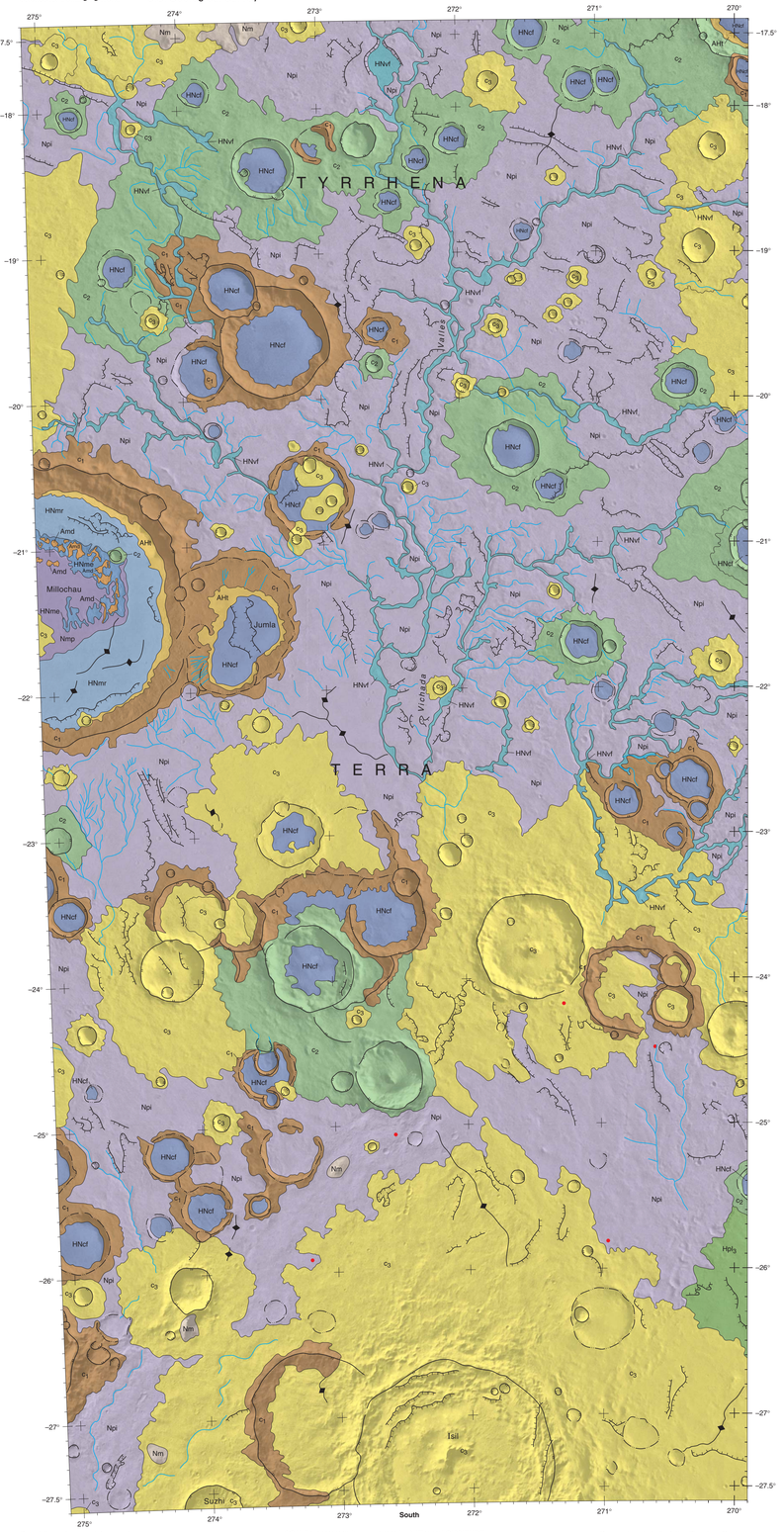
U.S. Department of the Interior
U.S. Geological Survey

