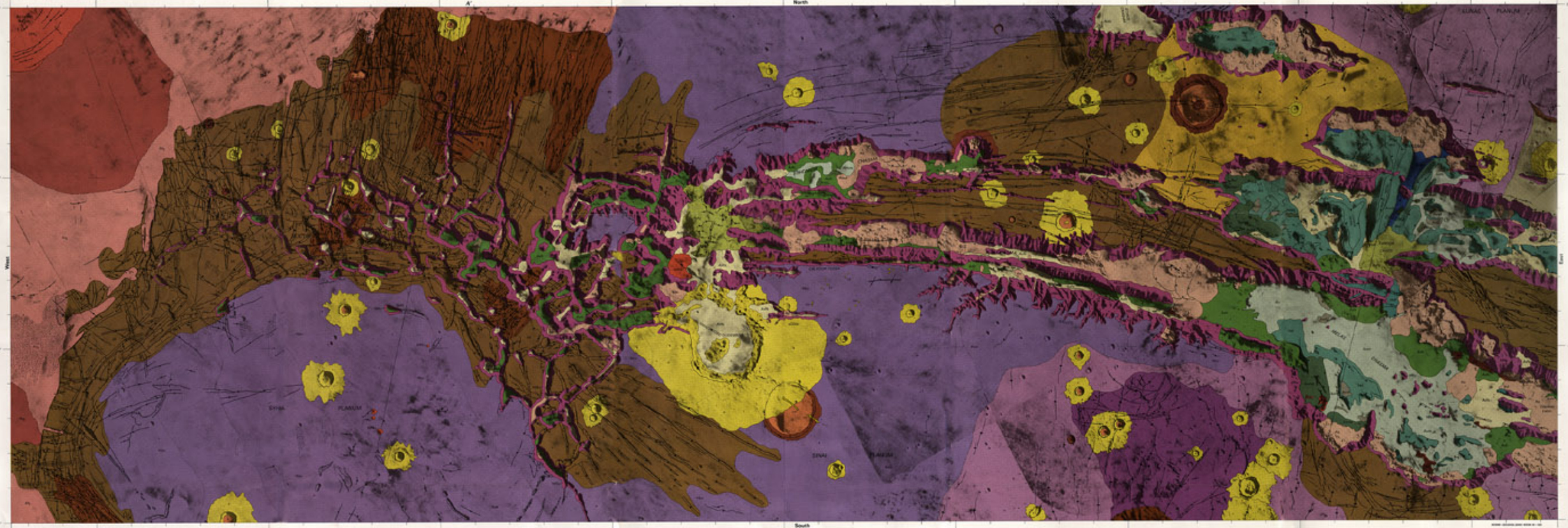
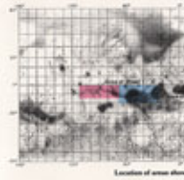
U.S. DEPARTMENT OF THE INTERIOR
U.S. GEOLOGICAL SURVEY

Prepared for the
NATIONAL AERONAUTICS AND SPACE ADMINISTRATION

ATLAS OF MARS
1:2,000,000-GEOLOGIC SERIES
VALLES MARINERIS REGION
MIM -7/90 G, 1991
MAP I-2010 (SHEET 1 OF 2)





Location of areas shown on sheets 1 and 2

Description of map units, chart showing map units and crater densities, and cross sections are shown on sheet 2

INTRODUCTION

This map, based on Viking images obtained during the late 1970's, supersedes I-1268, 1:5,000,000-scale maps of the region based on Mariner 9 data (Masursky and others, 1978; McCauley, 1978; Saunders, 1979). Geologic mapping was compiled on 1:2,000,000-scale photomosaics (1:2,000,000-scale mosaics MC-10NE, MC-10NW, MC-10SE, and MC-10SW) and of the Valles Marineris (MC-09SE and MC-09SW) Mosaic of the geologic units of the plateau and high plains assemblage were established during mapping at 1:500,000 scale of the western equatorial region of Mars (Scott and Tanaka, 1986), additional materials and units are employed here to reflect the complex geology within Valles Marineris. The units were identified on individual images and the age of each mapped unit was determined from crater counts (0 to 150 km/pixel). Inclusive ranges of the subequidistant MC-17NE were previously mapped (Scott and Tanaka, 1986) as part of a map series at 1:500,000 scale of the Tharsis and Syria Planum lava flows (Scott and others, 1981) whose ages were determined from crater counts (this 1981 map and the 1986 map of the western equatorial region, our interpretations on the current map are consistent with the latter because it is more recent and detailed in scope).

