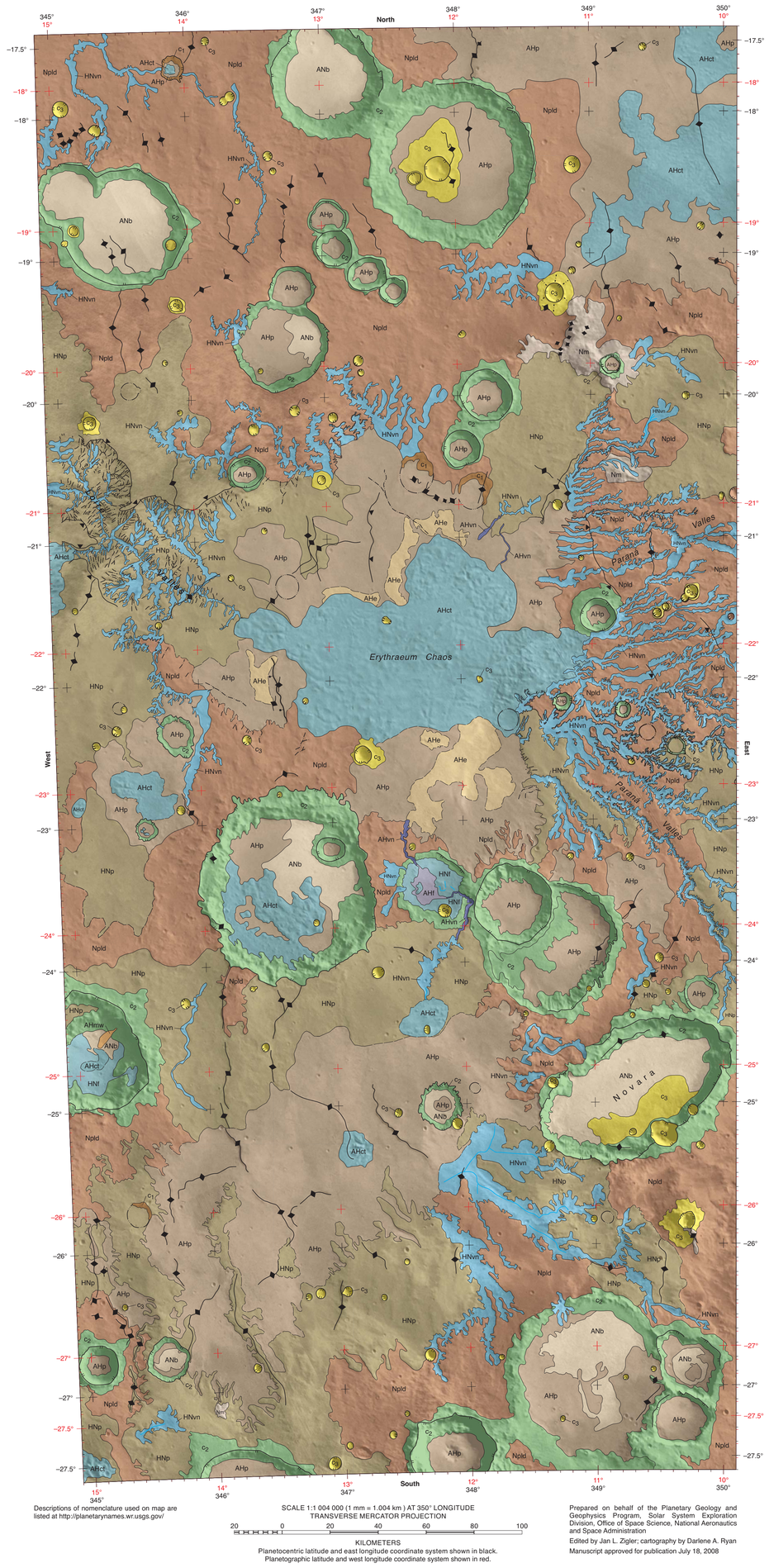
U.S. Department of the Interior
U.S. Geological Survey

Prepared for the
National Aeronautics and Space Administration

Scientific Investigations Map 3041
Atlas Of Mars: MTM –20012 and –25012 Quadrangles
Pamphlet accompanies map



Descriptions of nomenclature used on map are listed at http://planetarynames.wr.usgs.gov/

SCALE 1:1 004 000 (1 mm = 1.004 km) AT 350° LONGITUDE
TRANSVERSE MERCATOR PROJECTION

20 0 20 40 60 80 100
KILOMETERS

Planetocentric latitude and east longitude coordinate system shown in black.
Planetographic latitude and west longitude coordinate system shown in red.

