

Descriptions of nomenclature used on map are listed at <http://planetaryscience.org/units>.
Elevations are based on topography derived from the Mars Orbiter Laser Altimeter (MOLA) data (463 meters/pixel), an artificially illuminated MOLA hillshade (illumination from northwest), and a Thermal Emission Imaging System (THEMIS) daytime infrared image (IR) mosaic (100 meters/pixel).

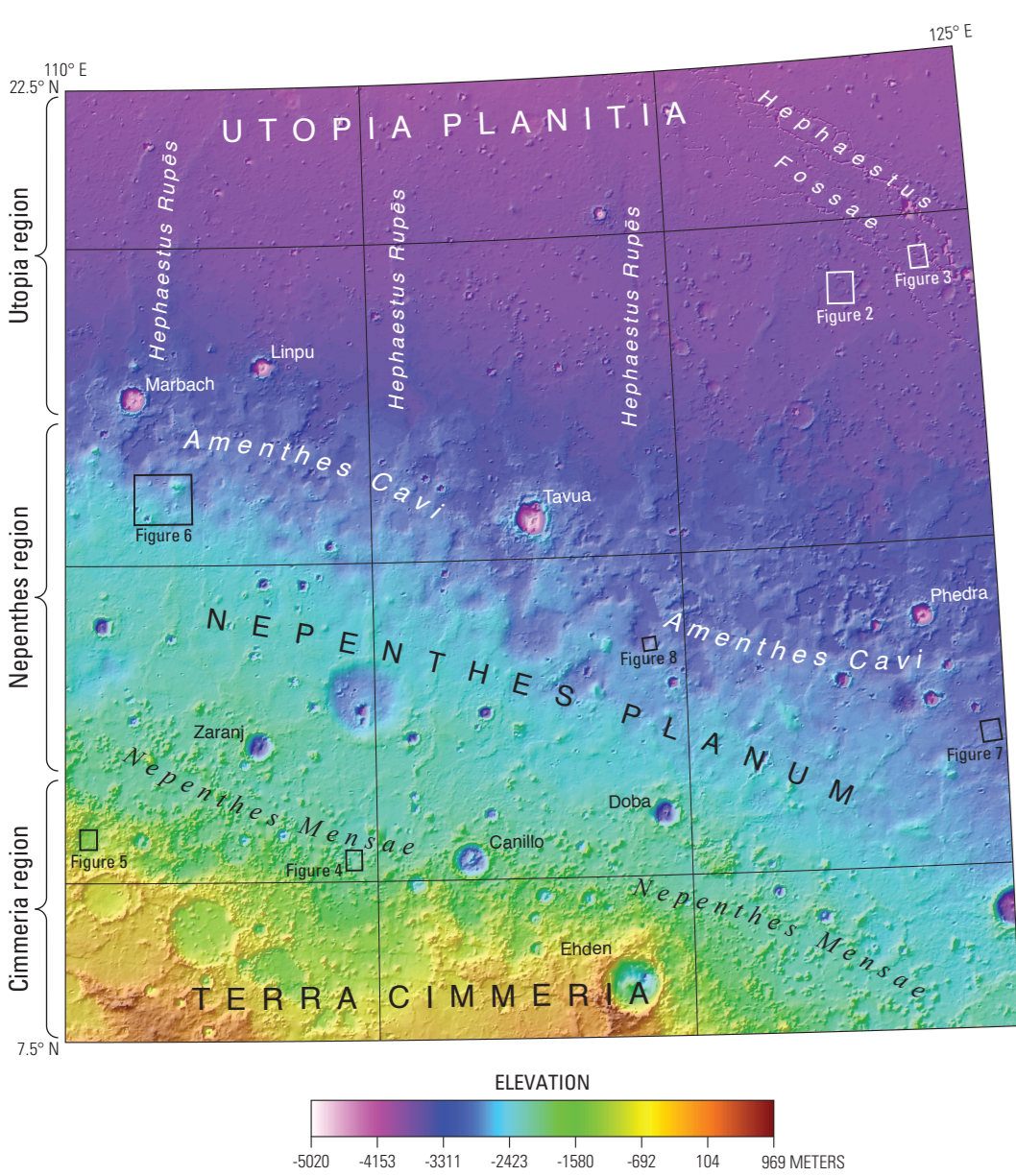


Figure 1. Color shaded-relief image of the Nepenthes Planum region of Mars. Geologic units grouped in this map are based on regions indicated on the left. Constructed from a digital elevation model of Mars Orbiter Laser Altimeter (MOLA) data (463 meters/pixel), an artificially illuminated MOLA hillshade (illumination from northwest), and a Thermal Emission Imaging System (THEMIS) daytime infrared image (IR) mosaic (100 meters/pixel).