Prepared for the
National Aeronautics and Space Administration

Scientific Investigations Map 2934
Atlas Of Mars: MTM –20272 and –25272 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 270° LONGITUDE
TRANSVERSE MERCATOR PROJECTION
20 0 20 40 60 80 100
KILOMETERS

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

Edited by Jan L. Zigler; cartography by Darlene A. Ryan

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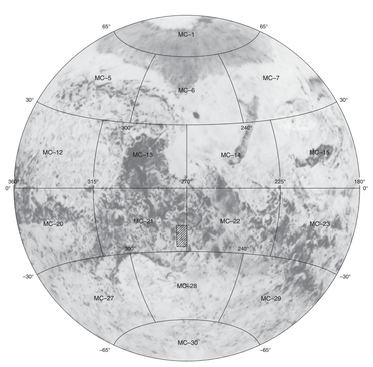

QUADRANGLE LOCATION
Photomosaic showing location of map area. An outline of 1:5,000,000-scale quadrangles is provided for reference.

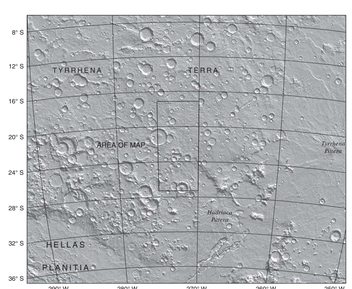

Figure 1. MOLA shaded-relief image showing regional highland terrains north and east of Hellas Planitia and the location of the map area (MTM –20272 and –25272 quadrangles). Image produced using GRIDVIEW software (Roark and others, 2000; Roark and Frey, 2001) and MOLA 32 pixels/degree DEM. North at top; projection, sinusoidal; illumination angle, 40°; azimuth, 30°.

Geologic Map of MTM –20272 and –25272 Quadrangles, Tyrrhena Terra Region of Mars

By
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2006

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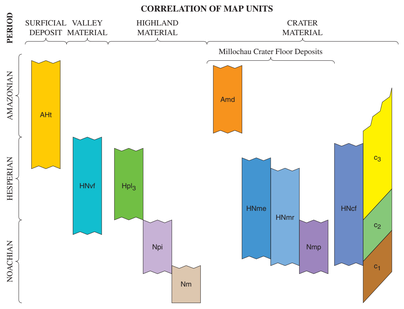
CORRELATION OF MAP UNITS



DESCRIPTION OF MAP UNITS

[Unit descriptions and interpretations are based on morphology, texture, brightness, and stratigraphic position as observed in VO, THEMIS, and MOC images]

SURFICIAL DEPOSIT

AHt — **Talus material (Late Hesperian or younger)**—Narrow deposits found along interior crater walls. Overlies crater floor material. Featureless in VO images; irregular surface textures and layering visible in high resolution MOC images. *Type area*: lat 21.4° S., long 273.8° W. *Interpretation*: Debris shed from crater rim material. Layering may be due to deposition of material in multiple mass-wasting events

VALLEY MATERIAL

HNvf — **Valley floor material (Late Noachian or younger)**—Deposits forming floors of valleys. Appears smooth to pitted in VO images. Dunes or ripples visible in high-resolution MOC images and oriented perpendicular to valley walls. *Type area*: lat 20.5° S., long 272.5° W. *Interpretation*: Sedimentary material derived from surrounding units and deposited within valleys by a combination of flowing water, mass wasting, and eolian processes. Dunes or ripples indicate movement of material along valley floors by eolian activity

HIGHLAND MATERIAL

Hpl5 — **Smooth plateau unit (Late to Early Hesperian)**—Regional unit described by Greeley and Guest (1987) as forming flat, featureless plains that locally embay other units; faults and flow fronts rare. Small surface area exposed in southeast corner of map; smooth to hummocky surface characterized by some wrinkle ridges. Moderately cratered. *Type area*: lat 25.5° S., long 270.3° W. *Interpretation*: Interbedded volcanic and sedimentary deposits of fluvial and (or) eolian origin (Greeley and Guest, 1987)