Prepared on behalf of the Planetary Geology and Geophysics Program, Solar System Exploration Division, Office of Space Science, National Aeronautics and Space Administration

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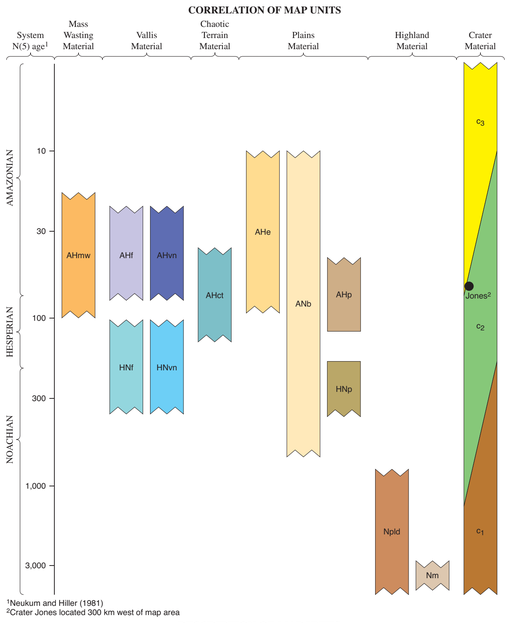
CORRELATION OF MAP UNITS



[1]Neukum and Hiller (1981)
[2]Crater Jones located 300 km west of map area

DESCRIPTION OF MAP UNITS

[Unit descriptions and interpretations are based on morphology, texture, albedo, and stratigraphic position as observed in Viking Orbiter, Mars Global Surveyor Mars Orbiter Camera (MOC), Odyssey THEMIS, and Mars Reconnaissance Orbiter HiRISE Images. THEMIS visible (VIS) image identification numbers, for example V14817005, are used to locate images (table 1, fig. 5)]

MASS-WASTING MATERIAL

AHmw **Mass-wasting material (Amazonian to Hesperian)**—Degraded, isolated tongue of material that originates in an alcove on a steep crater wall and extends onto the crater floor (V14817005). Overlies bright plains material (unit ANb). *Type locality*: lat 24.5° S., long 345.18° E. *Interpretation*: Failure of steep wall-rock material emplaced in a mass-wasting event. Unit is younger than bright plains material (unit ANb), but degraded appearance is inconsistent with very recent activity

VALLIS MATERIAL

AHf **Younger fan material (Middle Amazonian to Late Hesperian)**—Forms a smooth to variably rough, sometimes light-toned, locally lobe-shaped deposit on the floor of an unnamed crater south of Erythraeum Chaos. Deposits incise and bury older fan deposits (unit HNf); channels and depositional lobes exhibit fairly uniform, intermediate brightness temperature in THEMIS nighttime IR data. *Type locality*: lat 23.5° S., long 347.7° E. *Interpretation*: Alluvial fans and associated distal alluvium composed of relatively coarse alluvium and (or) partially lithified material deposited on older alluvium (unit HNf). Depositional lobes radiating from mouth of younger inlet valley (unit AHvn) lack steep fronts, suggesting much of the discharge was subaerial and perhaps deposited as debris flows. Preserved lobes indicate episodic flow contemporaneous with associated younger valleys; limited evidence of flow from crater suggests ponding was likely and deposits may extend across crater floor and beyond lobes

AHvn **Younger valley network material (Middle Amazonian to Late Hesperian)**—Deposits within generally isolated, narrow valleys. Few examples found in and south of Erythraeum Chaos where valleys appear to incise plains materials (units HNp, AHp). Valleys are generally narrow and sharply defined relative to older valleys (unit HNvn) with abrupt headward terminations; no evidence of incised channels or developed tributaries. Valleys sometimes entirely confined within younger plains materials, but examples incising segments of older valleys and (or) emerging from broader and apparently older materials occur within map area (for example, lat 23.7° S., long 348.0° E.). Accumulations of light-toned, eolian drift exhibit low brightness temperature in THEMIS nighttime IR. *Type locality*: lat 20.93° S., long 348.24° E. *Interpretation*: Sedimentary materials eroded from surrounding plains and uplands and deposited by water flowing through poorly integrated valleys. Valley morphometry suggests a groundwater source for discharge, perhaps in association with emplacement of younger plains materials and (or) final drawdown of regional aquifers. Limited slope/colluvial processes likely contributed to greater valley widening and extension