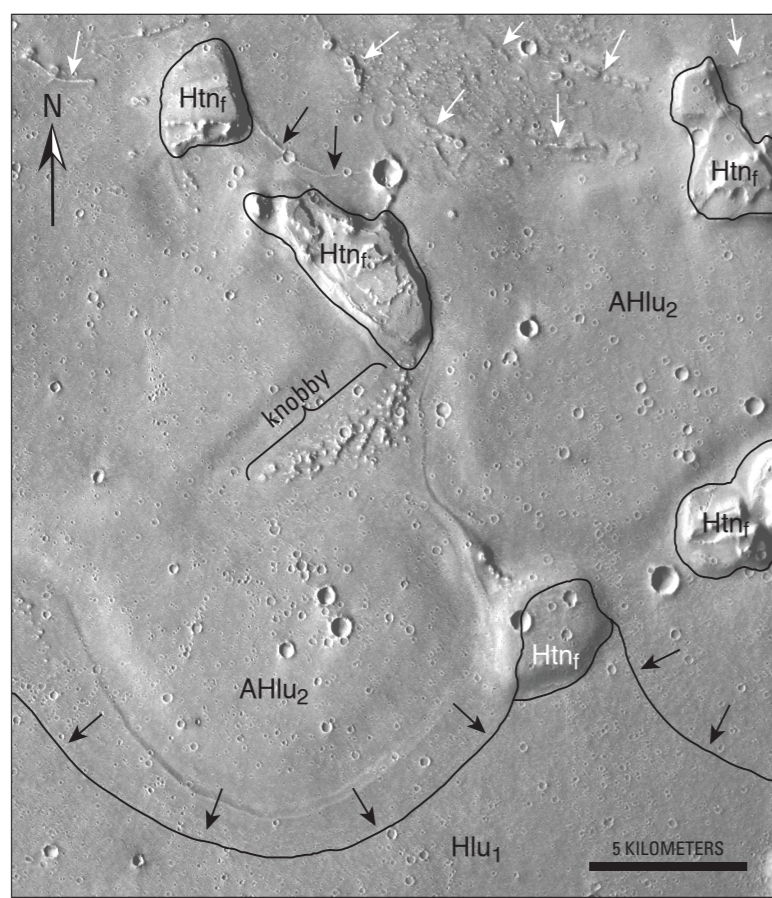


Figure 2. Image showing landforms associated with the southern margin of the Utopia lowland 2 unit (Ahtu2). South-facing lobes (black arrows) overlap and surround low-relief topographic promontories, which are mapped and interpreted as erosional vestiges of the Nepenthes flow unit (Hhtf). Narrow, arcuate ridges have similar orientations as the marginal lobes but are commonly made up of small diameter pitted cones (white arrows). The cones locally form a dense field, particularly on the south side of knobs labeled 'Snobby'.

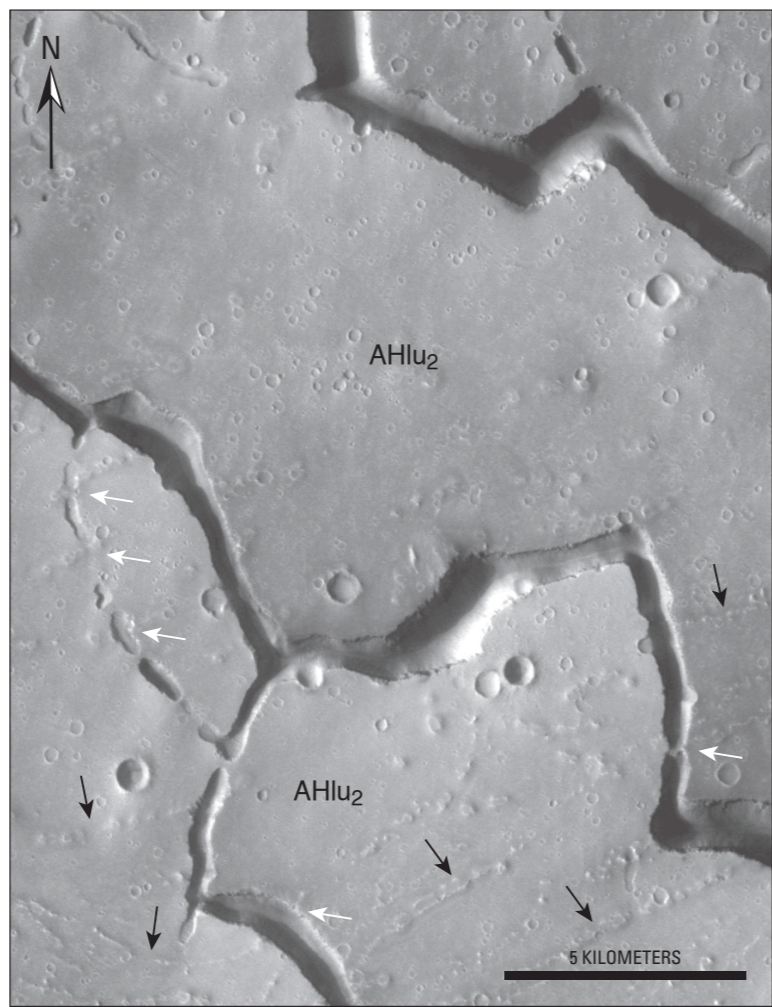


Figure 3. Image showing an example of the troughs of Hephaestus Fossae in the northeastern part of the map region. The troughs occur in the Utopia 2 unit (Ahtu2). Small pitted cones are common, where they are either isolated or grouped into narrow, arcuate ridges (black arrows). Ridges of small pitted cones are aligned on either side of shallow, narrow depressions (white arrows), providing evidence that these cones and narrow, arcuate ridges pre-date the formation of Hephaestus Fossae. Except of Thermal Emission Imaging System image number V2667039 (centered at lat 19.43° N, long 124.27° E; location shown on map).

