

Figure 1. Regional view of Deuteronilus Mensae (lat 39°–48° N, long 15°–40° E) with MTM quadrangles 3537, 4037 and 4537 outlined in white. The approximate location of the Arabia shoreline as defined by Clifford and Parker (2001) is shown in orange. Most of the shoreline coincides with the highland-lowland boundary scarp. Viking MDM 2.1 at 256 pixel/degree (NASA/JPL/USGS) merged with 128 pixel/degree gridded MOLA topographic data in simple cylindrical projection.

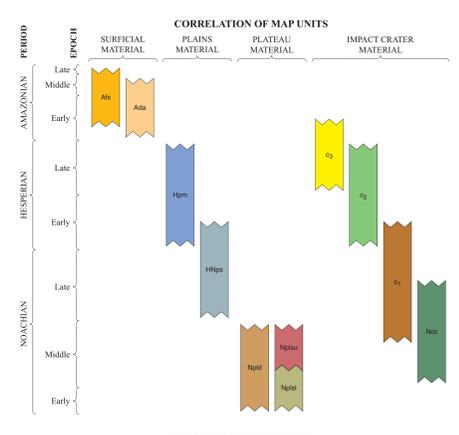
Descriptions of nomenclature used on map are listed at <http://planetarynames.usgs.gov/>

SCALE 1:1 004 000 (1 mm = 1.004 km) AT 35° LONGITUDE TRANSVERSE MERCATOR PROJECTION

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DESCRIPTION OF MAP UNITS

SURFICIAL MATERIAL

**Afs** Smooth fill material (Late to Early Amazonian)—Smooth deposits surrounding the areas between blocks and knobs on the floors of closed depressions (lat 36.5° N, long 23.3° E), covering parts of the floors of some impact craters, including Cerulli crater, and the small isolated flow along the rim of Cerulli crater; patches of small knobs within fill deposits below mappable scale are denoted by hachures; grooves in deposits on some impact crater floors follow the curvature of crater walls (lat 36.8° N, long 22.2° E). Interpretation: Mass-wasted debris and silt materials, possibly mixed with ice, that have filled and in some cases, flowed towards the center of low-lying features. Within closed depressions, knobs are remnants of eroded blocks and debris from collapse of plateau surfaces. Within several impact craters, flow convergence at crater center may form concentric grooves; alternatively, grooves may be eroded airfall deposits producing similar concentric patterns (Zimbelman and others, 1989).

DEBRIS APON MATERIAL (Middle to Early Amazonian)

**Ada** Debris apon material (Middle to Early Amazonian)—Smooth, lobate deposits surrounding and extending beyond the bases of mesas, knobs, crater rims, and fretted valley walls; bulbous lobes that extend through breaks in upper plateau material (unit Npsu) (lat 39.8° N, long 23.0° E) and along margin of Deuteronilus Colles (lat 41.8° N, long 21.2° E); some surfaces have lineations parallel to or transverse to apparent flow direction; some deposits near the slope base are partially covered by one or more apon deposits above, forming successive lobate fronts (lat 40.0° N, long 20.5° E); 1–2 km gap between bases of knobs, mesas, and fretted valleys and the apon head are common (lat 40.1° N, long 23.6° E); materials overlie or embay crater ejecta, knobs, plains, and plateau materials (units Npsu, Npsl, Npsd, Hpsu, Hpsl, Hpsd, Cg, and Cg). Interpretation: Mixtures of ice and mass-wasted detritus that have flowed down slope and covered older units. Apon flows indicate multiple flow events. Deuteronilus Colles apon materials may be eroded remnants of an ancient central peak structure. Gaps may represent upper margin retreat or downslope advance of the apon mass with cessation of supply.

