 9 UVS altimetry: Icarus, v. 29. no. 1. p. 83-90.

Survey Interagency Report: Astrogeology 55, 36 p.

nal of Geophysical Research, v. 79, no. 26, p. 3933-3941.

Geological Survey Miscellaneous Investigations Map 1-895.

Carr, M. H., 1974, Tectonism and volcanism of the Tharsis region of Mars: Journal of Geophysical Research, v. 79, no. 26, p. 3943-3949. Carr, M. H., Masursky, Harold, and Saunders, R. S., 1973, A generalized geologic map of Mars: Journal of Geophysical Research, v. 78, no. 20, p. 4031-4036. Carr, M. H., Masursky, Harold, Baum, W. A., Blasius, K. R., Briggs, B. A., Cutts, J. A., Duxbury, T. C., Greeley, Ronald, Guest, J. E., Smith, B. A., Soderblom, L. A., Veverka, Joseph, and Wellman, J. B., 1976, Preliminary results from the Viking Orbiter imaging experiment: Science, v. 193, p. 766-776. McCauley, J. G., Carr, M. H., Cutts, J. A., Hartmann, W. K., Masursky, Harold, Milton, D. J., Sharp, R. P., and Wilhelms, D. E., 1972, Preliminary Mariner report on the geology of Mars: Icarus, v. 17, no. 2, p. 289-327. Milton, D. J., 1975, Geologic map of the Lunae Palus quadrangle of Mars: U.S. Geological Survey Miscellaneous Investigations Map 1-894. Scott, D. H., and Carr, M. H., 1978, Geologic map of Mars: U.S. Geological Survey Miscellaneous Investigations Map I-1083. Soderblom, L. A., Condit, C. D., West, R. A., Herman, B. M., and Kreidler, T. J., 1974. Martian planetwide crater distributions: Implications for geologic history and surface processes: Icarus, v. 22, no. 3, p. 239-263. U.S. Geological Survey, 1976, Topographic map of Mars: U.S. Geological Survey Wilhelms, D. E., 1972, Geologic mapping of the second planet. U.S. Geological

Note: Mismatches of craters and other features across quadrangle boundaries may result from errors inherent in the semicontrolled bases provided for geologic

Wilhelms, D. E., 1974, Comparison of martian and lunar geologic provinces: Jour-

Wilhelms, D. E., 1976, Geologic map of the Oxia Palus quadrangle of Mars: U.S.

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