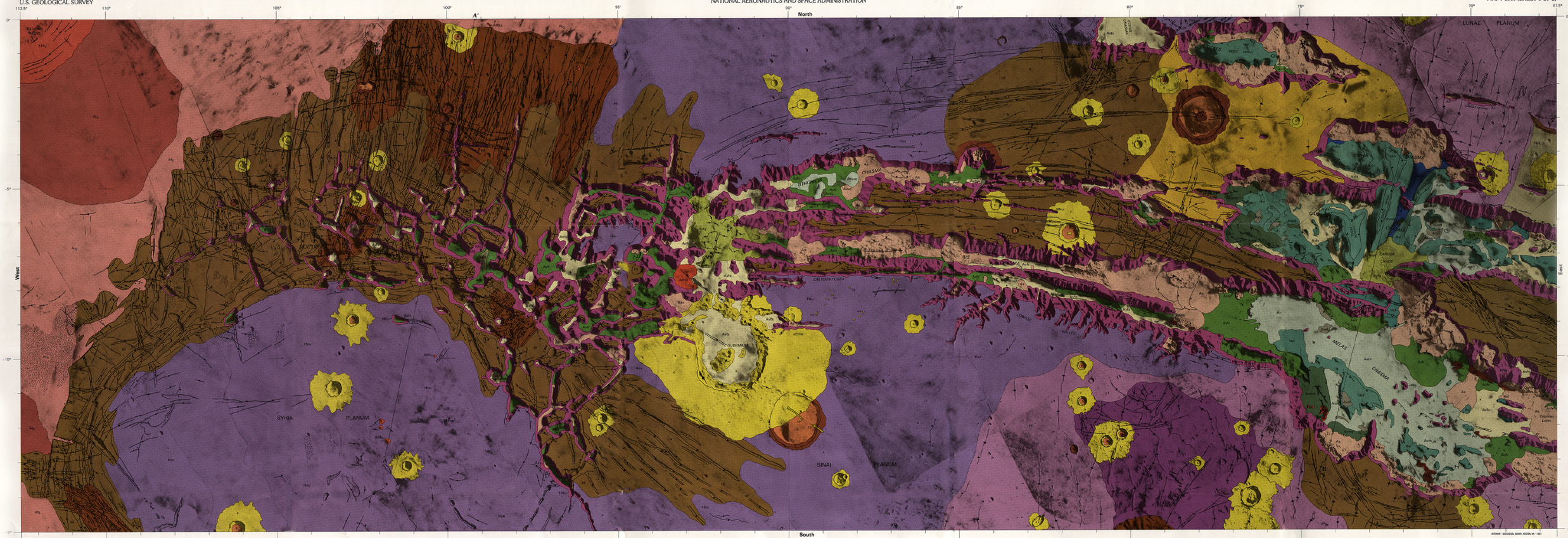
U.S. DEPARTMENT OF THE INTERIOR
U.S. GEOLOGICAL SURVEY

Prepared for the
NATIONAL AERONAUTICS AND SPACE ADMINISTRATION

ATLAS OF MARS
1:2,000,000 GEOLOGIC SERIES
VALLES MARINERIS REGION
M2M -7/90 G, 1991
MAP I-2010 (SHEET 1 OF 2)



Base from U.S. Geological Survey, 1979, Controlled photomosaic of the Phoenicis Lacus northeast quadrangle of Mars (MC–17NE) and from U.S. Geological Survey, 1979, Controlled photomosaic of the Coprates northwest quadrangle of Mars (MC–18NW), U.S. Geological Survey Miscellaneous Investigations Series Maps I–1250 and 1257

SCALE 1:2000000 (1mm = 2km) AT ~27.3°
MERCATOR PROJECTION

KILOMETERS

WORKMAN—GEOLOGICAL SURVEY, RESTON, VA—1991

Prepared on behalf of the Planetary Geology Program, Solar System Exploration Division, Office of Space Science, National Aeronautics and Space Administration, under contract W–15,814