Npi — **Intercrater plains material (Late to Middle Noachian)**—Irregularly to heavily pitted surface dissected by well-integrated networks of valleys. In MOC images, darker material fills low-lying areas among more heavily cratered and pitted plains and exhibits dune features. In north, numerous scarps; sparse dunes on dark material; heavily cratered surface. South of lat 24° S., fewer channels and scarps than in north; dunes or ripples abundant on dark material and high-standing exposures; moderately cratered surface. *Type areas*: lat 20.7° S., long 272.3° W. (pitted) and lat 25.1° S., long 270.4° W. (dune covered). *Interpretation*: Volcanic and (or) sedimentary deposits subjected to impact and fluvial processes. Valleys believed to be fluvial in origin. Pitted surface results from small (<1 km diam) poorly preserved impact craters. Dunes or ripples result from redistribution of sediments within plains by wind. Pitted material (concentrated in north) previously mapped as hilly and cratered material by Schaber (1977) and dissected plateau material by Greeley and Guest (1987); smoother material located in south previously mapped as dark mottled plains material by Schaber (1977) and ridged plains material by Greeley and Guest (1987)

Nm — **Mountainous material (Middle to Early Noachian)**—Forms small isolated massifs within younger units. *Type area*: lat 17.6° S., long 273.6° W. *Interpretation*: Ancient crustal material uplifted during formation of impact basins and large craters (Greeley and Guest, 1987)

CRATER MATERIAL

[Impact craters with rim diameters <3 km not shown; crater material includes floor deposits that postdate crater formation]

Millochau Crater Floor Deposits

Amd — **Millochau dune material (Early Amazonian or younger)**—Forms deposits that fill pits, small craters, and depressions within pitted material (unit Nmp) and forms dune fields that cover large areas within etched material on floor of Millochau. Generally darker than underlying material in MOC images. Consists of long- and short-wavelength (40–170 km and 10–30 km, respectively) dunes or ripples. Long-wavelength dunes or ripples are generally oriented east-west and span widths of depressions in which they occur. Short-wavelength dunes or ripples are shorter and narrower than long-wavelength dunes; dunes oriented parallel and, less commonly, perpendicular to long-wavelength dunes and typically oriented perpendicular to slopes of local topographic highs. *Type area*: lat 21.3° S., long 274.4° W. *Interpretation*: Sedimentary material eroded from interior floor deposits of Millochau and redistributed within low-lying areas by wind to form dunes or ripples

HNme — **Millochau etched material (Late Hesperian to Middle Noachian)**—Forms surfaces within depressions that border central plateau of Millochau. Displays smooth, lineated, and irregular surface textures and variations in brightness in MOC and THEMIS images. Comprises layers of different thickness exposed along scarps and knobs. Unit contains few fresh impact craters, and some craters appear to have been exhumed. Found adjacent to units Nmp and HNmr. *Type area*: lat 21.2° S., long 274.5° W. *Interpretation*: Crater floor material undergoing erosion and redistribution; locally, removal of overlying material appears to reveal surfaces that once accumulated craters. Deposits consist of interlayered sedimentary, volcanic, and (or) impact material that has undergone collapse and (or) been eroded by fluvial, eolian, and mass wasting processes. Some deposits derived from adjacent interior deposits. Overlain by small scattered deposits of dune material (unit Amd)

HNmr — **Millochau rugged material (Late Hesperian to Middle Noachian)**—Consists of deposits covering the floor of Millochau and surrounding the central plateau; extends from depressions that border the plateau to base of inner rim of Millochau. Forms irregular surface that displays numerous degraded craters (<1 km diam) and pits similar to pitted material (unit Nmp). Contains numerous low-relief scarps that appear to act as boundaries between materials with different brightness. Locally, layering exposed along scarps that form boundaries of closed depressions. *Type area*: lat 20.8° S., long 274.8° W. *Interpretation*: Deposits consisting of interlayered sedimentary, volcanic, and impact materials. Sedimentary material could be material eroded from interior crater walls, eolian deposits, or lacustrine deposits. Pits may be collapse features, degraded craters, or wind-modified depressions. Scarps may be erosional (fluvial and (or) eolian), tectonic (collapse or faulting), or possibly a deposit margin