PLAINS MATERIAL

**Hps** Mottled plains material (Late to Early Hesperian)—Topographically variable materials with bright flat-topped surfaces and surrounding lower dark hummocky surfaces; margins of some bright surface bounded by scarps; hummocky surfaces have small knobs in some locales (lat 45.8° N, long 20.5° E); where adjacent to smooth plains (unit Npsu), elevation is similar along the contacts; surfaces are topographically below both smooth plateau units (Npsu and Npsl). Interpretation: Origin of this unit is unknown, but could be related to erosion and redistribution of plateau materials, a transition from highland plateau to northern lowlands terrain, or a dark smooth fill material covered with bright patches of lava (lat 40.5° N, long 29.1° E) ejecta.

**Npsu** Smooth plains material (Early Hesperian to Late Noachian)—Smooth, relatively featureless materials with regions of variable albedo north of continuous cratered highlands; exhibits scattered clusters of small circular to irregular knobs (denoted on map by hachures); dark streaks appear to extend beyond the margin of some dark albedo regions (lat 40.0° N, long 21.2° E); where adjacent to mottled plains (unit Hps), elevation is similar along the contacts. Interpretation: Eroded plateau material (units Npsu, Npsl, and Npsd) deposited in low-lying areas, mixed and/or covered with coltan deposits. Patchy dark albedo areas covered with thin dust mantle that is modified by eolian activity, producing wind streaks.

PLATEAU MATERIAL

**Npsl** Dissected plateau material (Middle Noachian or older)—Portions of continuous cratered highlands with sinuous channels, elongate depressions and secondary crater fields associated with Cerulli crater rim common; channels are concentric to a sub-circular basin and well-preserved impact crater near lat 36.8° N, long 22.3° E; where adjacent to upper smooth plateau material (unit Npsu), the materials are at similar elevations. Interpretation: Ancient highland plateau modified by impact cratering and fluvial activity. Channels may be related to fluvial dissection from fluid migration within impact-fractured plateau materials.

**Npsu** Upper smooth plateau material (Middle Noachian or older)—Portions of continuous cratered highlands that are smooth with minor sinuous channels south of the plateau margin and polygonal mesas north of the plateau margin; elevation and crater density of mesa top surfaces generally decrease northward; large elongated depressions within continuous highlands contain irregular blocks or knobs of the original surface (lat 36.5° N, long 23.3° E); where in contact with lower smooth plateau material (unit Npsl), this unit is positioned above unit Npsl (lat 46.0° N, long 21.4° E), forming a layered sequence of plateau materials revealed in polygonal mesas. Interpretation: Ancient highland plateau modified by impact cratering, minor fluvial activity, and surface collapse above volatile-rich zones. Mesas are in-situ remnants of plateau beyond continuous margins. Knobs are smaller, more eroded remnants of the plateau. Knobs in Deuteronilus Colles may be remnants of a central peak from an impact structure.

**Npsd** Lower smooth plateau material (Middle Noachian or older)—Portions of cratered highlands above surrounding plains (units Hpsu and Hpsl) that are smooth with few impact craters; elevations of mesa-like surface tops are consistently between ~3,700 m and ~3,800 m; albedo generally darker than plains in Viking Orbiter data, where in contact with upper smooth plateau material (unit Npsu), this unit is positioned below unit Npsu (lat 46.0° N, long 21.4° E). Interpretation: Stratigraphically lower portion of ancient highland plateau in relation to Npsu materials.

IMPACT CRATER MATERIAL

**Cg** Well-preserved crater material (Early Amazonian to Late Hesperian)—Pronounced, continuous rim with significant relief relative to surrounding surfaces and continuous ejecta blanket; ejecta blankets commonly have impact margins (lat 42.4° N, long 22.4° E); many crater floors are covered by surficial smooth fill material (unit Afs). Interpretation: Deposits exhibiting little degradation that form ejecta, rims, and floors of impact craters.

**C2** Moderately degraded crater material (Late to Early Hesperian)—Continuous rim with minor relief relative to surrounding surfaces and continuous to semi-continuous ejecta blanket; ejecta blankets have smooth to pitted surfaces; many crater floors are covered by younger surficial smooth fill material (unit Afs). Interpretation: Deposits exhibiting moderate degradation that form ejecta, rims, and floors of impact craters.