The canyons of Valles Marineris were named in honor of the Mariner 9 mission to Mars, which discovered them in 1972. These canyons intersect to form a 4,000-km-long system (fig. 1), the largest known in the Solar System. They cut highland plateaus as much as 10 km high made up of ancient cratered material (proposed at Margaritifer Terra), which is covered by a veneer of intermediate-age (Hesperian) plateau material in the western and central parts of the canyon system. In the north of Valles Marineris (along the lobate vertical stratigraphic sections on Mars, exposing some of the planet's oldest and deepest crustal rocks. Uplift and crustal shifting associated with tectonic activity in the Tharsis region to the west appear to be the processes responsible for the formation of these spectacular canyons. The eastern canyons contain chaotic terrain (closely spaced knobs and mesas) associated with huge outflow channels. Both layered and massive rocks are present within the canyons. Faulting, landsliding, wind erosion, and eolian and fluvial deposition have modified the canyon walls.

The structural development of the canyon system is complex. Although Noctis Labyrinthus connects with the west end of Valles Marineris, the structures of the two canyon systems have distinct patterns and histories. Analysis of gravity profiles and topography and comparisons with terrestrial rift systems provide clues to the nature of the tectonic processes at work. Of the much smaller Grand Canyon on Earth, the canyons of Valles Marineris have provided geologic information that has advanced our knowledge of the regional and global geology of Mars.

PHYSIOGRAPHIC SETTING

The Valles Marineris region lies east of Tharsis Montes (which extend from lat 10° N., long 90° to 120° W.). Part of the region is in the center of a vast plateau bounded on the west and east by Claritas and Noctaris Fossae, respectively, that extends southward from near the equator into southern Xanthe Terra and western Margaritifer Terra. Channel bends, escarpments, graben, landwide alignments of knobs and mesas on the surface north and west of the canyons shape toward Chryse Planitia (centered at about lat 25° N., long 40° W.). Within the broad Valles Marineris region, three distinct physiographic provinces are recognized (fig. 1): (1) the Noctis Labyrinthus province, consisting of a high plateau cut by a network of structurally controlled troughs; (2) the Valles Marineris province, characterized by broad, linear valleys bordered by thousands of kilometers long; and (3) the eastern canyon province, containing irregularly distributed troughs as much as 300 km across. Topography has been determined from a preliminary stereophotogrammetric map having a contour interval and a precision of about 1 km (Wu and others, 1986) and from individual tracks of radar altimetry having a precision of 100 m (Roth and others, 1980). (See perspective view, fig. 2.)The topographic map was used to coordinate geologic cross sections, and minor discrepancies in geographic locations between the photomosaic and topographic bases occur in places. Formal geographic names are used wherever possible; the few informal names that are used are within quotes.

NOCTIS LABYRINTHUS PROVINCE

In the map area north of lat 10° S. and west of 100° W., the canyons of Noctis Labyrinthus cut an elongate, crested plateau, the "Syria rise." The rise has the form of a broad arc that partly encircles northern Syria Planum and reaches an elevation of about 9 km above the surrounding plains, or about 10 km above the Mars datum. The canyons of Noctis Labyrinthus are arranged in a radial pattern and, in this sense, and from a complex, crisscrossing pattern of faults, grabens, and collapse depressions. Noctis Labyrinthus grades northward into the fractured zone of Noctis Fossae and southeastward into Claritas Fossae, a complex of faults that cut a north-trending ridge rising about 1 km above the adjacent plains. Together, the rise and the widening Noctis Labyrinthus separate Syria Planum from the plains surrounding Tharsis Montes.

VALLES MARINERIS PROVINCE

This province includes the high, east, ridged plateau of Ophir Planum and east of Sinai and Lunae Plana and the long, linear, central canyons of Valles Marineris between long 67° and 84° . Three smaller isolated canyons (Ophir, Hebes, and Juventae Chasmata) are north of the main canyon system. Ophir Valles (lat 18° to 27° S., long 56° to 76°), which are large outflow channels from Echus Chasma, form the present-west margin of Lunae Planum south of the map area; the east margin is dissected by Maja Valles, large outflow channels from Juventae Chasma that are also north of the map area (at lat 8° to 25° N., long 49° to 67°). Both channel systems terminate in Chryse Planitia to the northeast.