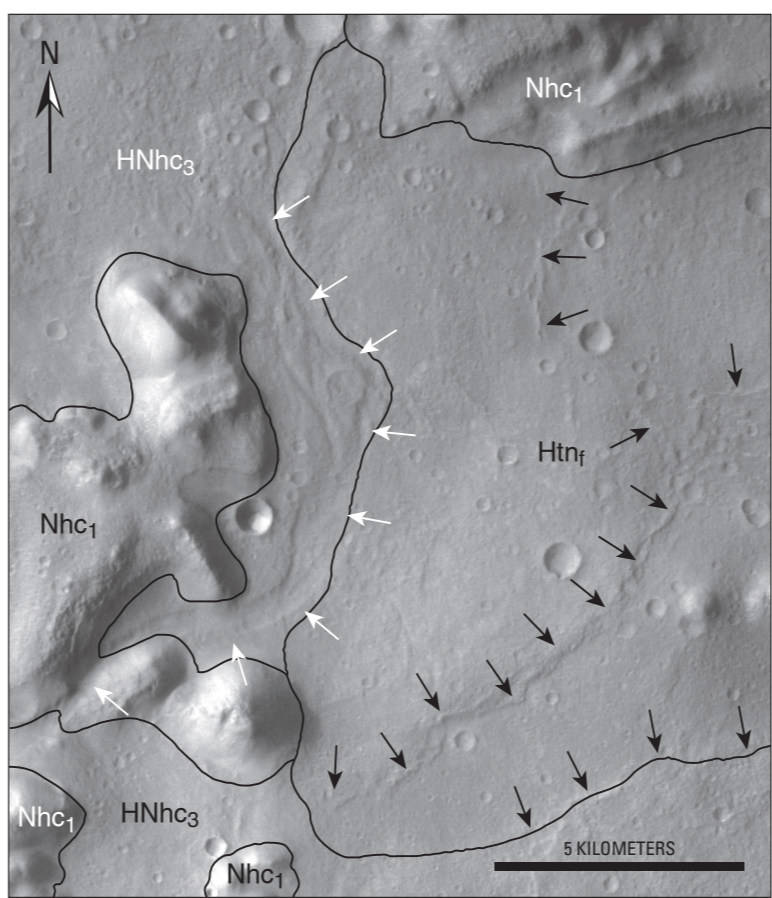


Figure 4. Image showing braided, sinuous channels in the Cimmeria 3 unit (Hhtc3) overcutting Nepenthes Mensae and Terra Cimmeria. We interpret the braided channels (white arrows) as inverted channels formed by the erosion of unit Hhtc3, which here forms the floor of a 25-kilometer-diameter irregularly shaped basin. Unit erosion Hhtc3 and Hhtf, which characteristically contains lobate scarps (black arrows). The lobate scarps (black arrows) are characteristic of unit Hhtf. Facies of Thermal Emission Imaging System image number V27416032 (centered at lat 10.26° N, long 114.57° E; location shown on map).

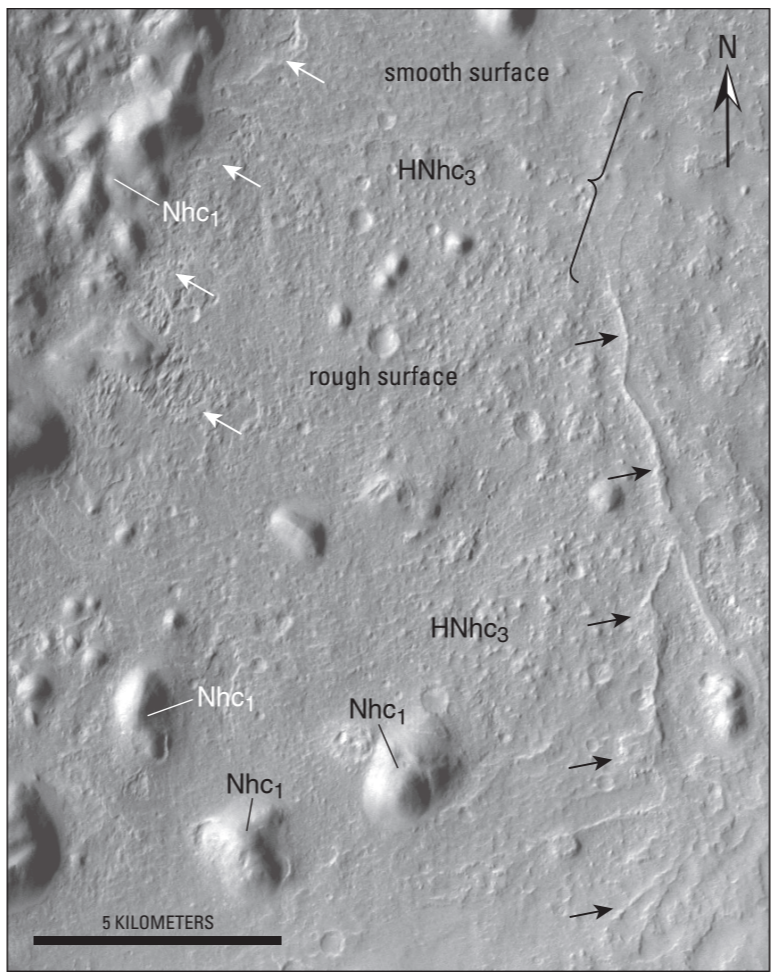


Figure 5. Image showing raised sinuous ridges and depression in the Cimmeria 3 unit (Hhtc3). We interpret the raised ridges (black arrows) as inverted channels formed by the erosion of unit Hhtc3, which here forms the floor of a 25-kilometer-diameter irregularly shaped basin. Unit erosion Hhtc3 and Hhtf, which characteristically contains lobate scarps (black arrows) suggestive of flow-like emplacement. Unit Hhtf contains smooth and rough surface textures, which we interpret as differentially eroded material and (or) post-emplacment modification. The Utopia 1 unit (Ahtu1) occurs as sinuous material that occupies Amnethes Cavi, which are commonly bounded by narrow trough (white arrows) interpreted to be features. Note the occurrence of a large pitted cone along these subbed grooves, suggesting these grooves are the surface expression of fractures that served as pathways for erupted material. Excerpt of Thermal Emission Imaging System image mosaic (centered at lat 10.65° N, long 111.50° E; location shown on map).