**C1** Highly degraded crater material (Early Hesperian to Middle Noachian)—Partial to discontinuous rim with little or no relief relative to surrounding surfaces; some ejecta blankets could only be identified from brightness differences in THEMIS daytime IR data (lat 42.7° N, long 21.0° E); some crater floors are covered by younger surficial smooth fill or debris apon materials (units Afs and Ada). Interpretation: Deposits exhibiting extensive degradation that form ejecta, rims, and floors of impact craters.

**Ncu** Cerulli crater material (Late to Middle Noachian)—Pronounced, continuous rim with significant relief relative to surrounding surfaces and continuous ejecta blanket; numerous channels along crater interior walls (lat 32.8° N, long 22.1° E); and outer portions of ejecta blanket; secondary craters and crater fields from the impact scattered throughout ejecta blanket and on adjacent plateau materials (units Npsu and Npsl); linear grooves radial to crater center; crater floor and low-lying regions within rim materials covered with surficial smooth fill material (unit Afs). Interpretation: Moderately degraded deposits that form ejecta, rim, and floor of Cerulli crater.

**Contact**—Dashed where approximately located; short dashed where inferred

**Crater rim**—Showing crest. Dashed where approximately located, short dashed where inferred. D > 4.5 km

**Crater rim**—Showing crest. 3 < D < 4.5 km

**Crater central peak**

**Rimless crater**

**Crater ejecta rampart scarp**

**Closed depression**—Showing margin

**Scarp**—Hachures point downslope

**Radial groove**

**Wrinkle ridge**

**Flow lineation**

**Groove**

**Channel**

**Graben**

**Flow front**—Arrow indicates flow direction

**Secondary crater field**

**Hummocky texture in smooth fill material (unit Afs)**

**Knobby texture in smooth plains material (unit Hps)**

**Ribbed texture**

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**Flow front**—Arrow indicates flow direction

**Secondary crater field**

**Hummocky texture in smooth fill material (unit Afs)**

**Knobby texture in smooth plains material (unit Hps)**

**Ribbed texture**

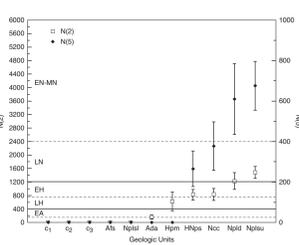


Figure 2. Plot of crater density data for geologic units in the Deuteronilus Mensae map region (see table 1 for data values, error range calculation, and unit names). Solid horizontal lines are breaks between epochs as defined by Tanaka (1986). EN-MN, Early to Middle Noachian; LN, Late Noachian; EH, Early Hesperian; LH, Late Hesperian; EA, Early Amazonian.

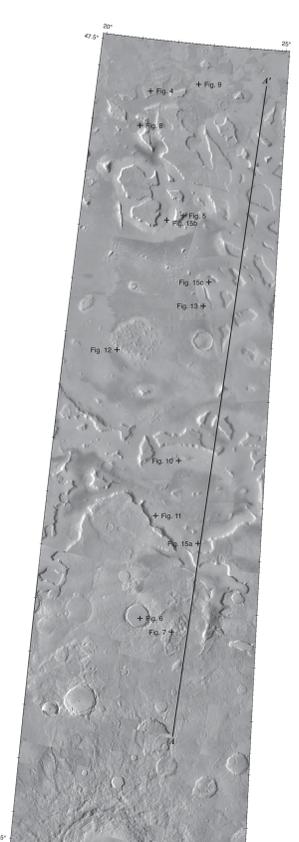


Figure 3. Location map for figures 4–13 and 15A–C. Image center locations are approximate. Topographic profile A–A' is shown for figure 14. Background Viking MTM mosaic at 50 m/pixel.