Nmp — **Millochau pitted material (Late to Middle Noachian)**—Covers central plateau of Millochau and exhibits heavily pitted and cratered surface. Most craters and pits have diameters < ~1 km. Surface exhibits variations in brightness that correspond to different degradational states; dark material is more rugged and contains more pits and small craters than bright material, and craters and pits in dark material are more degraded; dark material is locally a few meters lower in elevation than bright material. Layering is exposed along scarp that defines north and east edges of plateau. *Type area*: lat 21.3° S., long 274.7° W. *Interpretation*: Deposits consisting of interlayered sedimentary, volcanic, and impact materials. Sedimentary material could be material eroded from interior crater walls, eolian deposits, or lacustrine deposits. Pits may be collapse features, degraded craters, or wind-modified depressions. Bright material represents upper surface of pitted material that is being eroded, exposing dark substrate, lag deposits, or sediments that accumulated in local low-lying areas.

Other Crater Deposits

HNcf — **Crater floor material (Late Hesperian to Middle Noachian)**—Exhibits smooth surfaces on crater floors in VO images and rugged surfaces in MOC images; some deposits display lobate margins against interior crater walls. *Type area*: lat 19.7° S., long 273.4° W. *Interpretation*: Sedimentary material deposited on crater floors due to erosion of crater rims and eolian activity. Deposits within breached craters are partially derived from material outside crater rim. Floor deposits may be partially lacustrine. Some craters may contain units similar to those mapped in Millochau that we are unable to distinguish at available image resolutions

c_3 — **Well-preserved crater material (Early Hesperian or younger)**—Characterized by pronounced, continuous crater rim elevated relative to surrounding material and by well-defined, continuous ejecta blanket. *Interpretation*: Pristine impact crater material exhibiting little degradation. Some crater floors may contain deposits emplaced by mass wasting, eolian activity, and (or) fluvial processes

c_2 — **Moderately degraded crater material (Early Hesperian to Middle Noachian)**—Characterized by a crater rim that may exhibit only minor relief above surrounding material and by discontinuous, poorly exposed ejecta. *Interpretation:* Impact craters with moderate degree of degradation. Most crater floors contain deposits emplaced by mass wasting, eolian activity, and (or) fluvial processes

c_1 — **Highly degraded crater material (Late to Early Noachian)**—Characterized by a degraded crater rim that may be discontinuous and exhibits little relief relative to the surrounding material; displays no ejecta and contains smooth, featureless crater floors in VO images. *Interpretation*: Highly degraded impact crater material. Ejecta has been completely eroded or mantled by younger material; rim has been modified by erosion. Most crater floors contain deposits emplaced by mass wasting, eolian activity, and (or) fluvial processes

Contact—Internal contact provides relative age relations between crater materials, where visible

Ridge crest

Scarp—Hachures point downslope

Channel

Crater rim crest—Hachures point into crater

Degraded crater rim crest

Location of MOC image containing dune field

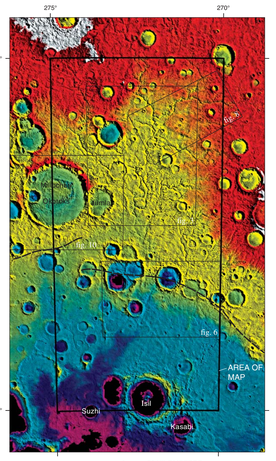


Figure 2. Viking MDIM 2.0 photomosaic merged with MOLA elevation data (lat 16.5°–28.5° S., long 268°–276° W.; 32 pixels/degree DEM). The photomosaic provides a regional view of the topography within and surrounding the map area, which slopes gradually to the south toward Hellas Planitia; however, the terrain drops ~600 m (approximately along dashed line), and this elevation change is traceable east and west of the map area. Most valleys in the map area are within an elevation range of ~1.5–2.5 km, but some tributaries head at higher elevations. Locations of figures 3, 6, 8, and 10 are shown. North at top; image centered at lat 22.52° S., long 271.61° W.; projection, Mercator; illumination from upper right.