HNf **Older fan material (Hesperian to Late Noachian)**—Forms a smooth to variably rough, locally elevated, fan-shaped deposit(s) and associated materials mantling floors of two unnamed craters. Multiple channels and depositional lobes preserved in some cases; deposits exhibit fairly uniform, intermediate-brightness temperature in THEMIS nighttime IR data. Surface gradients of fans vary (V18199004). Underlies younger fan unit (AHf) in one location (lat 23.5° S., long 347.75° E.). *Type localities*: lat 23.5° S., long 347.9° E.; lat 24.8° S., long 345.1° E. *Interpretation*: Alluvial fans, deltas, and associated alluvium consisting of relatively coarse alluvium and (or) partially lithified material deposited on crater floors. Steep fronts suggest some material may have been deposited in crater-lake settings. Preserved lobes and distributary channels indicate sustained or perhaps episodic flow, probably contemporaneous with period of widespread valley formation (unit HNvn)

HNvn **Older valley network material (Hesperian to Late Noachian)**—Generally smooth and widely distributed deposits that fill numerous valleys throughout map area. Valleys often well integrated with preserved first- and second-order tributaries; valley floors do not typically exhibit preserved, incised channel features and low- to high-brightness temperatures in THEMIS nighttime IR data. Proximal reaches of Loire Valles exhibit a highly dissected, crenulated morphology. *Type localities*: Paraná and Loire Valles (for example, lat 22.35° S., long 348.9° E.; lat 21.15° S., long 345.62° E.). *Interpretation*: Sedimentary materials of perhaps varying composition and (or) mineralogy, eroded from surrounding plains and uplands and deposited by water flowing through multi-digitate, parallel to dendritic valley networks. Valley floors exhibit uneven accumulations of eolian drift and dunes. Small valleys likely formed by fluvial processes related to precipitation-recharged groundwater sapping. Crenulated morphology likely caused when discharge from Erythraeum Chaos caused down-cutting and headward erosion of the main branch of Loire Valles and associated tributaries

CHAOTIC TERRAIN MATERIAL

AHct **Chaotic terrain material (Middle Amazonian to Hesperian)**—Closely spaced, rounded to flat, elongate plateaus, buttes, knobs, and linear ridges, typically separated by troughs. Troughs between plateaus have an approximate east-west orientation but are occasionally interrupted by troughs with a north-south orientation. Plateau surfaces generally smooth at scales of tens to hundreds of meters; most appear stripped and expose more resistant material and low, narrow, linear, intersecting ridges. Plateau surfaces exhibit intermediate- to high-brightness temperatures in THEMIS nighttime infrared (IR) data, whereas intervening troughs are intermediate to dark. Height relative to adjacent troughs ranges from tens of meters (north and east of Erythraeum Chaos, for example, lat 18.7° S., long 349.2° E.) to 100–200 m in Erythraeum Chaos and as much as ~275 m (for example, lat 23.7° S., long 346.7° E.). AHct sometimes occurs in depressions bounded along their margins by discontinuous troughs on the order of 50–100 m deep and 3-7 km wide (for example, Erythraeum Chaos), whereas in other locations, material rises above the level of surrounding plains (for example, lat 23.7° S., long 346.7° E.). Wrinkle ridges occur locally and are oriented roughly north-south. Variably embays and cuts adjacent younger plains materials (units AHp, AHe, ANb), consistent with crater statistics (N5 age of ~100). *Type locality*: Erythraeum Chaos (for example, lat 22° S., long 348.5° E.). *Interpretation*: Remnants of possibly more resistant alluvial (ice-rich?) deposits emplaced in association with older vallis materials (unit HNvn) and subsequently modified and exposed by eolian and (or) alternate processes. Collapse played a minimal role in formation, whereas some locations rising above level of surrounding plains may have experienced substantial constructional contributions via accumulation and upward expansion of ice, sedimentary diapirism, or mud volcanism. Expression of wrinkle ridges requires some internal strength that may reflect persistence of volatiles in what may be sedimentologically varied alluvium. Local intersecting ridges may reflect small, relatively resistant dikes exposed via differential erosion of the surface. Stratigraphic relations indicate a younger age than bulk of valley network materials (units HNvn, AHvn) and may be younger than younger plains materials (units AHp, AHe, ANb). Origin of dikes may be sedimentary or diagenetic, but proximity of valleys and paucity of volcanic landforms argues against a volcanic origin

PLAINS MATERIAL

AHe **Etched plains material (Late Amazonian to Late Hesperian)**—Local scabby to rough, knobby, pitted materials; express relatively high, local relief. Deposits occur along margins of chaotic terrain materials (unit AHct) in Erythraeum Chaos; surrounded by younger plains materials (unit AHp). Exhibit intermediate brightness temperature in THEMIS nighttime IR data. Margins occasionally lobate. *Type locality*: lat 22.4° S., long 348° E. *Interpretation*: Possible volatile-rich flow deposits similar in origin to chaotic terrain materials, but intermediate strength between younger plains and chaotic terrain materials due to intermediate volatile content. Differential welding and subsequent eolian stripping possibly responsible for etched appearance