The central canyons cut the summit of a broad topographic high (~4 km in elevation. The floors of Candor and Melas Chasmata are as low as 7 km below datum, resulting in a canyon relief of as much as 10 km. Lobate mesas (Mesas, Candor, and Iberia Mensae) within Hebes, Ophir, and Candor Chasmata approach the elevations of the surrounding canyon rims. Within the chasmata, the broad high is also cut by smaller, generally shorter troughs and lows (including Iberia, Ceti, and Hydroe Chasmata; Capri, Eurus, and Tithonia Catenae; and Eos Chasma).

The "Coprates rise," a broad ridge cut by Melanis Fossae, is 2 to 5 km above the surrounding plains. This rise and small portions of adjacent terrain lave local highlands on the chasmata south of Coprates Chasma, similar patches form high areas on Sinai Planum.

EASTERN CANYON PROVINCE

The eastern part of the canyon system extends across a relative—to—plateau region known as Xanthe Terra. Light has been deeply eroded by Eos, Capri, Eos, and Gangis Chasmata and small areas of chaotic terrain (including Aurorae, Margaritifer, and Pyrrhae Chaos). Relatively shallow channels (such as Ravi Vallis) cut the plateau surface and connect with these chasmata and chaotic terrain. The chasmata are characterized by wide depressions that also contain chaotic terrain (Eos, Hydroe, and Auroram Chaos) and that merge with broad channels extending northward to Chryse Planitia. Canyons form an elongate trough that, like those in Valles Marineris, overlies rocks of the plateau sequence in the west half of the map area, and is buried by younger units in the east half. The ridged plateau material has been estimated to have a maximum thickness of about 1.5 km in the western part of Lunae Planum and in this escarpment (Schultz and others, 1982), whose south rim is breached by Ophir Valles.

STRATIGRAPHY

Relative ages of the geologic units are determined from crater de—nsities (table 1) and stratigraphic and structural relations. The units are assigned to formal stratigraphic systems (Hesperian, Noachian, and Amazonian) formulated by Scott and Carr (1978). In many cases, more precise designations of the relative ages of units are given in terms of Early, Late, middle, and lower divisions of the system(s) defined by Tanaka (1986). Maps of the general stratigraphic observations and inferences and of the rock units in the Valles Marineris region were published by Lucchitta (1981) and the geologic map of the western equatorial region of Mars (Scott and Tanaka, 1986).

Following a mapping procedure developed by Scott and others (1981), we have classified crater materials as superposed or partly buried on the basis of their stratigraphic relation to adjoining geologic units, rather than according to their degradational state. As shown on the correlation chart, the map units are grouped into four main types: dune and slide materials; channel system materials; Valles Marineris interior deposits, and the plateau and high plains assemblage. The composition of map units is similar to that used by Scott and Tanaka (1986).

The dune and slide materials are composed of young surficial deposits having the morphologic characteristics of similar features found on Earth. Channel system materials consist of channel-floor deposits and crosscut material (which is common at the heads of outflow channels). Valles Marineris interior deposits occur locally in canyons and range in age, although they may have been emplaced during the Late Hesperian and Amazonian. Some are interpreted as a product of chaotic terrain formation, and others are interpreted as landslide deposits. The plateau and high plains assemblage consisting of materials forming the plateaus, high plains, and mesas. Materials are separated on canyon walls and on accordance with their stratigraphic position. Within each of the units, unit names are italicized where important informational and characteristics of individual units are given.

NOACHIAN SYSTEM

The Noachian System comprises the oldest materials exposed on Mars (Scott and Carr, 1978). During the Noachian Period, a high flux of meteorites produced impact basins and large impact craters. The amount of volcanic activity was probably relatively small, and the dominant geologic processes were those of fluvial erosion and deposition. Most materials of the plateau sequence were emplaced throughout the highlands of Mars. These high, cratered plateaus are made up of ancient, heavily cratered rocks exposed in the eastern canyon province and where they are highly deformed by faults in the west canyons.