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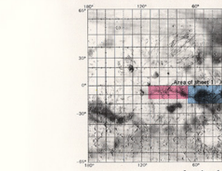

Location of areas shown on sheets 1 and 2

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, superseides 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 12,000,000-scale photomosaics of subquadrangles MC–17NE, MC–18NE, and MC–19NW and of the northern thirds of MC–18SE and MC–19SW. Most of the geologic units of the plateau and high-plains assemblage were established during mapping at 1:5,000,000 scale of the western equatorial region of Mars (Scott and Tanaka, 1986); additional units and symbols are employed here to reflect the complex geology within Valles Marineris. The units were identified on individual images and large-scale mosaics mapping in resolution from about 10 to 150 m/pixel. (Volcanic rocks of the subquadrangle MC–17NE were previously mapped (Scott and Tanaka, 1986)as part of a map series at 1:2,000,000 scale of the Tharsis and Syria Planum lava flows (Scott and others, 1981); where minor discrepancies exist between 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 global 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 (exposed at Margaritifer Terra), which is covered by a veneer of intermediate-age (Hesperian) plains material in the western and central parts of the canyon system. The walls of Valles Marineris display the thickest vertical stratigraphic section on Mars, exposing some of the planet's oldest and deepest crustal rocks. Uplift and crustal rifting associated with tectonic activity in the Tharsis region to the west appear to be the primary processes that formed the high plateaus and deep canyons. The eastern canyons contain chaotic terrains (closely spaced knobs and mesas) associated with huge outflow channels. Both layered and massive deposits occur within the canyons. Faulting, landsliding, wind erosion, and collapse have shaped the canyon walls in recent geologic time.

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

PHYSIOGRAPHIC SETTING

The Valles Marineris region lies east of Tharsis Montes (which extends from lat 12° to 20° N., long 101° to 120°). Part of the region is in the midst of a vast plateau bounded on the west and east by Claritas and Noctaria Fossae, respectively; the remainder extends farther east into southern Xanthe Terra and western Margaritifer Terra. Channel trends, stereophotogrammetry, and radar altimetry indicate that the surface north and east of the canyon slopes toward Chryse Planitia (centered at about lat 25°N., long 45°). Within the broad Valles Marineris region, three distinct physiographic provinces are recognized (fig. 1): (1) the Noctis Labyrinthus province, consisting of high plateau cut by a network of structurally controlled troughs; (2) the Valles Marineris province, characterized by broad, linear valleys hundreds to thousands of kilometers long; and (3) the eastern canyon province, containing irregular depressions as much as 900 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 latitudinal tracks of radar altimetry having a precision of 200 m (Roth and others, 1980). (See perspective view, fig. 2.)The topographic map was used to construct geologic cross sections; minor discrepancies in geographic locations between the photomosaic and topographic bases occur in places. Formal geographic names are used wherever possible; the less informal names that are used are within quotes.

NOCTIS LABYRINTHUS PROVINCE

In the map area west of long 90°, the topography of Noctis Labyrinthus cut an elongate, cratered plateau, the "Syria rise." This rise has the form of a broad arc that partly encircles northern Syria Planum and reaches an elevation of about 4 km above the surrounding plains, or about 10 km above the Mars datum. The canyons of Noctis Labyrinthus are as much as 3 km deep and 20 km across and form a complex, crosscutting pattern of halls, grabens, and collapse depressions. Noctis Labyrinthus grades northward into the densely fractured area of Noctis Fossae and southwestward into Claritas Fossae, a complex of faults that cut a north-trending ridge rising about 3 km above the adjacent plains. Together, this ridge and the adjoining Noctis Labyrinthus separate Syria Planum from the plains surrounding Tharsis Montes.