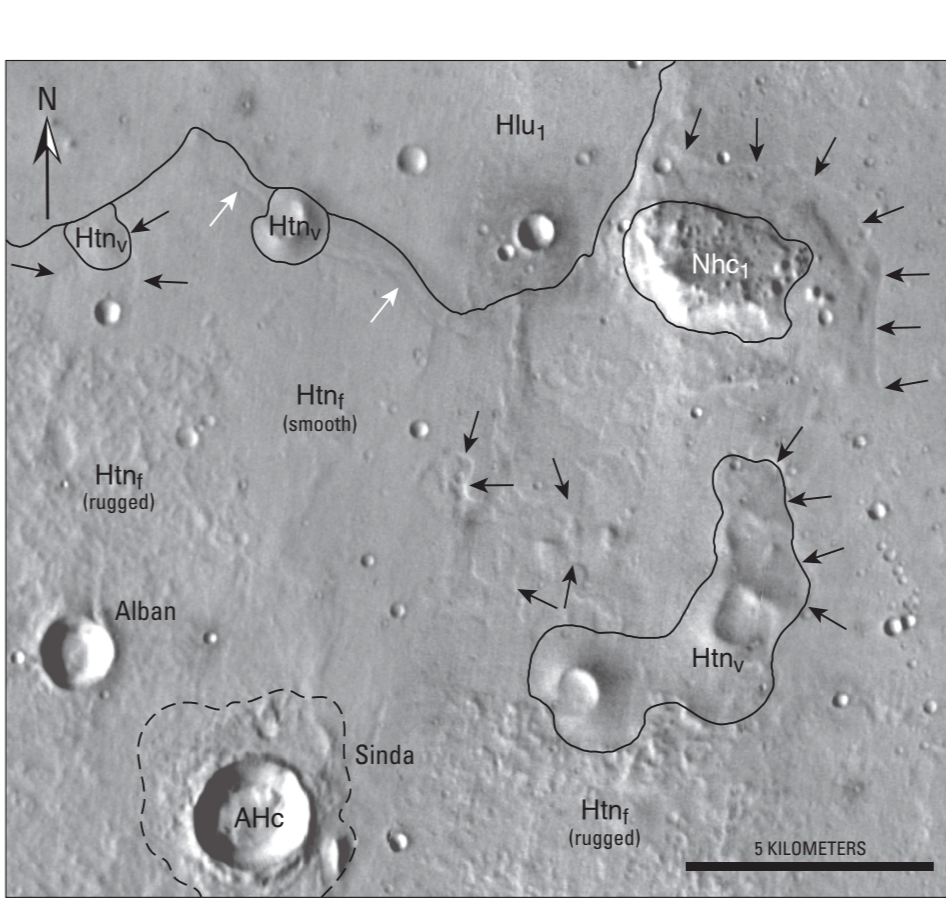


Figure 6. Image showing complexly overlapping lobate materials and source vents located between Nepenthes Mensae and Terra Cimmeria. We interpret these features as eruptive vents for the surrounding Nepenthes flow unit (Hhtf), which characteristically contains lobate scarps (black arrows). We interpret the small flow as mud volcano-like constructs formed through the vertical and (or) horizontal contraction of fluid-rich sediments (Tanaka and others, 2000b; Skinner and Tanaka, 2007; Skinner and Mazzini, 2009). Alternatively, these features may have been formed by igneous volcanism, as posited by Brož and Haber (2013). Excerpt of Thermal Emission Imaging System image mosaic V27501026 (centered at lat 11.88° N, long 124.90° E; location shown on map).

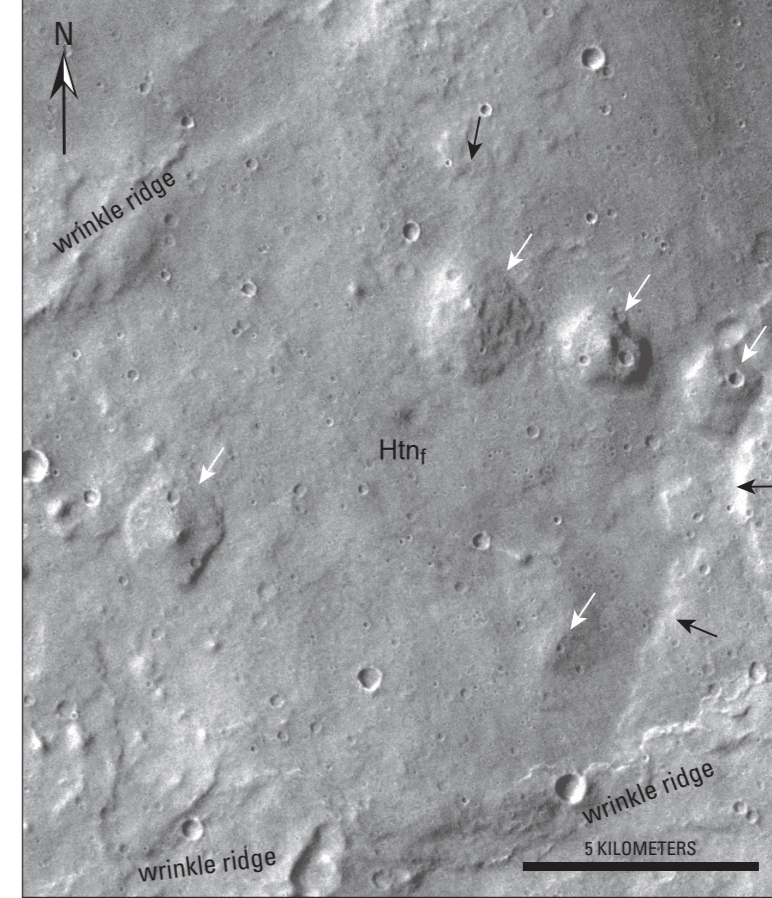


Figure 7. Image showing small tholi (mounds) located in Nepenthes Planum. Mounds (white circles) have conical planimetric shape and commonly have small cone-shaped landforms at their apes. Mounds are often associated with crumpled (wrinkled) ridges and lobate scarps (black arrows). We interpret the small tholi as mud volcano-like constructs formed through the vertical and (or) horizontal contraction of fluid-rich sediments (Tanaka and others, 2000b; Skinner and Tanaka, 2007; Skinner and Mazzini, 2009). Alternatively, these features may have been formed by igneous volcanism, as posited by Brož and Haber (2013). Excerpt of Thermal Emission Imaging System image mosaic V27501026 (centered at lat 11.88° N, long 124.90° E; location shown on map).