ANb **Bright plains material (Amazonian to Noachian)**—Rough to locally knobby material on crater floors. Exhibits high-temperature brightness in THEMIS nighttime IR data. Few, degraded impact craters preserved. *Type locality*: Novara crater. *Interpretation*: Coarse-grained or indurated/cemented, fine-grained materials. Possibly bedrock-impact-melt deposits exposed by surface deflation and stripping of superposing deposits. Rough texture, composition, knobby appearance, and occurrence of few, well-developed valleys within some of the associated craters suggests material is not alluvial in origin, and general paucity of volcanic terrains in map region argues against a volcanic origin

AHp **Younger plains material (Early Amazonian to Hesperian)**—Forms a widespread, lightly cratered plains surface; typically embays vallis materials (unit HNvn), older plains materials (unit HNp), mountainous material (unit Nm), and dissected unit of the plateau sequence (unit Npld). Occasionally embays chaotic terrain materials (unit AHct). Typically confined to topographic lows and basins, except where partially encircling chaotic terrain materials in Erythraeum Chaos. North-trending wrinkle ridges, partially buried craters (for example, lat 21.4° S., long 346.7° E.), and relatively few incised valleys preserved. Generally characterized by intermediate-brightness temperatures in THEMIS nighttime IR data. *Type locality*: lat 21° S., long 347.5° E. *Interpretation*: Sedimentary and (or) volcanic materials partially filling Erythraeum Chaos and burying other surfaces. Often surrounded by younger etched (AHe) or older plains (HNp) materials. If sedimentary in origin, location relative to older plains material suggests possible accumulations of locally eroded and redistributed older plains material. Paucity of incised valleys relative to surface area implies limited, primary alluvial contributions; general absence of volcanic edifices in map area argues against volcanic origin. May be expression of volatile-rich, partially welded eolian deposits or impact materials in some locations

HNp **Older plains material (Early Hesperian to Late Noachian)**—Forms a widespread, relatively low-relief, lightly cratered plains surface, often dissected by valley network material. Locally embayed by younger plains materials; mantles floors of some moderately degraded craters. Generally north-south-oriented wrinkle ridges and buried to partially buried/exhumed craters preserved. Topographically lower than older, exposed dissected unit of the plateau sequence (unit Npld) and mountainous material (unit Nm). Relatively older than valles materials and deposits (units HNf, HNvn), chaotic terrain material (unit AHct), and younger plains material (unit AHp). *Type localities*: lat 26.3° S., long 347.5° E. *Interpretation*: Mixture of fluvial/alluvial deposits, colluvium, and volcanic and (or) impact debris, which mantle topographic lows in dissected unit of the plateau sequence (unit Npld)

PLATEAU AND HIGHLAND MATERIAL

Npld **Dissected unit of the plateau sequence (Early to Middle Noachian)**—Widespread, heavily cratered surface dissected by small valley networks (not mapped individually) and troughs. Wrinkle ridges and scarps are present; generally moderate, locally high-relief surface. *Type locality*: lat 19.5° S., lat 347.5° E. *Interpretation*: Materials formed during period of high-impact flux and are likely a mixture of lava flows, pyroclastic material, and impact breccia (Greeley and Guest, 1987; Scott and Tanaka, 1988)

Nm **Mountainous material (Early Noachian)**—Topographically high, rugged, and isolated blocks. *Type locality*: lat 19.5° S., long 349° E. *Interpretation*: Ancient, resistant crustal material uplifted during formation of impact basins (Greeley and Guest, 1987)

CRATER MATERIAL

[Impact craters with rim diameters <2 km not mapped]

c_3 **Well-preserved crater material**—Characterized by pronounced, continuous crater rims elevated relative to surrounding materials, superposed on all surfaces. Well-defined, continuous ejecta blankets are often present. *Type locality*: lat 18.4° S., long 347.87° E. *Interpretation*: Pristine crater material exhibiting little degradation; some crater floors may contain deposits emplaced by mass-wasting, eolian, and (or) fluvial processes

c_2 **Moderately degraded crater material**—Characterized by mostly complex craters (>15 km and exhibiting terraces, central peaks/rings, and (or) flat floors; see Melosh, 1989) possessing subdued crater rims exhibiting minor relief relative to surrounding materials. Crater floors are typically infilled; some crater floors contain chaotic terrain (unit AHct). Partially buried or deflated ejecta blankets occasionally present. *Type locality*: lat 18.8° S., long 345.5° E. *Interpretation*: Impact craters with moderate degree of degradation; most crater floors contain deposits emplaced by mass-wasting, eolian, and (or) fluvial processes

c_1 **Highly degraded crater material**—Characterized by a degraded, incomplete crater rim that exhibits little relief relative to the surrounding materials, a featureless crater floor, and lack of ejecta. *Type locality*: lat 20.5° S., long 347.7° E. *Interpretation*: Highly degraded impact crater material. Ejecta has been completely eroded or mantled by younger materials; rim has been heavily modified by erosion