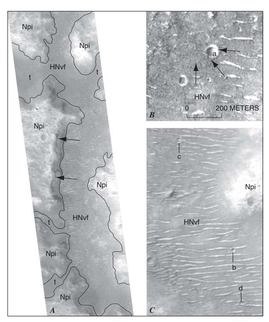


Figure 5. MOC image M08-02977 (*A*) shows part of the trunk valley and some tributaries (t) of Vichada Valles within the intercrater plains (unit Npi). Layers or terraces are exposed along the east-facing wall of the trunk valley (arrows) indicating stratigraphy within the plains material and (or) evidence of flow events. Most valleys in the map area contain valley floor material (unit HNvf), which commonly consists of sediments remobilized to form parallel sets of dunes oriented orthogonal to valley walls (*A–C*). Crosscutting relations between impact craters and dunes are shown in *B* and *C*. In *B*, ejecta (arrows) from an ~80-m-diameter crater (a) superposes dunes and, in *C*, crater b appears to bisect a dune, whereas craters c and d are superposed by dunes. North is to the top in each image. M08-02977 (*A*): image centered at lat 20.7° S., long 272.8° W.; image width, 2.88 km; resolution, 2.81 m/pixel. M04-02305 (*B*): image centered at lat 19.1° S., long 271.5° W.; image width, 2.16 km; resolution, 2.82 m/pixel. M19-00428 (*C*): image centered at lat 19.2° S., long 272.1° W.; image width, 1.44 km; resolution, 2.82 m/pixel. Illumination from left for *A–C*; images from NASA/JPL/MSSS (available at http://www.msss.com/). See figures 2 and 3 for figure location.

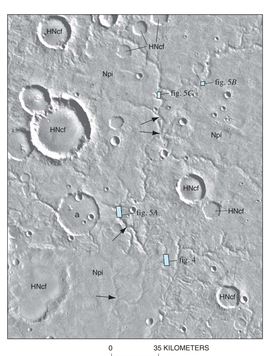


Figure 3. Part of Viking photomosaic of MTM –20272 quadrangle showing the intercrater plains (unit Npi), which are characterized by a smooth to irregular surface dissected by large-scale, well-incised valley networks and contain many impact craters exhibiting various degrees of preservation. In several places and at different scales, the main trunk valley of Vichada Valles splits and rejoins downstream (arrows). The image also shows a large crater (a; 34 km diam) that is breached along its west rim by an inlet valley and along its southeast rim by an outlet valley. Most craters in the map area contain deposits of crater floor material (unit HNcf), presumably consisting of material eroded from the crater rim, deposited by eolian processes, or deposited via fluvial or lacustrine processes as in the case of crater a. Locations of figures 4 and 5*A–C* are shown. North at top; image centered at lat 20° S., long 272.2° W.; illumination from upper right. See figure 2 for figure location.

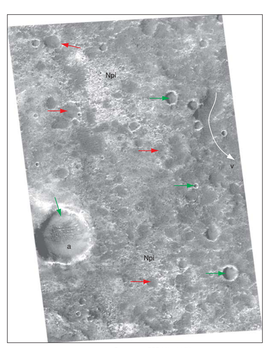


Figure 4. MOC image M04-00851 showing typical intercrater plains material (unit Npi). The plains display a surface pockmarked with many small (<1 km diam) degraded craters with morphologies ranging from visible rims and some infilling (green arrows) to little or no rims and almost completely filled interiors (red arrows). Most low-lying areas, such as craters, valleys (v; white arrow points downstream), and other depressions, are filled with dark sediments that generally form dunes, such as in crater a. North at top; image centered at lat 21.4° S., long 272.1° W.; image width, 2.88 km; resolution, 1.41 m/pixel; illumination from left; image from NASA/JPL/MSSS (available at http://www.msss.com/). See figures 2 and 3 for figure location.