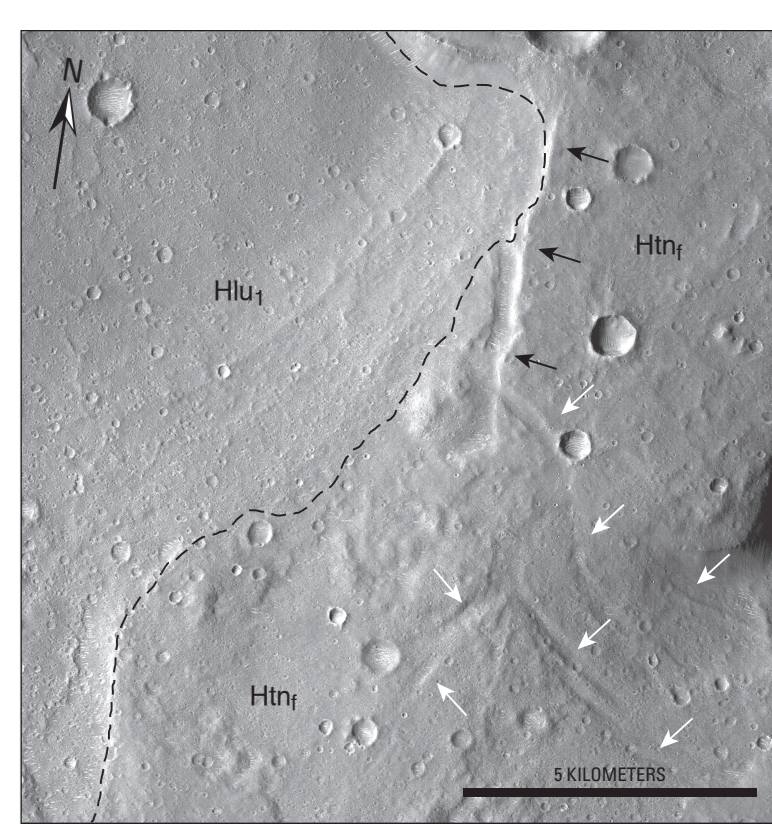
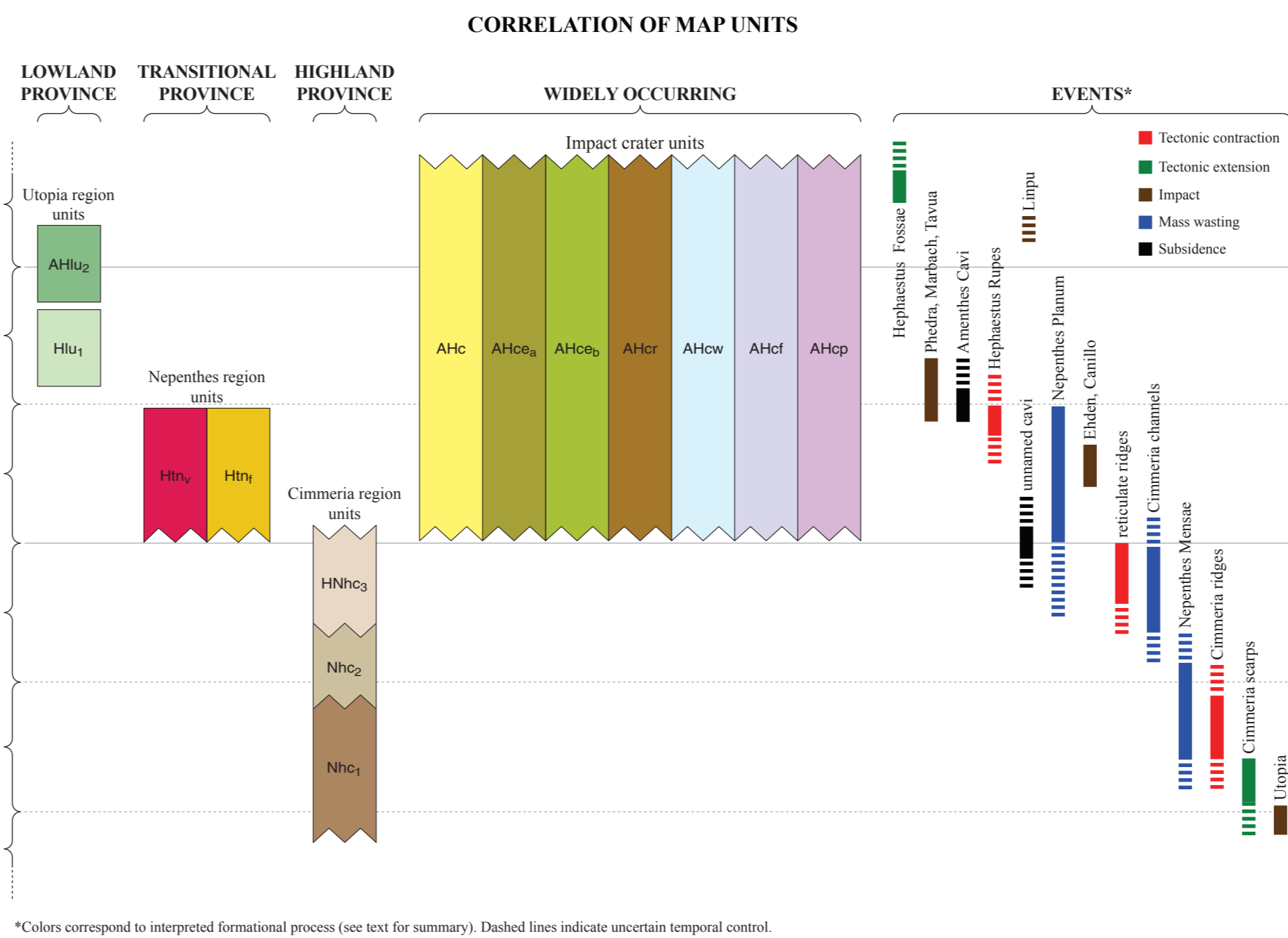


