GEOMORPHOLOGIC MAP OF AN ICY HUMAN EXPLORATION ZONE: DEUTERONILUS MENSAE.

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Introduction: We have performed morphology-focused geologic mapping of a 100-km-radius circle within Deuteronilus Mensae, Mars, in order to elucidate the geology of this potential future site of human exploration. This location was proposed as one of 47 sites discussed at a 2015 Mars Exploration Zone Workshop [1]. In this proposal, diverse geomorphologic units were distinguished and correlated chronologically based on relative stratigraphy. Located at approximately 41°N, 22°E, the landing site sits directly along the dichotomy boundary in northern Arabia Terra and offers potential samples of both the ancient highlands and younger lowlands. Additionally, lobate flow structures may provide evidence of the presence of significant quantities of water ice in the near subsurface, increasing the scientific and resource potential of the site.

Background: The proposed landing site is centered in a semi-circular ring of elevated structures. An expansive, flat, and low elevation landscape is available here, ideal for safe landing amongst occasional craters.

Previous mappers of this region and nearby areas noted evidence for aeolian, fluvial, tectonic, glacial, and volcanic processes [2,3,4]. Chuang and Crown produced the hitherto highest resolution map of the region within a 1:1,004,000 scale strip from the southern highlands to northern lowlands using primarily THEMIS day-IR and VIS mosaics (~50 m/pixel) [4]. The present work adds critical details incorporated from higher resolution imagery and additional datasets.

Data & Methods: Geologic mapping was primarily done on a basemap of Context Camera (CTX) images (6 m/pixel) from the Mars Reconnaissance Orbiter. Auxiliary resources came from the MOLA, THEMIS (IR), and HiRISE instruments. Mapping for our 1:250,000-scale map was done at a scale of 1:100,000 using Esri's ArcGIS software. Contacts between geologic units were mapped as well as linear geologic features (e.g., ridges) and surface features (e.g., dark ejecta debris).

Results: In creating a geologic map, we first mapped nine geomorphologic units, which can be divided into 4 groups:

Platform units. The platform unit (P; **Fig. 1A**) represents the elevated, relatively flat features of the southern highlands. This unit contains small craters and low hills as well as narrow and wide ridges and troughs. The slopes of this unit and the more rugged associated units were mapped as the platform degraded unit (Pd; **Fig. 1B**). These polygonal structures are typically a few kilometers on a side and may slope gradually in one or more directions. At smaller scales, the interplatform unit (Pi; **Fig. 1C**) denotes regions of platform-associated mounds intermixed with the lobate features related to the surrounding prominent platform units. The interplatform chaotic unit (Pic; **Fig. 1D**) is found solely in the eastern portion of Deuteronilus Colles, a large cluster of Pi material north of the center of the map. At this location, the geology resembles that of the interplatform material but has a much more tumultuous topography than the typical smoothness of the Pi unit.

Lobate units. Two related but distinct lobate units can be observed. Dominating the southern portion of the map, the lobate linear unit (Ll; **Fig. 1E**) follows the borders of large P and Pd outcrops. The Ll unit, when uninhibited, will gently slope away from the escarpment of the P unit for distances up to 15-25 km. A repeating lobate structure can be observed with additional lineations perpendicular to the platform walls. The Ll unit is relatively smooth with very few craters. The lobate centered unit (Lc; **Fig. 1F**) can be found tucked closely to the scarp face of the P and Pd units, extending up to a few km away. The smooth appearance of the Lc unit contrasts with the linear features and texture of the Ll unit such that contacts tend to be certain. Linear features on the lobate units were mapped with the term flow lineations.

Floor unit. The largest fraction of the map area is covered by the floor unit (F; **Fig. 1G**). This unit is rela-

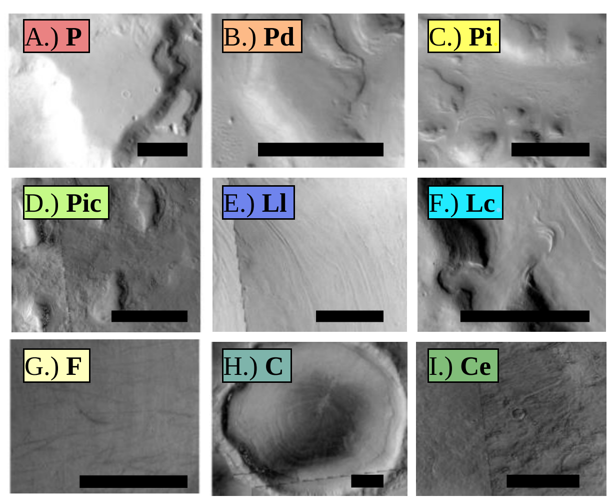


Figure 1. Examples of mapped units: (A) platform unit, (B) platform degraded unit, (C) interplatform unit, (D) interplatform chaotic unit, (E) lobate linear unit, (F) lobate centered unit, (G) floor unit, (H) crater unit, and (I) crater ejecta unit. Scale bars ~5 km. Image seams cut some samples.

tively flat yet displays distinctive albedo variations in CTX and THEMIS IR data. The lower visible albedo regions are mapped as a dark-colored mantling material and typically display a crosshatched pattern of cracks at a scale of hundreds of meters. The boundary between the lower and higher albedo regions is crisscrossed by a multitude of dark linear features mapped as lineations. These surficial features are typically <500 m wide and extend for 10s of km. A few narrow ridges and sinuous grooves are also mapped within this unit. Craters appear in a variety of preservation states, with some circular features interpreted as buried crater rims.