The oldest exposed materials are basin-rim material (unit Mbr), knobby sections of undivided material (unit Hkp), and the hilly unit (unit Nplh) of the plateau sequence. The "Ladon basin" is surrounded by isolated mountains that are remnants of basin-rim material; its rim is deeply eroded and the basin is embayed by younger materials. In the canyon walls and the "Ladon basin" and throughout the region, the lower part of the undivided material represents possibly the thickest deposits of this material on Mars (as much as 10 km below Lunae Hesperian material). Little is known about the older undivided material except that it forms the deepest ridged slopes and has locally massive layers about 1 km thick. A much more complex stratigraphy in the canyon walls cannot be ruled out; a study of Landsat images of the Grand Canyon, at resolutions similar to those of Viking, indicates that major stratigraphic unconformities in the canyon walls are commonly unrecognizable. The hilly unit of the plateau sequence forms rugged, heavily cratered terrain on the plateau northeast of the central canyons. The northeast trends of all lobes that cut the hilly unit are unrelated to the trend of the younger canyons, indicating that the unit was deformed prior to canyon formation.

Later, during the continued bombardment and perhaps widespread volcanic activity (Saunders, 1979; Greeley and Spudis, 1981), the cratered and (unit Npl) of the plateau sequence was emplaced. This material probably covered all lower lying areas of Mars. It now forms parts of many rims, but it cannot be separately identified on the Viking images and is here included in undivided material. The unit's thickness was largely determined by preexisting topography and is probably highly varied. The unit is interpreted to be volcanic, as are most major rock units on Mars, but lava volcanic vents are visible where the unit occurs; many could be buried.

One construct that appears to be a volcano forms a conical mountain east of Noctaris Fossae. This mountain has a summit crater more than 20 km in diameter and its flanks display radial channels; it is embayed by younger Noachian material. The mountain material is mapped as older (lower and shield material, undivided (unit Nhs). Saunders and others (1980) and Scott (1982) interpreted this feature as a shield volcano and noted other possible old volcanoes south of the map region.

Valles networks doesn't many areas of the hilly and cratered units (for example, the slopes of "Ladon basin"). The valleys are small, commonly steeply gullies, brought a few tens of kilometers long, and they may have been formed by rainwater runoff (Masursky and others, 1977) or groundwater sapping (Pieri, 1980, p. 148). The areal density of valleys appears to be proportional to surface age (Schultz and Britt, 1986).

Valleys are uncommon in structures and intracanyon areas of the older terrains that are partly smoothed by resulting deposits, which are the major unit mapped as the subdued cratered unit (unit Npcs). This material may be made up in part of low-resolution Viking images. Other geologic processes of formation include activity that had produced the cratered unit; however, diagnostic surface features such as lobate scarps are few. In "Ladon basin," the unit may consist of flood plain materials deposited from Ladon Valles. The erosion and resurfacing associated with eruption and transport of the outflow channel materials and as well, which has virtually the same crater densities as the subdued cratered unit in the map region (table 1).

Southeast of Valles Chasma, a rough cratered surface having sublinear to irregular ridge characterizes the ridged unit (unit Npkr). Both textural and structural origins have been proposed for the ridges (Scott and Tanaka, 1986). Crater densities (table 1) and the unit's superposition by Hesperian plains material place the age of the ridged unit in the Middle to Late Noachian.

In the southern and western parts of the map region (notably in Noctis, Claritas, and Noctaris Fossae), Noachian surfaces are cut by numerous complex fractures and graben bounding faults and have higher relief than surrounding plateau material. The rocks of these areas are mapped as older fractured material (unit Nf). Structures dissecting the unit have obliterated many preexisting landforms and have created a fault-block topography that, in the width of the grabens (about 0.5 to 10 km) are less numerous than on other Noachian surfaces and were apparently destroyed by the fracturing. Crater densities on older fractured material differ from place to place (table 1), episodic deformation.

HESPERIAN SYSTEM

Extensive volcanism, tectonism, canyon erosion and channel development occurred during the Hesperian Period (Scott and Tanaka, 1986). The Hesperian System is divided and subdivided on the basis of geologic processes modifying the surface of the planet. Extensive areas of Noachian materials, particularly in the Noctis Labyrinthus and Valles Marineris provinces, were buried by lava flows of the ridged plains material and the Syria Planum and Syria Planum Formations.