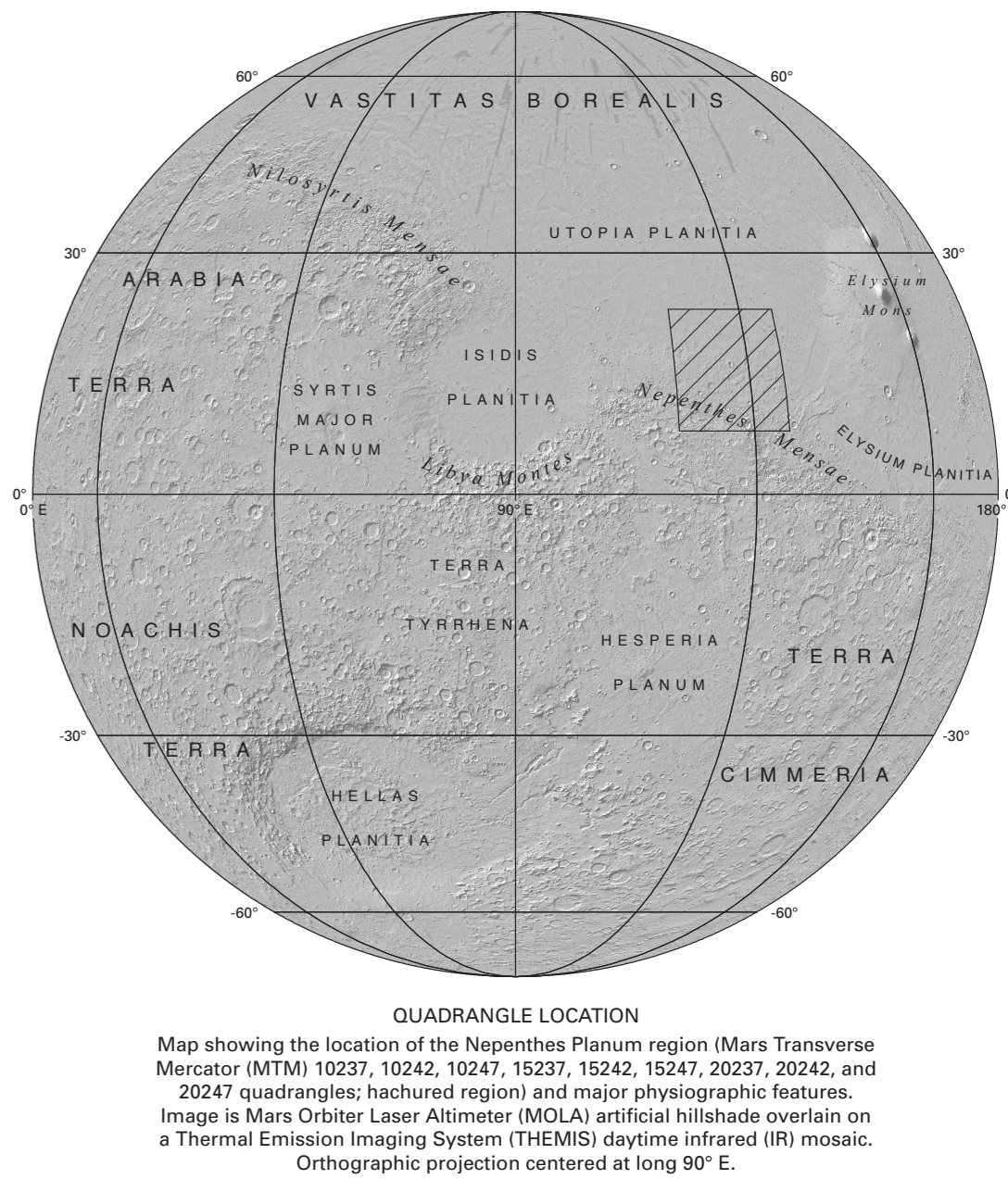
Figure 8. Image showing an example of the narrow troughs (black arrows), which commonly bound Amnethes Cavi. We interpret these as fractures that occur in the Nepenthes flow unit (Hhtf). Note the braided channel-like depressions (white arrows) that emanate from the narrow troughs. We interpret these channel features as forming through the eruption of subsurface fluids, which emplaced the Utopia lowland 1 unit (Ahtu1), the approximate margin of which is identified by the dashed line. Excerpt of Context Camera image number P03_00230_1945 (centered at lat 13.58° N, long 119.46° E; location shown on map).



*Colors correspond to interpreted formation process (see text for summary). Dashed lines indicate uncertain temporal control.