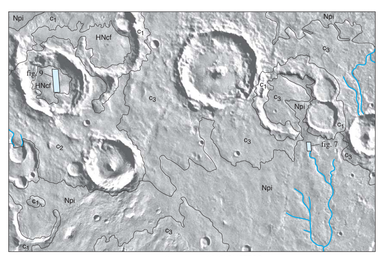


Figure 6. Part of Viking MTM –25272 quadrangle photomosaic showing major geologic contacts and valleys (blue). Intercrater plains (unit Npi) appear subdued compared to exposures in the north (fig. 3). The southeast corner of the image shows one of the best examples of fluvial activity preserved in the southern part of the map area. These valleys are shallower than those in the north, possibly due to a greater amount of eolian infilling (fig. 7). The locations of figures 7 and 9 are shown. North at top; image centered at lat 24.5° S., long 271.5° W.; illumination from upper right for most of image and from upper left for bottom center of image. See figure 2 for figure location.

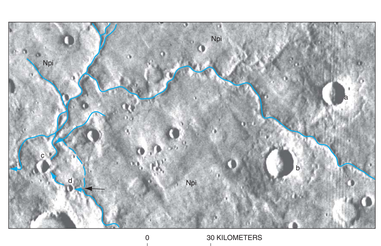


Figure 8. View of Vichada Valles and its tributaries (solid blue lines with arrows pointing in the presumed direction of flow) showing cross-cutting relations with impact craters in intercrater plains (unit Npi). Two large craters on the right side of the image (a, b) show ejecta blankets that are either (1) eroded by an incised valley or (2) mantle a pre-existing valley. At the available image resolution, it is not clear whether ejecta material is present on the valley floor. There is no evidence for ponding or diverting of this valley, suggesting that fluvial processes were active before crater formation or that fluids moved easily through the valley following ejecta emplacement. Near the left edge of the image, craters c (6 km diam) and d (3 km diam) bisect a tributary of Vichada Valles. The presence of a shallow valley to the east that connects deeper segments of this tributary upstream and downstream of these craters suggests flow may have been diverted (black arrow) via the course shown by the dashed blue line. VO image 625A25: north toward upper right corner; image centered at lat 18.5° S., long 271° W.; resolution, 239.82 m/pixel; illumination from right. See figure 2 for figure location.

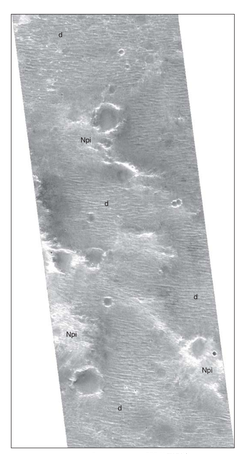


Figure 7. MOC image M11-03386 shows that the subdued appearance of the southern intercrater plains material (unit Npi) appears to be caused by a thin mantle of sediments. Dark sediments mantle and subdue the irregular surface texture formed by high-standing remnants of intercrater plains material typically seen to the north, bury many small craters and pits, and form dune fields (d). North at top; image centered at lat 24.5° S., long 270.6° W.; image width, 1.43 km; resolution, 2.80 m/pixel; illumination from upper left; image from NASA/JPL/MSSS (available at http://www.msss.com/).