VALLES MARINERIS PROVINCE

This province includes the high, vast, ridged plains of Ophir Planum and part of Sinai and Lunae Plana and the long, linear, central canyons of Valles Marineris between long 53° and 94°. Three smaller isolated canyons (Echus, Hebes, and Juventae Chasmata) are north of the main canyon system. Ravni Valles (lat 18° to 27° N., long 56° to 75°), which are large outflow channels from Echus Chasma, form the present west margin of Lunae Planum north 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 16° to 21° N., long 49° to 57°). Both channel systems terminate in Chryse Planitia to the northeast.

The central canyons cut the summit of a broad topographic high 6 km to 8 km in elevation. The floors of Candor and Melas Chasmata are as low as 1 km below datum, resulting in a canyon relief of as much as 10 km. Lesser mesas (Hebes, Candor, and Ophir Mesas) within Hebes, Ophir, and Candor Chasmata approach the elevations of the surrounding canyon rim. Near the chasmata, the broad high is also cut by smaller, generally elongate pit chains and fractures (including Baetis, Ceti, and Hydrae Chasmata; Ceti, Gangas, and Tithonia Catenae, and Tithonia Fossae).

The "Coprates rise," a broad ridge cut by Noctaria Fossae, is 2 to 3 km above the surrounding plains. This rise and small patches of deferred terrain form local highlands on the plains south of Coprates Chasma and similar patches form high areas on Sinai Planum.

EASTERN CANYON PROVINCE

The eastern part of the canyon system extends across a relatively smooth plateau (only a few kilometers high) that has been deeply eroded to form Capri, Eos, and Gangis Chasmata and small areas of chaotic terrain (including Aeolscopus, Margaritifer, and Pyrrhae Chaos). Relatively shallow channels (such as Reull Vallis) cut the plateau surface and connect some these chasmata and chaotic terrains. The chasmata are characterized by wide depressions that also contain chaotic terrains (Eos, Hydraotes, and Aureum Chaos) and that merge with broad channels extending north-northeast to Chryse Planitia from Ophir and Candor Chasmata and from adjacent plateaus. East of Eos Chasma, the landscape is dominated by a large, eroded, and partly filled impact structure informally named the "Ladon basin" (Schultz and others, 1982), whose south rim is breached by Ladon Valles.

STRATIGRAPHY

Relative ages of the geologic units are determined from crater counts (table 1) and stratigraphic and structural relations. The units are assigned the formal stratigraphic designations of Tanaka (1986), where possible, formulated by Scott and Carr (1978). In many cases, more precise descriptions of their relative positions are given in terms of series (oldest, middle, and lower divisions of the system) defined by Tanaka (1986). Many of the general stratigraphic observations and inferences and the rationales of crater densities to stratigraphic units were taken from Tanaka (1986) 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 a basis of their stratigraphic relation to adjoining geologic units, rather the 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. This organization 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 coarse material (which is common at the heads of outflow channels). Valles Marineris interior deposits occur locally in canyons and range in age, albeit, layering character, and thickness. The plateau and high-plains assemblage consisting of materials forming the plateaus, high plains, and other highlands, is exposed in canyon walls and on surrounding plateaus. (In the remainder of this section, unit names are italicized where important relevant 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 atmosphere was probably denser and surface temperatures were higher than later in Mars' history, and local channels formed in rugged highland terrain. Volcanism and tectonism were widespread, but many of the resulting landforms have been obscured by younger deposits. Crustal materials of the plateau sequence were emplaced throughout the highlands of Mars. These highly cratered volcanic flows and plutonic materials and impact ejecta exposed in the eastern canyon province and where they are highly deformed in places by faults and ridges.