EXPLANATION OF MAP SYMBOLS

- Contact—Dashed where approximately located; internal contacts shown in impact crater units mark superposition relations
- Ridges
 - Crenulated (wrinkled) ridge crest
 - Narrow, arcuate ridge crest—Unit Ahtu2 only
- Depressions
 - Subbed groove—Size of symbol may vary
 - Trough—Dashed where discontinuous
 - Channel—Locally forms positive relief sinuous ridges
- Scarp
 - Base of scarp—Barb points downslope
 - Lobate scarp—Flare points downscarp
- Crater rim—For all impact craters >5 kilometers in diameter
 - Raised rim of impact crater
 - Subbed, degraded, or buried rim of impact crater
- Large pitted cone—1.9 to 9.1 km in diameter
- Small pitted cone—500 m and <1.0 km in diameter
- Small tholi—2.6 to 6.6 km in diameter
- Rugged surface—Unit Hhtf only



DESCRIPTION OF MAP UNITS

[Note: Unit groups, names, and labels are discussed in the accompanying pamphlet. Unit definitions are based exclusively on characteristics observed in Thermal Emission Imaging System (THEMIS) camera daytime infrared range mosaics and include morphologic character, interior and marginal landforms, infrared brightness or albedo (where diagnostic), and cross-cutting and emplacement relationships. Additional characteristics are based on THEMIS visible range images (image numbers denoted by "V"), and Context Camera (CTX) visible range images (image numbers denoted by "P", "B", or "C"). See Geologic Summary in pamphlet for further discussion of map units.]