SYMBOL EXPLANATION

Contact—Dashed where approximately located or gradational. Internal contact distinguishes impact features

Fault—Bar and ball on downthrown block

Wrinkle ridge—Line delineates ridge crest

Scarp—Line marks top of slope; hachures point downslope

Small valley

Channel

Radial grooves in ejecta (schematic)

Crater rim—Showing crest where preserved and defined. Hachures point into crater

Buried or exhumed crater

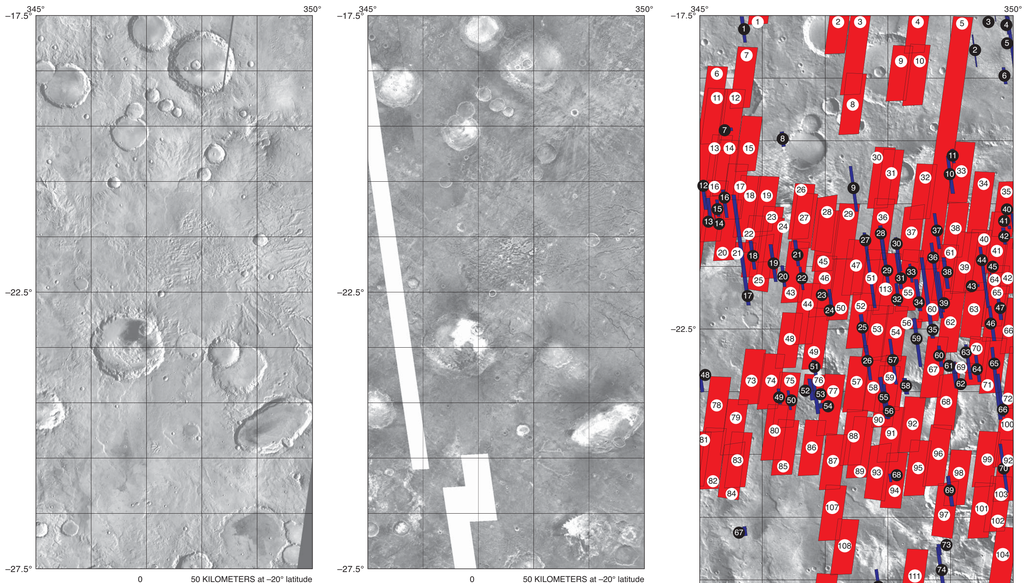
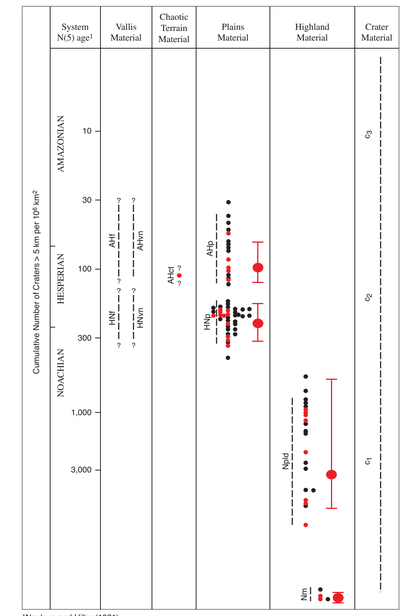


Figure 3. Subframe of global Thermal Emission Imaging System (THEMIS) daytime infrared image mosaic (http://themis.asu.edu) covering MTM –20012 and –25012 quadrangles, Mars (~230 m/pixel resolution; see fig. 1 for regional setting). Solid black swaths indicate gaps in data coverage. Simple cylindrical projection. North towards top of image.

Figure 4. Subframe of global Thermal Emission Imaging System (THEMIS) nighttime infrared mosaic (http://themis.asu.edu) covering MTM –20012 and –25012 quadrangles, Mars (~230 m/pixel resolution; see fig. 1 for regional setting). Some of the plains materials within large crater (unit ANb) display relatively higher nighttime brightness temperatures, whereas some of the valley network (unit HNvn) floors have lower brightness temperatures (see map text for discussion). Solid white swaths indicate gaps in data coverage. Simple cylindrical projection. North towards top of image.