The oldest exposed materials are *basin-rim material* (unit *Nbr*), lower sections of undifferentiated material (unit *Nhu*), 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 σ-ridge throughout the region, the lower part of the undivided material represents possibly the lowest, deepest exposed rocks on Mars (as much as 10 km below Lunae Hesperian material). Little is known about the older unit *Nhu* materials except that it forms rugged slopes and has locally massive bases 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 inconclusive. The hilly unit of the plateau sequence forms rugged, heavily cratered terrain on the plateau northeast of the central canyons. The northeast trends of old faults 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, owing to continued bombardment and perhaps widespread volcanic activity (Saunders, 1979; Greeley and Spudis, 1981), the cratered rim wall (unit *Nrc*) of the plateau sequence was emplaced. This material probably covered all lower lying areas of Mars. It now forms parts of many cliffs, but it cannot be separately identified on the cliff faces and is there 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 lee volcanic vents are visible where the unit occurs; many could be buried.

One crater-fill deposit appears to be a volcanic form a conical mountain west of Nectaris 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 floor and shield material, undivided* (unit *Nfu*). 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 Marineris dissects areas of the hilly and cratered units (for example, the slopes of "Ladon basin"). The valleys are small, commonly single gullies or troughs 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 intercrater and intracrater areas of the older terrains (*hilly unit*) smoothed by resetting deposits, which are mapped as the *subdued cratered unit* (unit *Nplc*). This material may be made up in part of lavas emplaced during the waning stage of the postulated volcanic 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 resetting associated with emplacement of the unit greatly affected the cratered unit as well, which has virtually the same crater densities as the subdued cratered unit in the map region (table 1).

Southward of Melas Chasma, a rough cratered surface having sublinear to irregular ridges characterizes the *ridged unit* (unit *Nplr*). Both tectonic and volcanic origins have been proposed for the ridges (Scott and Tanaka, 1986). Crater densities (table 1) and the unit's superposition by Hesperian ridged 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 Noctaria Fossae), Noachian surfaces are cut by complex systems fractures and graben bounding faults and have higher relief than surrounding younger plains material. The rocks of these areas are designated as *older fractured material* (unit *Nf*). Structures dissecting the unit have obliterated most primary morphologic features, and fracturing has greatly affected the cratered rim walls of the craters (about 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 those in place (table 1), probably because of local, episodic deformation.

HESPERIAN SYSTEM

Extensive volcanism, tectonism, and canyon and channel development occurred during the Hesperian Period (Scott and Tanaka, 1986). The impact cratering rate declined and cratering was no longer the major process modifying the surface of the planet. Extensive areas of Noachian materials, particularly in the Noctis Labyrinthus and Valles Marineris provinces, are buried by lava flows of the ridged plains material and the Tharsis Montes and Syria Planum Formations.

Ridged plains material (unit *Hr*), the basal rock stratigraphic unit of the Hesperian System (Scott and Carr, 1978), is one of the most extensive units on Mars. It occurs almost everywhere in the plateau between Valles Marineris, overlies rocks of the plateau sequence in the east half of the map region, and forms the plains surrounding Tharsis Montes and Syria Planum in the west half. 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 to thin eastward (DeHon, 1982), overlapping older rocks of the plateau sequence. It is thought to consist of low-viscosity lava flows erupted from fissures in high-extension zones (Greeley and Spudis, 1981). Lobate flow fronts are rare. North of Valles Marineris, the unit is dissected by long, sinuous channels (for example, Ares Vallis) resembling those produced by lava flows. Volcanic sources of ridged plains material on Lunae Planum may be fissures associated with the incipient formation of Valles Marineris.

The smooth unit (unit *Hsr*) of the plateau sequence, generally younger than the ridged plains material, was emplaced adjacent to the central and eastern canyons and south of Lunae Planum. It forms the Syria Fossae of adjacent younger fractured material (unit *Hf*). At Aurorae Planum and in areas north of Gangis Chasma, the smooth material surrounds exposed scarps arcuate 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 unit consists of fluid lava or pyroclastic material during early chasma development.