| Unit label | Unit name | Unit definition | Additional characteristics | Interpretation |
|-------------------------------|------------------------------|---|--|---|
| LOWLAND PROVINCE | | | | |
| Utopia region units | | | | |
| Ahtu2 | Utopia 2 unit | Smooth, undulating, to hummocky unit located in southern Utopia Planitia. Margin made up of south-facing lobes as much as tens of kilometers across. Contains dense networks of narrow, arcuate ridges and aligned, small pitted cones. Circular, narrow fractures and scarps frequent. | Narrow, arcuate ridges frequently made up of small pitted cones (V1861016). Hummocks dominate intersecting arcuate ridges (V27491028). Marginal lobes ramp onto (V19691008) and surround (P14_006671_1983) knobs and plateaus. Unit outcrops and buries ejecta of some large-diameter (>5 km) craters (B20_017539_2003). | Sedimentary plains deposited by local to regional outflow channel and (or) atmospheric fallout. Lobe and ridge morphologies may reflect deposition or modification, perhaps by liquefaction. Thickness uncertain, though southward thinning implied by outcrop relations |
| Ahtu1 | Utopia 1 unit | Smooth, planar unit located in land extending north of Amnethes Cavi. Abuts and partly buries outer ejecta of Marbach and Phedra craters. Low-relief knobs, plateaus, and scarps common, oriented north-south. Buried and partly buried impact craters frequent. | Embays narrow fractures of the Nepenthes flow unit (Hhtf) (P19_008099_1948). Crenulated ridges common in depressions of Amnethes Cavi (G03_019382_1928). Locally surrounds the Amnethes Cavi indicate contemporaneous origin. Deformed by local contraction | Sedimentary and (or) volcanic plains deposited as low viscosity flows. Erupted from fractures that surround Amnethes Cavi, perhaps triggered by surface impact or seismic events. Close association with Amnethes Cavi indicate contemporaneous origin. Deformed by local contraction |
| TRANSITIONAL PROVINCE | | | | |
| Nepenthes region units | | | | |
| Nhtv | Nepenthes vent unit | Smooth, sloping unit located in Nepenthes Planum and some depressions of Amnethes Cavi. Isolated and coalesced, cone- and mound-shaped outcrops diagnostic. Cones locally emanate lobes of the Nepenthes flow unit (Hhtf). | Overlapping circular depressions common at centers of cone-shaped outcrops (V27054039). Subtle knob or mound common near center of mound-shaped outcrops (B20_017549_1923). Unit locally associated with narrow fractures (G04_019172_1964). | Constructional vents deposited by effusively erupted lava and (or) fluidized sediment (mad breccia). Morphologies variation due to different eruptive styles, volatile content, and (or) tapping depth. Gradation with the Nepenthes flow unit (Hhtf) indicates contemporaneous origin |
| Nhtf | Nepenthes flow unit | Rugged to smooth, undulating unit that dominates Nepenthes Planum and Amnethes Cavi. North-south- and east-west-oriented ridges and knobby ridge segments common. Emanates from and surrounds the Nepenthes vent unit (Hhtv). Contains narrow, subbed grooves that define the depressions of Amnethes Cavi. Makes up plateaus and knobs in Utopia 1 (Ahtu1) and 2 units (Ahtu2). Buried and partly buried impact craters abundant. South-facing lobes make up part of the unit's southern margin. | Rugged texture locally defined by closely spaced hummocks (V27510027) and sharply crested hills, swales, or ridges (B21_009374_1964). Complexly overlapping lobes dominant (P21_009163_1958). Buries some cones of the Nepenthes vent unit (Hhtv) (V26006025). Channels that emanate from subbed grooves around Amnethes Cavi are frequent (P03_002280_1945, G03_019382_1928). | Lava and (or) sedimentary flows erupted from large pitted cones and mounds of the Nepenthes vent unit (Hhtv). Variable rugged to smooth texture results from different eruptive styles and (or) erosional modification. Gradation with the Nepenthes flow unit (Hhtf) indicates contemporaneous origin |
| HIGHLAND PROVINCE | | | | |
| Cimmeria region units | | | | |
| Hhtc3 | Cimmeria 3 unit | Smooth, sloping, moderately cratered unit located on slopes and between knobs and plateaus of Nepenthes Mensae and on floors of impact and basins in northern Terra Cimmeria. Narrow, braided valleys and ridges common. Forms patches of bright, sloping, and hummocky surface at the margins of some highland basins. | Margins locally lobate and show clear abutment of transitional knobs and plateaus (V06587016). Pits and hummocks characteristic (V31144017_1819_010956_1884). Margins frequently defined by low-relief scarps between knobs and plateaus (P13_006223_1919). | Intact and degraded sedimentary plains emplaced by fluvial, colluvial, and (or) lacustrine processes. Braided ridges are likely inverted channels. Channel convergence indicates northward transportation. Locally overthrust (and perhaps interbedded with) dust mantles |
| Hhtc2 | Cimmeria 2 unit | Smooth, undulating, ridged, and moderately cratered unit expands located in inter-center plains in northern Terra Cimmeria; some exposures occur in Nepenthes Mensae. Forms parts of the floors of impact basins. Speckled bright-dark surface common. | Occupies depressions between knobs and plateaus of the Cimmeria 1 unit (Hhtc1) (P15_006737_1991 and G02_019079_1899). Ridge crests common (V27770024). Basal by the Cimmeria 3 unit (Hhtc3) locally masks ridge morphology (V06300021). | Highland regolith consisting of various undifferentiated amalgamations of impact units and degraded sedimentary plains emplaced by fluvial, colluvial, and (or) lacustrine processes. Local volcanic rocks and sediments likely. Deformed by regional and (or) local tectonic compression. Grades with older Cimmeria 1 unit (Hhtc1) and younger Cimmeria 1 unit (Hhtc1). |
| Hhtc1 | Cimmeria 1 unit | Rugged, densely cratered, high-standing unit composed of massifs, knobs, plateaus, and crater basin rims in northern Terra Cimmeria. Forms highland ridges and plateaus in Nepenthes Mensae and Nepenthes Planum. Flat-floored, rimmed and rimless impact basins common. Ridges, scarps, and subbed grooves frequent. | Massifs made up of rugged undulations and hillocks with sinuous grooves and linear gullies (V05214009). Crenulated ridges commonly transect massifs and plateaus (V05214009). Subbed grooves and troughs define some basins (V06587016, B21_017747_1933). | Intact and fractured regolith and crustal rocks. Massifs composed of crustal rocks uplifted by basin forming processes. Intermixed impact-related, volcanic, and erosional rocks and sediments likely. Knobs and plateaus formed by extension along highland-toward boundary |
| WIDELY OCCURRING | | | | |
| Impact crater units | | | | |
| Ahtc | Crater unit, undivided | Ejecta, rim, wall, and floor units of well-preserved impact craters with diameters between 5 and 16 km. Layered and lobate ejecta morphologies well-preserved and pervasive. | Lineaments and sinuous striations common on ejecta lobes (V2741027). Floor peaks and wall slumps common on craters with diameters >8 km (V27129025). | Rocks and sediments emplaced by impact-related ejection and deformation of target units. Pervasive layered and lobate ejecta morphologies indicate water- and (or) ice-rich target rocks |
| Ahtca | Crater ejecta unit, facies a | Hummocky, lined, and lobate unit located around all impact craters with diameters >16 km. Multiple, rugged, overlapping, outward-facing lobes characteristic. Hummocks typical near crater rim, grading outwardly into lobes and lineaments. | Crescentic ridges, hummocks, and lineaments oriented radial to crater center common (V1804017). Shallow, sinuous grooves with fan-like extensions evident but rare (P18_008025_1951). | Rocks and sediments emplaced by impact-related ejection of target units. Layered, lobate ejecta indicates water- and (or) ice-rich target rocks. Smooth surface indicates uniform flow with no velocity gradient during emplacement |
| Ahtcb | Crater ejecta unit, facies b | Smooth, lined, and lobate unit located around all impact craters with diameters >16 km. Multiple, smooth, overlapping, outward-facing lobes characteristic. Locally peripheral to crater ejecta unit, facies a (Ahtca). | Smooth to undulating surface with overlapping lobes and lineaments oriented radial to crater center common (V2882614). | Layered sediment and breccia formed by the impact into—and ejection of—stratified units. Layered, lobate ejecta indicates water- and (or) ice-rich target rocks. Smooth surface indicates uniform flow with no velocity gradient during emplacement |
| Ahtcr | Crater rim unit | Rugged unit that defines the continuous to discontinuous, sharply crested rim scarp of all impact craters with diameters >16 km. Steep interior, basin-facing wall with smooth grooves and scarp. | Rim crest often plays into two or more closely spaced, discontinuous, and sub-parallel scarps or ridges (V9117013). Interior rim wall crevasses, lower slope smooth to lined (B21_017938_1957). | Upthrust target rocks and sediments, locally deformed by mass wasting |
| Ahtcw | Crater wall unit | Rugged unit composed of hillocks, blocks, and scarps located near interior base of crater rim. Discontinuous horizontal to slightly tilted terraces common. | Locally hummocky to undulating where extending onto crater floor (V2672019). Concentric ridges and grooves common between hillocks (H18_016679_1897). | Layered sediment and breccia formed by the impact into—and ejection of—stratified units. Layered, lobate ejecta indicates water- and (or) ice-rich target rocks. Smooth surface indicates uniform flow with no velocity gradient during emplacement |
| Ahtcf | Crater floor unit | Smooth, planar to sloping, locally pitted unit located between interior rim and central peak of impact craters with diameters >16 km. | Low-relief surface pits, scallops, and sinuous scarps common (V9117013). Layering locally exposed (B20_017457_1903). | Impact-melt and (or) impact-generated fines, modified by de-volatilization of interstitial water and (or) ice reservoirs. Likely includes post-impact sedimentary fill |
| Ahtcp | Crater peak unit | Grooved, rugged, mound- or cone-shaped unit located at or near center of all impact craters with diameters >16 km. Circular to ovoid planimetric shape. Central pits common. | Subbed to sharply crested radial ridges common (V9117013, V26580031). Smooth to etched surface frequent (G02_019145_1942, P15_006895_1984). | Deformed, fractured, and uplifted materials of the pre-impact surface. Central pit perhaps formed because of vaporization and collapse of water- or ice-rich target rocks |

Geologic Map of the Nepenthes Planum Region, Mars

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