DEPOSITION AND EROSION OF THE SCALLOPED DEPRESSION BEARING TERRAIN IN WESTERN UTOPIA PLANITIA, MARS.
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Introduction: Western Utopia Planitia has long been an area of interest based on the presence of potential glacial and periglacial features. In particular, the high concentration of scalloped depressions in Utopia relative to the rest of the planet [e.g., 1, 2] has led to a debate on the geologic history of the area in the Late Amazonian. Some authors have suggested that the terrain hosting the scalloped depressions is a distinct, unique geologic unit [e.g., 3, 4], while others suggest the scallops occur within or as part of the latitude dependent mantle (LDM) [e.g., 5, 6]. Here we investigate the geomorphology of this scalloped depression bearing terrain (herein referred to as SDBT) to gain insight into its formation.

Methods: Mapping and image analysis were completed using MRO Context Camera (CTX) and High Resolution Imaging Science Experiment (HiRISE) images in the Java Mission-planning and Analysis for Remote Sensing (JMARS) software package [7] spanning 30–60°N and 70–150°E.

Regional Characterization: The SDBT extends from ~38–54°N and 70–128°E. We observe occurrences of scalloped depressions within craters out to ~60°N and ~150°E, and poleward of 50°N some craters exhibit possible signs of scalloped depressions in very early stages of formation. The occurrence of scallops gradually tapers off with increasing latitude (consistent with Morgenstern et al. [2]).

The SDBT gradually becomes discontinuous near the margins of the "ABp" unit mapped by Kerrigan [4] at its southern boundary before no visible evidence of it is preserved. Near its southern extent, the SDBT typically appears darker toned than the surrounding terrain. Along the northern boundary, the tone of the SDBT is comparable to that of the surrounding terrain.

Within the ABp boundaries mapped by Kerrigan [4], the tone of the SDBT is highly variable. However, the tonal differences between the SDBT and the underlying/surrounding units do not appear to be a primary feature of the unit. The mottled tonal differences across the SDBT appear to arise from differences in dust cover based on observations in areas of concentrated dust devil tracks, revealing darker-toned material amidst lighter-toned (interpreted as dusty) areas.

Ground Ice Presence: The SDBT has been found to contain ice in excess of available pore space ("excess ice") based on SHARAD detections of a reflector coinciding with the base of the layered scarps of the SDBT [6]. The dielectric properties are consistent with porous, slightly dirty H_2O ice (50–85% ice by volume) ranging in thickness from ~80–170 m [6]. This excess ice suggests emplacement via atmospheric deposition rather than enrichment of existing regolith [6].

A large ice component in the SDBT is also supported by the lack of talus along scarp edges within the unit. If the SDBT is composed of ice-cemented dust (or other fine-grained material such as ash [8]), then any dust left behind upon sublimation of the ice would be easily transported by wind and thereby largely removed over time. This could explain both the lack of debris along scallop/scarp slopes, as well as the dark tone of the SDBT relative to the terrain to the south (with darker areas being less dusty).

Role of Storms: Under current martian conditions, west-to-east storm activity in Utopia Planitia is common during certain times of the year. This storm activity is predominantly driven by a combination of topography and temperature differentials between the seasonal north polar cap and the adjacent frost-free ground [9]. Therefore, it is expected that such a pattern would hold during past climate conditions that are similar to the present, and these winds could mobilize dust off the surface of the SDBT. A positive feedback cycle for erosion of the SDBT is thus created: (i) removal of the protective surface lag exposes more near-surface ice to sublimation; (ii) desiccation and a new non-cohesive surface lag of dust; (iii) subsequent removal by aeolian activity. The process then repeats itself with the cyclic variations in martian obliquity.

Depositional Model: Based on observations with MOC NA and HiRISE, some previous authors [e.g. 3, 10] state that the LDM overlies the SDBT in Utopia. However, other workers [e.g., 6] propose that the locations interpreted by [3] to be LDM deposited within depressions in the SDBT are actually "gaps" in the SDBT that expose an underlying lighter-toned unit [e.g., 6]. Inspecting the SDBT vs. the lighter-toned unit using both HiRISE images and anaglyphs, our observations support the hypothesis that the lighter-toned unit underlies the SDBT.

The lighter-toned unit is heavily cratered relative to the nearly crater-free SDBT and lacks the polygonal fracturing observed on the SDBT. Craters within the lighter-toned unit are often partially filled with material that is morphologically identical to the surrounding SDBT scarps, suggesting the material within the craters is the same as that which composes the SDBT.