The *younger fractured material* (unit *Hf*) occurs at Noctis Labyrinthus and surrounds the west end of Valles Marineris. It is highly faulted and trenched by grabens and collapse depressions. The unit is commonly smoother with or slightly younger than ridged plains material. The faults are closely spaced and commonly have a northeast trend. The unit may consist of the smooth unit, ridged plains material, and older flows of Syria Planum that later were faulted beyond recognition. Faults in the unit are more closely spaced than those of the older fractured material, but the two units generally have the same trend. The younger fractured unit also contains deposits into the smooth unit of the plateau sequence in southwestern Ophir Planum. The younger fractured unit is the most extensively fractured by crater densities, by its embayment of older fractured material cut by Noctis Fossae, and by burial of its faults by Upper Hesperian flows of the Syria Planum Formation.

More difficult to estimate is the time of formation of Valles Marineris. Its great relative direct measurements by crater counting and superposition relations because faulting and erosion of the canyon walls continued into Late Amazonian time. We infer, however, that the major episode of canyon development occurred during faulting of the younger fractured material, for several reasons: (1) Noachian materials adjacent to the canyons generally have lower crater densities than younger Hesperian materials in the hilly unit (unit *Nplh*), which is cut by northeast-trending faults apparently unrelated to canyon formation. (2) Hesperian ridged plains material (unit *Hr*) of the "Coprates rise," which material may have been faulted by local deformation, (3) Many faults, grabens, and collapse depressions of the younger fractured material parallel the large canyons. (3) Small, linear, incipient canyons (for example, pit chains south of Coprates Chasma) have developed along the faults. This same relation probably holds for Noctis Labyrinthus and its adjacent faults. The inferred timing of canyon development is in general agreement with other studies of the structural history of the region (see below).

Stratigraphic relations indicate that the eastern canyons, chaotic terrain, and outflow channels were formed at about the same time as the central canyons. However, the eastern canyons are not structurally controlled as are the central canyons, and they generally have floors of chaotic terrain that are connected with huge outflow channels (Carr, 1981, p. 136). Two stages of formation are reflected in the mapped channel system units. Where the canyons are commonly structurally controlled, the hilly unit of the plateau sequence forms rugged, heavily cratered terrain on the plateau northeast of the central canyons. The northeast trends of old faults that cut the hilly unit are unrelated to the trend of the younger canyons, indicating that the unit was deformed prior to canyon formation.

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HESPERIAN SYSTEM

Extensive volcanism, tectonism, and canyon and channel development occurred during the Hesperian Period (Scott and Tanaka, 1986). The impact cratering rate declined and cratering was no longer the major process modifying the surface of the planet. Extensive areas of Noachian materials, particularly in the Noctis Labyrinthus and Valles Marineris provinces, are buried by lava flows of the ridged plains material and the Tharsis Montes and Syria Planum Formations.

Ridged plains material (unit *Hr*), the basal rock stratigraphic unit of the Hesperian System (Scott and Carr, 1978), is one of the most extensive units on Mars. It occurs almost everywhere in the plateau between Valles Marineris, overlies rocks of the plateau sequence in the east half of the map region, and forms the plains surrounding Tharsis Montes and Syria Planum in the west half. 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 to thin eastward (DeHon, 1982), overlapping older rocks of the plateau sequence. It is thought to consist of low-viscosity lava flows erupted from fissures in high-extension zones (Greeley and Spudis, 1981). Lobate flow fronts are rare. North of Valles Marineris, the unit is dissected by long, sinuous channels (for example, Ares Vallis) resembling those produced by lava flows. Volcanic sources of ridged plains material on Lunae Planum may be fissures associated with the incipient formation of Valles Marineris.

The *smooth unit* (unit *Hsr*) of the plateau sequence, generally younger than the ridged plains material, was emplaced adjacent to the central and eastern canyons and south of Lunae Planum. It forms the Syria Fossae of adjacent younger fractured material (unit *Hf*). At Aurorae Planum and in areas north of Gangis Chasma, the smooth material surrounds exposed scarps arcuate 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 unit consists of fluid lava or pyroclastic material during early chasma development.