Figure 4. Polygonal mesa consisting of upper smooth plateau material (unit Npsu) on top of lower smooth plateau material (unit Npsl) with exposure of Npsl surfaces along the mesa scarp. The shared contacts and vertical sequence of these two units suggests that they are related. Npsl surfaces may be exposed lower layers of plateau materials. Image center near lat 46.0° N, long 21.4° E. Portion of THEMIS VIS image V13954002 (NASA/JPL/ASU), North towards top of image.

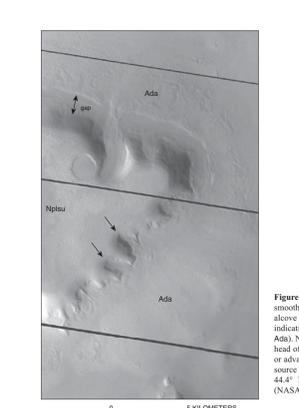


Figure 5. Sloves (arrows) along the scarps of a polygonal mesa of upper smooth plateau material (unit Npsu). The smooth materials within some above floors have minor surface lineations and (or) raised lobate fronts, indicating downslope flow of materials similar to lobate debris aprons (unit Ada). Note the approximately 1.4 m gap between the base of the mesa and the head of the apon mass. The gap may have formed by upper margin retreat or advancement of the apon mass with cessation of debris supply from the source area. Black lines arrow image are data gaps. Image center near lat 44.4° N, long 22.5° E. Portion of THEMIS VIS image V01131004 (NASA/JPL/ASU), North towards top of image.

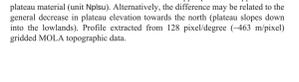


Figure 14 (right). Topographic profile from the continuous highlands to the outermost polygonal mesas shows the same relative elevation of near-boundary mesas and highland plateau, but a difference in elevation of some far-boundary mesas. Profile location (A–A') is shown in Figure 3. This difference, and the general decrease in crater density northward from the continuous plateaus, can be attributed to an erosional event that removed the upper portion of upper smooth plateau material (unit Npsu). Alternatively, the difference may be related to the general decrease in plateau elevation towards the north (plateau slopes down into the lowlands). Profile extracted from 128 pixel/degree (–463 m/pixel) gridded MOLA topographic data.

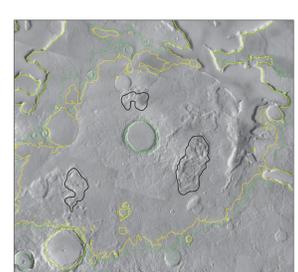


Figure 6. Close-up view of irregularly shaped depressions (black outline) with polygonal blocks and (or) knobs within a sub-circular basin in the highland plateaus. The basin is roughly defined by the –2,000 m (green) and –2,100 m (yellow) contours from MOLA gridded topography. The knobs and blocks range from a few hundred meters to several kilometers across. The areas between the knobs and blocks are occupied by smooth fill material (unit Afs). Together, the knobs and smooth fill form a hummocky depression floor. The well-preserved impact crater near the center of the basin is located at lat 36.8° N, long 22.3° E. Background is Viking MDM 2.1 at 256 pixel/degree (NASA/JPL/USGS). North towards top of image.



Figure 7. Portion of a closed depression in the highland plateau with smooth fill material (unit Afs) occupying areas between adjacent blocks of upper smooth plateau material (unit Npsu). Two surfaces along the edge of one block are clearly visible, suggesting that plateau materials may be layered in places. The block also stands higher along this edge, suggesting that it is tilted down into the smooth fill deposits along the opposite edge. Image center near lat 36.8° N, long 22.3° E. Portion of MOC NA image E130024 (NASA/JPL/SSS), North towards top of image.

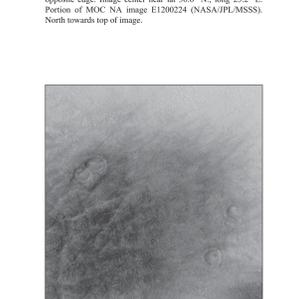


Figure 11. Lobate debris apon material (unit Ada) extending down slope and to the northeast from an escarpment has flowed around small knobs (arrows) of upper smooth plateau material (unit Npsu). Curved lineations transverse to the apparent flow direction along upper slopes could be ridges of material displaced towards the downslope. Image center near lat 38.8° N, long 22.5° E. Portion of THEMIS VIS images V11146004 and V10834007 (NASA/JPL/ASU), North towards top of image.