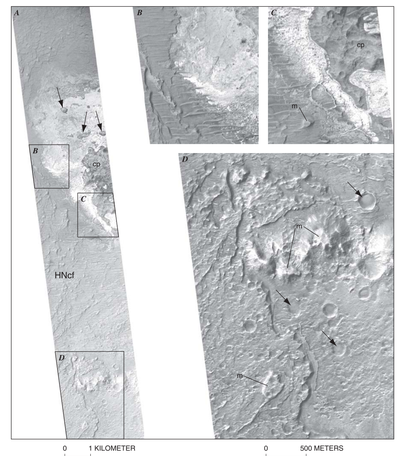


Figure 9. MOC image E16-01083 (*A*) showing crater floor material (unit HNcf) within a 36-km-diameter crater at lat 23.5° S., long 273.5° W. Crater floor material exhibits irregular surfaces and layering is visible in close-ups *B–C*. A rugged and cratered plateau (cp), located just northeast of this crater's center, is visible in *C* and is surrounded by very bright deposits (*B*, *C*) that appear to embay the plateau or were exposed upon erosion of the rugged surface. Possible outliers of the plateau are also visible in image *A* (arrows). Surrounding and apparently overlying the bright material are layered deposits that display irregular surfaces (*B–D*); some layers were eroded to form mesas (m; see *C*, *D*) and reveal exhumed craters (arrows in *D*). Dunes observed in *B* and *C* superpose the bright and layered material. Close-ups *B–D* are shown at the same scale. Image *A* centered at lat 23.9° S., long 273.3° W.; image width, 3.03 km; resolution, 2.95 m/pixel; illumination from upper left; image from NASA/JPL/MSSS (available at http://www.msss.com/).

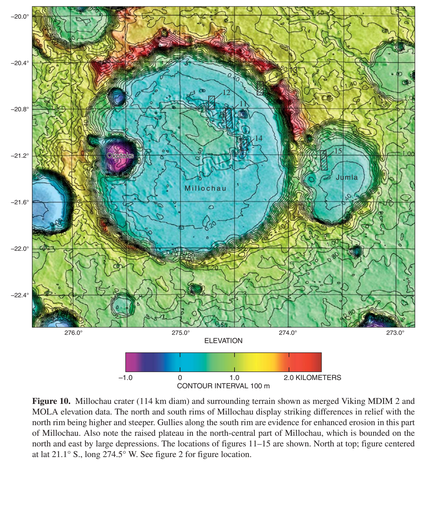
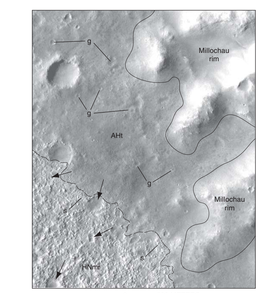


Figure 10. Millochau crater (114 km diam) and surrounding terrain shown as merged Viking MDIM 2 and MOLA elevation data. The north and south rims of Millochau display striking differences in relief with the north rim being higher and steeper. Gullies along the south rim are evidence for enhanced erosion in this part of Millochau. Also note the raised plateau in the north-central part of Millochau, which is bounded on the north and east by large depressions. The locations of figures 11–15 are shown. North at top; figure centered at lat 21.1° S., long 274.5° W. See figure 2 for figure location.



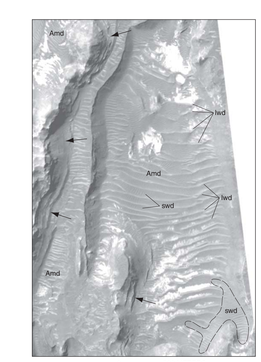


Figure 14. Part of MOC image M18-00592 showing both long- and short-wavelength dunes visible in one of the larger exposures of dune material (unit Amd) in Millochau. Long-wavelength dunes (lwd) are typically oriented east-west and span the widths of the depressions in which they occur. Short-wavelength dunes (swd) occur at all orientations, typically forming perpendicular to topographic highs, such as at the base of the layered knobs (arrows). Short-wavelength dunes also form perpendicular to the long-wavelength dunes as seen in the center of the image. North at top; image centered at lat 21.17° S., long 274.4° W.; image width, 2.8 km; resolution, 2.81 m/pixel; illumination from left; image from NASA/JPL/MSSS (available at http://www.msss.com/). See figures 2 and 10 for figure location.

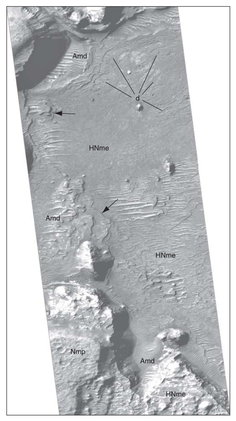


Figure 11. Part of MOC image E01-01209 showing lineated (middle) and irregular (bottom) Millochau etched (unit HNme), pitted (unit Nmp), and dune (unit Amd) materials. Lineated etched material contains positive relief features that connect patches of smooth material with similar albedo. Orthogonal lineations form irregularly shaped polygonal depressions (d); some depressions are filled with bright material and (or) dune material. Step-like layers (arrows), exposed at the center, suggest portions of the Millochau interior deposits are composed of relatively thin layers of easily eroded material. Millochau dune material, found along the edges of scarps and knobs, mantles the etched material. North at top; image centered at lat 20.9° S., long 274.6° W.; image width, 2.9 km; resolution, 2.82 m/pixel; illumination from left; image from NASA/JPL/MSSS (available at http://www.msss.com/). See figures 2 and 10 for figure location.