Figure 5. Image showing location of THEMIS Visible (VIS) images in red (resolution of ~18 m/pixel) and Mars Orbiter Camera (MOC) narrow angle (NA) images in blue (generally <10 m/pixel) within MTM –20012 and –25012 quadrangles, Mars (see fig. 1 for regional setting; use location numbers to find image numbers in table 1). Images locally reveal increased detail that helps to define the morphology and limits of various surfaces within the map area. Simple cylindrical projection. North towards top of image. THEMIS VIS and MOC images released June 2007.



[1]Neukum and Hiller (1981)

Figure 6. Summary chart of crater statistics compiled by Grant (1987) for surfaces in MTM –20012 and –25012 quadrangles, Mars (red dots) and adjacent regional surfaces (black dots). The average (red dot) and standard deviation (red line) for counts completed in the map area are indicated to the right of unit data. Vertical dashed black lines represent inferred ages of various vallis materials and are based on crosscutting and embayment relations with plains materials. The uncertainty associated with relative ages for counts within the map area is indicated by question marks. Relative ages inferred for mapped local and more regional surfaces are similar and imply that events distinguished within the map area affected regional surfaces as well. Relative ages were derived from the number of craters >5 km in diameter normalized to 10^6 km^2 and based on comparison to the standard curve published by Neukum and Hiller (1981). Comparison with alternate standard curves (Hartmann and Neukum, 2001) yields broadly similar results.

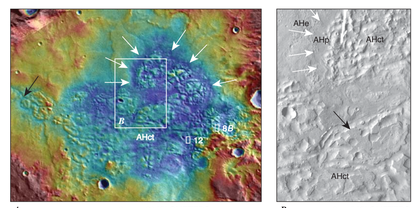


Figure 11. Images showing detail of Paraná Valles in MTM –20012 and –25012 quadrangles, Mars. (***A***) The largest exposure of chaotic terrain material (unit AHct) is located in Paraná basin (see fig. 2 for map location). The north edge of the chaotic terrain material is bound by discontinuous troughs along its margin (white arrows). The head of Loire Valles is located on the west margin of the chaos material (black arrow). The white outline shows the location of figure 11*B*; black oulines show the approximate location of figures 8*B* and 12. MOLA topography (463 m/pixel) over a portion of the Mars Viking MDIM 2.1 mosaic (~231 m/pixel). North to top of image. (***B***) The chaotic terrain is characterized by knobs, linear ridges, and buttes that are separated by narrow troughs and irregular depressions. The trough along the margin of the chaotic unit in Paraná basin (white arrows) is generally 50–100 m deep and 3–7 km wide. Large, discontinuous plateaus in the midst of the chaotic terrain suggest resistant capping material in some locations (black arrow). Subframe of THEMIS VIS images V18461004, V02298003, V10474003, and V06405002. North towards top of image.

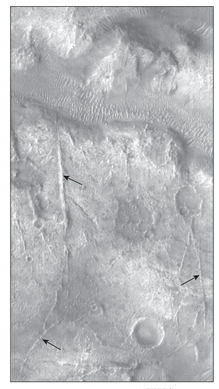


Figure 12 (left). Image showing detail of Paraná Valles in MTM –20012 and –25012 quadrangles, Mars. Plateaus in the chaotic terrain materials (unit AHct) appear stripped and exhibit narrow, crisscrossing dikes (arrows) that consist of apparently more resistant materials. These dikes could mark locations where limited water moving through fractures in the material resulted in alteration and local diagenesis. Many troughs within the chaos materials, such as the trough near top of image (~140 m deep relative to surrounding plateaus), are commonly partially filled with light-toned eolian materials. Subframe of MOC NA image M0900897 (see fig. 11A for location). North towards top of image.