Impact Crater units. Two units have been associated with several craters in the mapped region. The crater unit (C; **Fig. 1H**) maps the largest few craters (>2 km wide). Within these basins, typically smooth semi-concentric features can be found resembling the lobate units described above. Several impact craters also exhibit surrounding material commonly interpreted to be ejecta blankets and thus mapped as the crater ejecta unit (Ce; **Fig. 1I**). Overlapping lobate edges extend 10s of km away from the largest impact and exhibit radial grooves. This unit also includes the crater basins and surrounding ejecta of smaller impact sites, though origins and ages certainly vary.

Interpretations: We utilized our geomorphologic map (**Fig. 2**), superposition relationships, and albedo variations of individual units to construct an approximate chronologic sequence of genetic events.

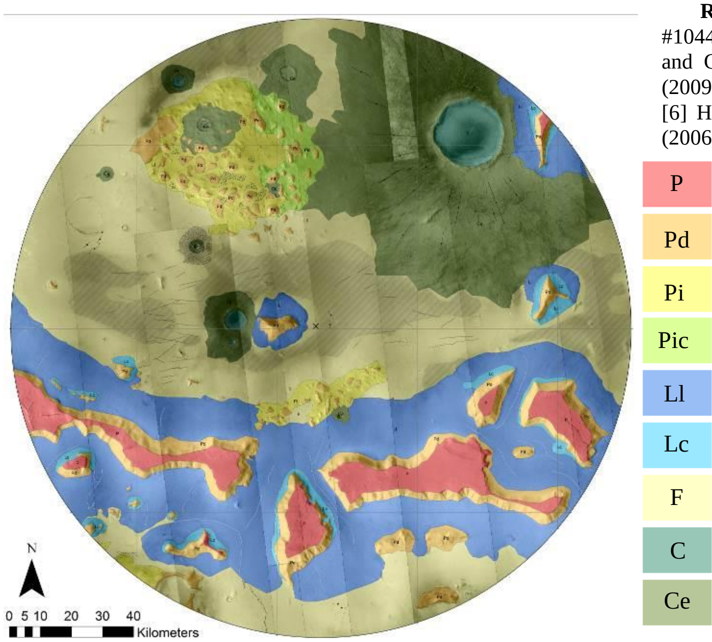
Though the floor unit appears as the most low-lying strata, its relative smoothness suggests an age younger than that of the platform units. Platform units are likely remnants of the cratered highlands to the south, commonly understood to be ancient compared to material north of the dichotomy boundary. Degradation state of these units increases northward from partially (Pd) to nearly completely (Pi, Pic) eroded. A variety of both physical and chemical weathering processes were likely responsible for this transition [4].

We interpret the lobate units as analogous to terrestrial rock glaciers where long linear features represent moraines and multiple overlapping flows can be interpreted as the interaction of distally sourced glaciers, possibly allowing for significant transport of weathered platform materials. Interior to the Ll unit, the lobate centered unit (Lc) is generally superposed on Ll (as in **Fig. 1F**) and therefore younger in age. Lobate units have continued activity until geologically recent time, as supported by a relative paucity of impact craters and studies of Martian climate change [5] and glaciation at mid-latitudes [6]. Based on superposition, some of the larger preserved impact craters (C) and their ejecta blankets (Ce) occurred before or early in the formation of lobate units (Ll, Lc).

Dark lineations appear on the floor unit (F, see **Fig. 1G**) as a layer of high albedo fine grains are removed to reveal underlying darker albedo material. This occurs in areas of strong aeolian activity, likely related to dust devils previously evidenced from orbit [7] and observed in-situ [8].

Given that long-term human activity on Mars will require access to critical resources such as water and that the geomorphology of the region suggests deposits mediated by water, the proposed landing site at Deuteronilus Mensae could supply such resources. The present map provides improved details about this important candidate site.

References: [1] Plaut J. J. (2015) *1st LS/EZ Workshop*, Abs. #1044. [2] Lucchitta B. K. (1978) *USGS IMAP 1065*. [3] Greeley and Guest (1987) *USGS IMAP 1802-B*. [4] Chuang and Crown (2009) *USGS SIM 3079*. [5] Head J. W. et al. (2003) *Nature 426*. [6] Head J. W. et al. (2005) *Nature 434*. [7] Cantor B. A. et al. (2006) *JGR 111*. [8] Greeley R. et al. (2006) *JGR 111*.



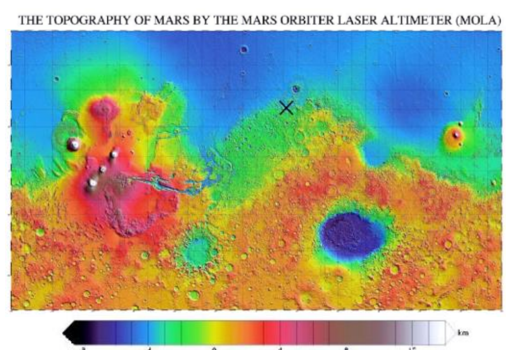


Figure 2. Geomorphologic map and key of the exploration zone with underlying CTX basemap (left) and MOLA topographic map of Mars with "x" denoting the mapped region (right).