The Hesperian material (unit Hr), the basal rock stratigraphic unit of the Hesperian System (Scott and Carr, 1978), is one of the most extensive volcanic units exposed on Mars. It occurs as lava flows that emanate from the Olympus Paterae, Syria Planum, Tharsis Montes, and Valles Marineris, overlies rocks of the plateau sequence in the west half of the map, and is buried by younger units in the east half of the region. The ridged plains material has been estimated to have a maximum thickness of about 1.5 km in the western part of Lunae Planum and in this escarpment (Schultz and others, 1982), whose south rim is breached by Ophir Valles. Volcanic sources of ridged plains material on Lunae Planum may be fissures associated with the incipient formation of Valles Marineris. The amount of volcanic activity of the Hesperian was probably greater than that of the ridged plains material; was emplaced adjacent to the central and eastern canyons of Valles Marineris and in Ophir Valles. Crater densities of adjacent younger fractured material (unit Hf). At Aurorae Planum and in areas south of Syria Planum, the fractured unit consists of extensive lava flows of outflow channels and fills a faulted trough adjacent to plateau chaotic material (unit Hcp). Although its origin is uncertain, these occurrences suggest that the fractured material is volcanic and was emplaced during early chasma development.

The Syria Planum Formation material (unit Hf) occurs at Noctis Labyrinthus and surrounds the west end of Valles Marineris. It is highly faulted and forms the rugged, heavily cratered plateau of Syria Planum and numerous smaller, and in slightly younger than ridged plains material. The faults are closely spaced and structure trend in most locations is radial to Syria Planum, which may have been present. The unit may consist of the smooth unit, ridged plains material, and other flows of Syria Planum that later were faulted and cratered. Crater densities on the Syria Planum Formation are relatively equal than those of the older fractured material, but the two units are distinguished on the basis of their structures. The plateau and high plains assemblage consisting of materials forming the plateaus, high plains, and mesas. Materials are separated on canyon walls and on accordance with their stratigraphic position. Within each of the units, unit names are italicized where important informational and characteristics of individual units are given.

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Figure 1. Physiographic provinces (dashed lines are boundaries) and major geographic features of Valles Marineris region.

Figure 2. Perspective view of central Valles Marineris looking due east at 20° above horizon. Canyon system is as much as 7 km deep. Interior chasmata are Melas, Candor, and Ophir Chasmata at top. Vertical exaggeration 5X. Produced from digital elevation data from stereophotogrammetry by U.S.C. Wu and natural-color Viking image processing by A.S. McEwen.

Table 1. Crater densities of selected map units

(Counting areas progressively less coarse in 12,000,000-scale subequidistant (see introduction). Only superposed craters counted except in counting areas of units marked by asterisk(*), where all observed craters were counted.)

Unit symbol	Location	Area (km²)	Density (No. craters/1 million km²) for diameters (km) equal to or greater than		
			2 km	5 km	16 km
	MC-10NE				
Ahg	Tharsis Montes	612,000	—	90± 10	10 ± 4
Ahv	Olympus Mons	612,000	—	110± 10	10 ± 4
Hf	Noctis Labyrinthus	71,304	—	159 ± 51	14 ± —
Nf	Noctis Fossae	61,296	—	484 ± 135	52 ± 31
	MC-09SE				
Hsv	M. Sinai Plateau	189,728	—	427± 58	121± 25	—
Hf	N. of Tithonium					
	Chasma	87,808	1,134±113	776± 96	214± 50	50±25
Hv	E. Sinai Plateau	113,960	1,990±150	652± 86	167± 38	46±20
Hv	E. Sinai Plateau	89,557	2,151±190	990± 117	185± 46	56±25
Npc	E. Sinai Plateau	84,532	1,090±180	1,010± 173	163±37	57±25
	MC-09NE, northern third of					
Hv	Ophir Planum	106,500	—	1,467± 159	272± 52	28± 16
Hv	E. Coprates Chasma	96,240	—	1,455± 195	351± 65	47±20
Hplg	Aurorae Planum	33,016	—	1,765±337	562±139	59±42
Hplg	Aurorae Planum	31,000	—	1,677±345	871± 181	97±52
Hplr	N. Coprates Chasma	28,520	—	1,038± 99	228± 35	35±14
Hplr*	N. Coprates Chasma	28,520	—	1,093±158	488± 66	139±28
	MC-09NW, northern third of					
Nplr	N. Capri Chasma	135,788	—	1,202±158	220± 46	36± 18
Nplr*	N. Capri Chasma	135,788	—	1,298±159	351± 76	72± 30
Nplr	S. Parchee Chasma	71,680	—	1,948±137	265± 36	32± 19
Nplr*	S. Parchee Chasma	71,680	—	1,436±135	370± 57	100± 40

(Mar, Geologic map of the western equatorial region of Mars: U.S. Geological Survey Miscellaneous Investigations Series Map I-1802-A, scale 1:15,000,000.

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