The *younger fractured material* (unit *Hf*) occurs at Noctis Labyrinthus and surrounds the west end of Valles Marineris. It is highly faulted and trenched by grabens and collapse depressions. The unit is commonly smoother with or slightly younger than ridged plains material. The faults are closely spaced and commonly have a northeast trend. The unit may consist of the smooth unit, ridged plains material, and older flows of Syria Planum that later were faulted beyond recognition. Faults in the unit are more closely spaced than those of the older fractured material, but the two units generally have the same trend. The younger fractured unit also contains deposits into the smooth unit of the plateau sequence in southwestern Ophir Planum. The younger fractured unit is the most extensively fractured by crater densities, by its embayment of older fractured material cut by Noctis Fossae, and by burial of its faults by Upper Hesperian flows of the Syria Planum Formation.

More difficult to estimate is the time of formation of Valles Marineris. Its great relative direct measurements by crater counting and superposition relations because faulting and erosion of the canyon walls continued into Late Amazonian time. We infer, however, that the major episode of canyon development occurred during faulting of the younger fractured material, for several reasons: (1) Noachian materials adjacent to the canyons generally have lower crater densities than younger Hesperian materials in the hilly unit (unit *Nplh*), which is cut by northeast-trending faults apparently unrelated to canyon formation. (2) Hesperian ridged plains material (unit *Hr*) of the "Coprates rise," which material may have been faulted by local deformation, (3) Many faults, grabens, and collapse depressions of the younger fractured material parallel the large canyons. (3) Small, linear, incipient canyons (for example, pit chains south of Coprates Chasma) have developed along the faults. This same relation probably holds for Noctis Labyrinthus and its adjacent faults. The inferred timing of canyon development is in general agreement with other studies of the structural history of the region (see below).

Stratigraphic relations indicate that the eastern canyons, chaotic terrain, and outflow channels were formed at about the same time as the central canyons. However, the eastern canyons are not structurally controlled as are the central canyons, and they generally have floors of chaotic terrain that are connected with huge outflow channels (Carr, 1981, p. 136). Two stages of formation are reflected in the mapped channel system units. Where the canyons are commonly structurally controlled, the hilly unit of the plateau sequence forms rugged, heavily cratered terrain on the plateau northeast of the central canyons. The northeast trends of old faults 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, owing to continued bombardment and perhaps widespread volcanic activity (Saunders, 1979; Greeley and Spudis, 1981), the cratered rim wall (unit *Nrc*) of the plateau sequence was emplaced. This material probably covered all lower lying areas of Mars. It now forms parts of many cliffs, but it cannot be separately identified on the cliff faces and is there 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 lee volcanic vents are visible where the unit occurs; many could be buried.

One crater-fill deposit appears to be a volcanic form a conical mountain west of Nectaris 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 floor and shield material, undivided* (unit *Nfu*). 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 Marineris dissects areas of the hilly and cratered units (for example, the slopes of "Ladon basin"). The valleys are small, commonly single gullies or troughs 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 intercrater and intracrater areas of the older terrains (*hilly unit*) smoothed by resetting deposits, which are mapped as the *subdued cratered unit* (unit *Nplc*). This material may be made up in part of lavas emplaced during the waning stage of the postulated volcanic 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 resetting associated with emplacement of the unit greatly affected the cratered unit as well, which has virtually the same crater densities as the subdued cratered unit in the map region (table 1).

Southward of Melas Chasma, a rough cratered surface having sublinear to irregular ridges characterizes the *ridged unit* (unit *Nplr*). Both tectonic and volcanic origins have been proposed for the ridges (Scott and Tanaka, 1986). Crater densities (table 1) and the unit's superposition by Hesperian ridged 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 Noctaria Fossae), Noachian surfaces are cut by complex systems fractures and grabens bounding faults and have higher relief than surrounding younger plains material. The rocks of these areas are designated as *older fractured material* (unit *Nf*). Structures dissecting the unit have obliterated most primary morphologic features, and fracturing has greatly affected the cratered rim walls of the craters (about 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 those in place (table 1), probably because of local, episodic deformation.

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