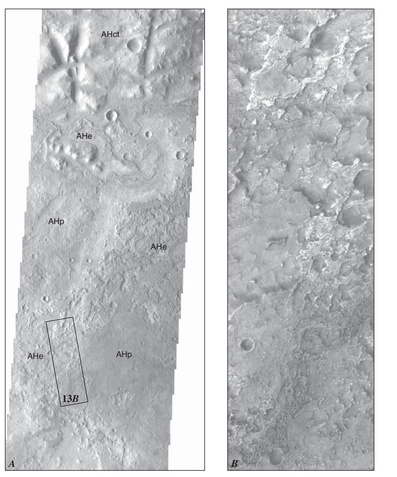


Figure 13. Image showing detail along Paraná Valles in MTM –20012 and –25012 quadrangles, Mars. (***A***) The etched plains material (unit AHe) occurs in patches between the margins of the chaotic terrain materials (unit AHct) in Paraná basin and the adjacent younger plains materials (unit AHp). The etched plains material exhibits dark-toned, somewhat flat mesas and pits exposing light-toned material. Black outline shows location of figure 13*B*. THEMIS VIS image V17837005 (see fig. 2 for map location). North to top of image. (***B***) Detail of the pitted, scabby, and knobby texture of the etched plains material (unit AHe) showing a range of dark- and light-toned materials. Light-toned eolian ridges are common throughout the unit. This complex topography, exposed by eolian stripping of the surface, is consistent with the juxtaposition of materials in alluvial depositional settings. The material may contain (or have contained) less ice than adjacent chaotic terrain materials (unit AHct), thereby leading to differential stripping rather than formation of additional chaos. Subframe of MOC NA E1500848. North towards top of image.

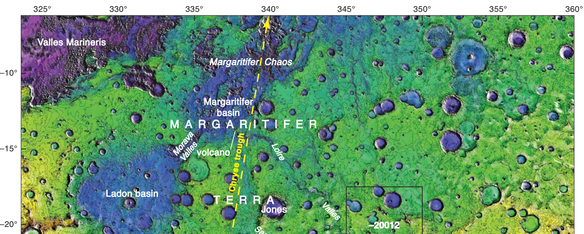


Figure 1. Image showing Margaritifer Terra, within lat 10°–25° S., and long 325°–350° E., which has been greatly modified by fluvial and other geomorphic processes and preserves one of the highest drainage densities of valley networks on Mars. Margaritifer Terra is roughly bisected by the north-south-oriented depression informally called the "Chryse trough" (approximate axis of the Chryse trough indicated by the dashed yellow line), which extends northward from the Argyre impact basin, south of the figure, to the northern plains. Paraná-Loire (PL) and Samara-Himera Valles (SH) drain the east side of the Chryse trough, whereas the Uzboi-Ladon-Morava (ULM) outflow system drains the west side of the trough. The confluence of these drainage systems occurs at the Margaritifer basin near a possible Amazonian-aged volcano. The map area divided into MTM –20012 and –25012 quadrangles (lat 17.5°–27.5° S., long 345°–350° E.) is outlined in black. Image is a display of Mars Orbiter Laser Altimeter (MOLA) topographic data (64 pixels/degree or 926 m/pixel) draped over a portion of the Viking MDIM mosaic. North towards top of image.

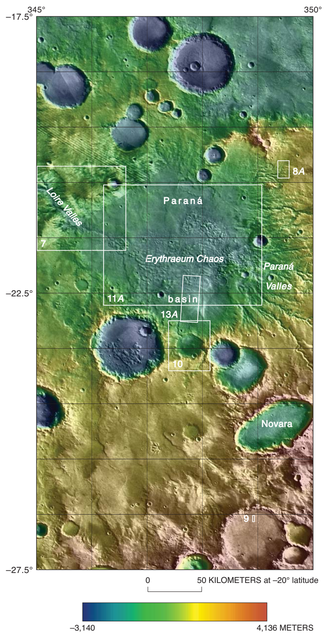


Figure 2. Image showing MOLA topography (463 m/pixel) over a portion of the Mars Viking MDIM 2.1 mosaic (~231 m/pixel) used as the base map for MTM –20012 and –25012 quadrangles (see fig. 1 for regional setting). MOLA data was used to determine elevation relations between mapped landforms and surfaces. The elevation within the map area ranges from roughly –3,100 m to over 1,400 m. A complete description of the MOLA data set can be found in Smith and others (1999). Features in the map area, including Loire Valles, Paraná Valles, Paraná basin, and Novara crater are labeled for reference. White outlines show approximate locations of figures 7, 8*A*, 9, 10, 11*A*, and 13*A*. Simple cylindrical projection. North towards top of image.

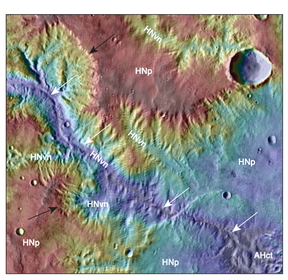


Figure 7 (left). Image of Loire Valles, west of the outlet from Paraná basin (see fig. 2 for map location), composed of valley network materials (unit HNvn) that were fed by numerous small tributary valleys. Most of the surrounding terrain is older plains materials (unit HNp). The deeply incised stem valley in the proximal reach of Loire Valles (white arrows) drains toward the northwest from Paraná basin. Numerous tributaries in the area impart a crenulated appearance to the surface. These tributaries likely incised as the trunk valley downcut in response to discharge from Paraná basin, enabling adjustments toward a more regional base level downstream and an overall widened valley form (boundary shown by black arrows). MOLA topography (463 m/pixel) over a subframe of the Mars Viking MDIM 2.1 mosaic (~231 m/pixel). North towards top of image.