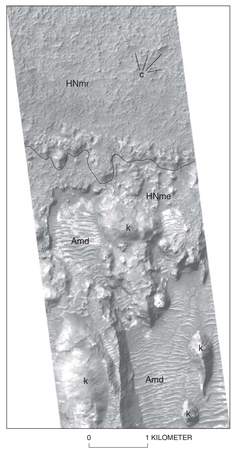


Figure 12. Part of MOC image M19-01414 showing Millochau rugged (unit HNmr) and etched (unit HNme) materials; a black line shows the contact between these units. Typical rugged material found within Millochau has a stucco-like texture and contains impact craters (c) that are heavily degraded. Etched material is irregular and contains several large knobs (k). Dune material (unit Amd) fills low areas of the etched material. North at top; image centered at lat 20.7° S., long 274.7° W.; image width, 2.8 km; resolution, 2.81 m/pixel; illumination from upper left; image from NASA/JPL/MSSS (available at http://www.msss.com/). See figures 2 and 10 for figure location.

Figure 13 (left). Part of MOC image R04-01308 showing the contact (dashed line) between the smoother talus material (unit AHt) and the irregular rugged material (unit HNmr) near the base of Millochau's inner wall (rim, right side of image). At some locations the contact is represented by a low-relief scarp (s), whereas in most places the contact is gradational. Craters within rugged material are being exhumed as talus material is being removed, which is shown by the presence of numerous ghost craters (g) within the talus deposit. North is to the top; image centered at lat 20.7° S., long 274.2° W.; image width, 3.02 km; resolution, 2.952 m/pixel; illumination from left; image from NASA/JPL/MSSS (available at http://www.msss.com/). See figures 2 and 10 for figure location.

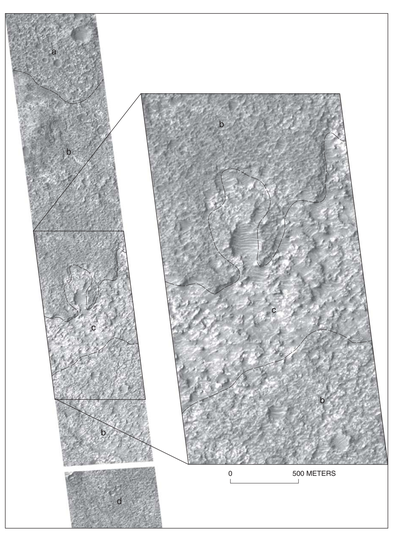


Figure 15. MOC image E04-02035 showing talus material (unit AHt) at the base of the inner rim of Jumla, a 43-km-diameter crater that adjoins the east rim of Millochau. Talus material displays several surfaces (a–d) that appear to reflect different amounts of erosion. Surface a appears to be the uppermost layer in this sequence and displays distinct, yet degraded, crater forms. Surface b also displays degraded craters (see close-up), which are less distinct than those on surface a. Surface c (see close-up) contains knobs and mesas that could be remnants of surfaces b or d. Surface d, separated by a data gap, contains mostly small degraded craters and appears the least eroded of the surfaces. Dune forms, visible in the close-up, are found in the low-lying areas of surfaces b and c, suggesting eroded sediments have been remobilized within this crater. North at top; image centered at lat 21.7° S., long 273.9° W.; image width, 1.45 km; resolution, 2.83 m/pixel; illumination from left; image from NASA/JPL/MSSS (available at http://www.msss.com/). See figures 2 and 10 for figure location.

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