Scalloped depressions that appear to be eroding atop the light-toned unit are also observed, with the SDBT displaying a pitted texture rather than (or in addition to) polygonal fracturing atop places where the light-toned unit appears to be thinly buried. SHARAD-derived SDBT thicknesses are consistent with the change in elevation (based on MOLA) from the polygonally fractured SDBT to the pitted-texture SDBT, supporting our interpretation that the pitted-texture areas represent thin SDBT deposits atop the lighter-toned underlying unit. These deposits are thin enough (≲10 m) that the reflectors, if present, are not resolvable by SHARAD.

Within larger craters that are partially buried by the SDBT, the crater wall mantling "pasted-on" material [11] appears to be continuous with the crater-filling material hosting scalloped depressions, suggesting they are a single depositional unit. Multiple generations of gullies are observed within the pasted-on material in Western Utopia, including both negative relief and inverted gully channels [12]. Along the crater wall contact, evidence for retreat of the SDBT is sometimes visible. The SDBT is thin enough within some craters that underlying concentric crater fill (CCF) patterns are visible, but thick enough in other craters that even when highly eroded, the surface patterns of the underlying CCF are not visible.

Implications: All of these observations suggest that the SDBT was deposited over the course of multiple obliquity cycles post-dating the CCF-forming glacial period. The SDBT was once more areally extensive, burying the light-toned unit (and CCF-bearing craters within it). Subsequently, the SDBT eroded to exhume the underlying light-toned unit, with deposits of the SDBT preserved within formerly buried craters. Based on the morphology, stratigraphic relationships, and SHARAD results [6], we interpret the SDBT to be ice-rich layered deposits emplaced at periods of high obliquity [e.g., 2, 5]. The typical lack of mass movement features along scalloped depression walls, despite slopes up to ~80° based on Mars Global Surveyor Mars Orbiter Laser Altimeter (MOLA) shots, combined with the relative lack of impact craters preserved on the SDBT surface supports the hypothesis that the scallops/scarps are rapidly degrading [6].

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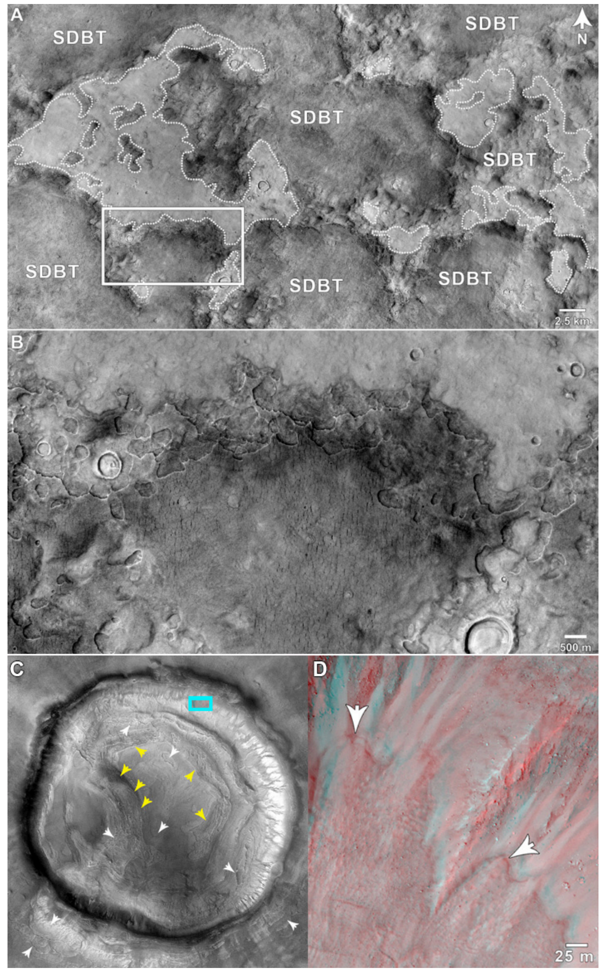

(A and B) Example of the scalloped depression bearing terrain (SDBT) in western Utopia Planitia at 42.3°N, 85.8°E. **(A)** CTX mosaic showing the SDBT and the contact with the underlying light-toned unit (white lines). White box denotes the location of B. **(B)** Close view of the SDBT, showing polygonal fractures and scallops. Subframe of CTX G02_018948_2237. **(C)** SDBT within a crater in Utopia. White arrows denote examples of scallops. Yellow arrows denote CCF textures. Teal box denotes the location of D. Subframe of CTX F16_041866_2287_XN_48N270W. North is up. **(D)** HiRISE anaglyph of small scarps (marked with white arrows) suggestive of retreat of the SDBT down a crater wall. North is up. Subframe of anaglyph from ESP_037646_2290 and ESP_028719_2290.