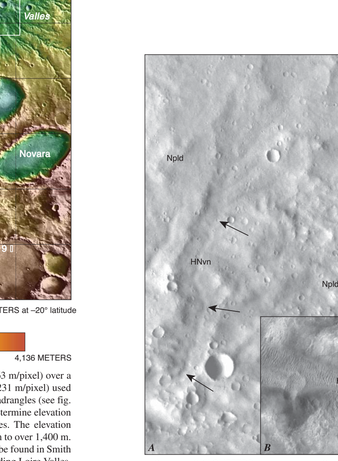


Figure 8. Images showing detail of Paraná Valles in MTM –20012 and –25012 quadrangles, Mars. (***A***) The valleys (unit HNvn) that make up multidigitate, parallel to dendritic valley networks in Paraná and Loire Valles are highly degraded. Very few channels on the valley floors are preserved in the map area, but a muted channel is distinguishable on the floor of a valley in Paraná Valles (arrows). Subframe of THEMIS VIS image V06742003 near lat 20.48° S., long 349.49° E. in Paraná Valles (see fig. 2 for map location). North to top of image. (***B***) Most valley floors in the map area are typically covered with light-toned, eolian ridges. Subframe of MOC image E1302176 near lat 21.92° S., long 348.53° E. in Paraná Valles (see fig. 11*A* for location). North towards top of image.

Figure 9. Enlarged image showing stripped, scabby, and light-toned nature of the bright plains materials (unit ANb) that occurs on the floors of some large craters (see fig. 2 for map location) in MTM –20012 and –25012 quadrangles, Mars. Unit ANb exhibits very high brightness temperatures in the THEMIS nighttime data (fig. 4), which is consistent with exposures of bedrock. Sparse valleys and the lack of nearby volcanic structures suggests the materials are exposed impact melts rather than alluvial, volcanic, or eolian in origin. The few craters present on the bright plains surfaces are highly modified and preclude the determination of a relative age, which suggests they are relatively young. Subframe of MOC R0200723 from crater floor located at lat 26.6° S., long 349° E. North towards top of image.

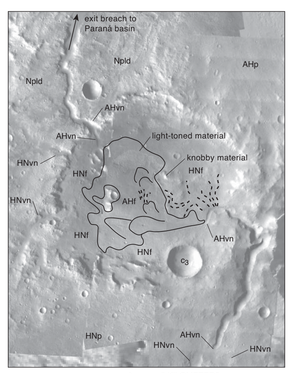
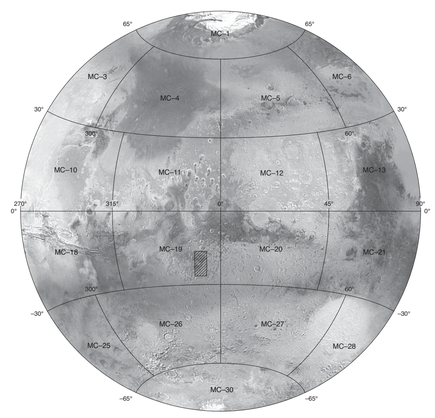


Figure 10. Image showing fan material (units HNf, AHf) on the floor of an unnamed 30-km-diameter crater south of Paraná basin (see fig. 2 for map location) in MTM –20012 and –25012 quadrangles, Mars. Multiple channels (dashed lines) and depositional lobes (solid lines) are preserved on the surface of the deposits. The elevated, oblong portion of the alluvial deposit (HNf, covering ~165 km^2) underlies a younger, sometimes light-toned fan material (unit AHf) in the center of the crater. Rugged knobs associated with this deposit may be remnants from the crater's central peak. An outlet breach in the northwest rim was primarily incised during the older fan (unit HNf) activity and only slightly modified during later activity. Few deposits outside of the crater outlet can be assigned to the younger fan (unit AHf). Subframes of THEMIS VIS images V16614006, V16302005 and V1960005. North towards top of image.



QUADRANGLE LOCATION

Photomosaic showing location of map area. An outline of 1:5,000,000-scale quadrangles is provided for reference.

Geologic Map of MTM –20012 and –25012 Quadrangles, Margaritifer Terra Region of Mars

By

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2009

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