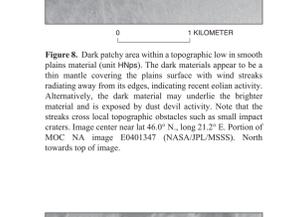


Figure 8. Dark patchy area within a topographic low in smooth plains material (unit Hps). The dark materials appear to be a thin mantle covering the plains surface with wind streaks radiating away from its edges, indicating recent eolian activity. Alternatively, the dark material may underlie the brighter material and is exposed by dust devil activity. Note that the streaks cross local topographic obstacles such as small impact craters. Image center near lat 46.0° N, long 21.2° E. Portion of MOC NA image E0401347 (NASA/JPL/SSS), North towards top of image.

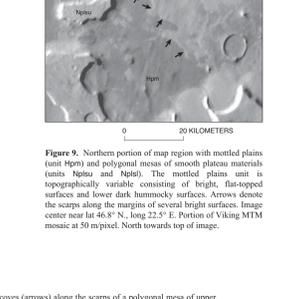


Figure 12. Lobes of debris apon material (unit Ada) that extend from the mound along the margin of Deuteronilus Colles and onto adjacent smooth plains material (unit Hps). Knobs of upper smooth plateau material (unit Npsu) surrounded by debris apon material may be the remains of a central peak from a large impact structure. Image center near lat 41.8° N, long 21.2° E. Portion of THEMIS VIS image V0636012 (NASA/JPL/ASU), North towards top of image.

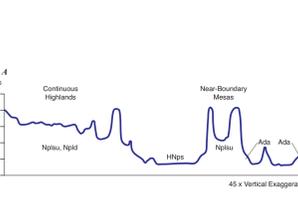


Figure 9. Northern portion of map region with mottled plains materials (unit Hps) and polygonal mesas of smooth plateau materials (unit Npsu). The mottled plains unit is topographically variable consisting of bright, flat-topped surfaces and lower dark hummocky surfaces. Arrows denote the scarps along the margins of several bright surfaces. Image center near lat 46.8° N, long 22.5° E. Portion of THEMIS VIS image V0636012 (NASA/JPL/ASU), North towards top of image.

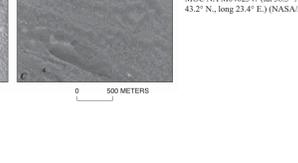


Figure 13. Ribbed pattern of ridges (shown by stippled pattern on map) along the margin of debris apon materials (unit Ada). Partial retreat of the apon margins or apon deposition over an uneven pre-existing surface (for example, see ejecta from nearby well-preserved impact crater (unit Cg) underlying the apon deposits) may have produced the ribbed appearance. Image center near lat 42.7° N, long 23.3° E. Portion of THEMIS VIS image V13592007 (NASA/JPL/ASU), North towards top of image.



Figure 15 (left). Four common surface textures observed on lobate debris aprons are (1) smooth with minor rills, (2) knobby, (3) linedated, and (4) ridge and valley. These textures likely formed within an ice-rich dust mantle on apon surfaces. In the left image (A), surface textures are evident along the edges of small craters and their floors are generally smooth, indicating the presence of mantling material. Modification of the mantle may have occurred from a combination of ice sublimation, which released the bound dust grains and eolian activity that removed the dust. Images A–C and their approximate center locations are portions of MOC NA M0402347 (lat 38.3° N, long 23.0° E), E1100663 (lat 41.4° N, long 22.2° E), and E11202903 (lat 43.2° N, long 23.4° E) (NASA/JPL/SSS).

Geologic Map of MTM 3537, 4037, and 4537 Quadrangles, Deuteronilus Mensae Region of Mars

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