COMPLEXITY IN THE STRATIGRAPHIC, EROSIONAL AND CLIMATIC RECORD OF THE NORTHERN POLAR PLATEAU OF MARS.
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1. Background: The north polar layered deposits of Planum Boreum are among the youngest and most complex geologic materials on Mars. Their formational history is thought to have been closely related to the recent climatic evolution of the planet [1-3]; nevertheless, the roles of independent geologic processes remain poorly understood.

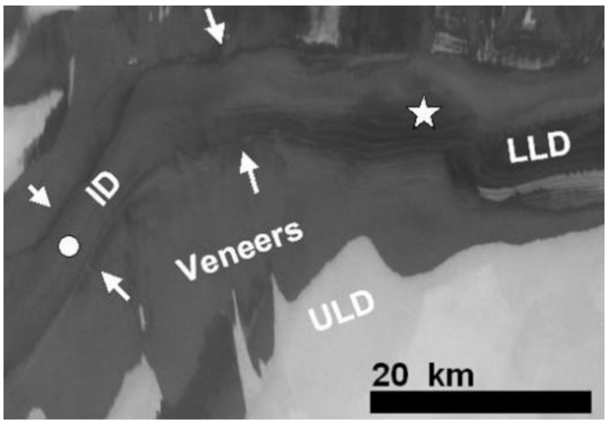

Fig. 1. *Polar trough east of Chasma Boreale in Planum Boreum, Mars (HRSC image centered at* 325.0° *E,* 82.8° *N; north toward upper right). The white arrows indicate trough margins. The maximum relief of exposed ID (at dot) is ~100 m, covering an exposed section of LLD as much as 240 m thick (at star). Thus ID materials may form relatively thick deposits within polar troughs. Erosion and mobilization of ID material has resulted in the exhumation of underlying LLD and the deposition of extensive veneers over the plateau surfaces that form the trough margins.*

2. Lower layered deposits (LLD): The LLD are made up of >250 layers that are generally 1-10 m thick and best exposed in poleward-facing scarp walls [1]. The layers form distinct sequences characterized by alternating albedo that are locally separated by unconformities [1-3]. The total thickness of the LLD may exceed 1000 m, but the local thickness is likely to be variable due to the apparent rugged topography of the underlying materials that form a sizable fraction of Planum Boreum and the LLD's eroded topography [1]. Radar sounding data collected by the MARSIS (Mars Advanced Radar for Subsurface and Ionosphere Sounding) instrument aboard Mars Express indicates that the materials of the north polar plateau have a composite dielectric of 3, which is close to that of pure ice [4]. However, neither the LLD nor the Udzha crater rim appears to have undergone topographic relaxation, which is expected for impact craters that form in icy targets [5]. Instead, the rim of Udzha crater consists of a knobby ridge and an apron of smooth deposits that does not appear to contain boulders [MOC image E22-01015] (Fig. 1). This mode of degradation is consistent with disaggregation and mass wasting of granular ice and dust due to the sublimation of cementing ice. A highly porous LLD is also consistent with: (1) modest down-warping of the circum-polar plains resulting from lithospheric loading [6] and (2) the low dielectric for the LLD [4], which may characterize highly porous basaltic dust as deduced from density vs. dielectric relations for loose, dry basaltic material determined by laboratory measurements [7]. The LLD that surround 43-km-diameter Udzha crater displays proximal concentric and radial fractures [1]. Impact generation of fractures and their subsequent preservation indicate that the LLD consisted at least partly of brittle geologic materials at the time of impact. As such, we propose that the LLD consist of ice-cemented, highly-porous dust deposits.

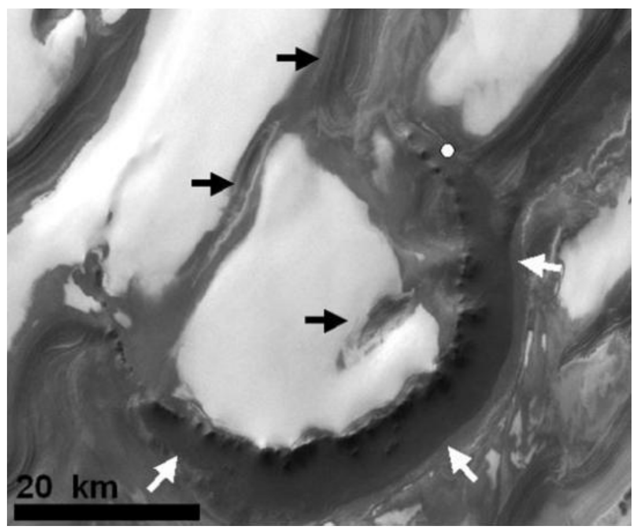

Fig. 2. *Udzha crater within Planum Boreum, Mars (HRSC image centered at 77.2° E, 82.0° N; north toward upper left). Trough-forming processes partly destroyed the crater rim (black arrows), indicating that the crater formed prior to or during formation of polar troughs. The rim of the impact crater has been reduced to a knobby ridge, indicating that disaggregating and sloughing has been a long-lived and significant geologic process in the resurfacing history of the impact crater.*

3. Intermediate deposit (ID): The ID consists of low-albedo material that overlies the LLD and forms sedimentary deposits within numerous polar troughs (e.g. Fig. 2). The ID appears to be readily eroded and mobilized into veneers (Figs. 2 and 3), indicating that it may consist of disaggregated materials--most likely sand-sized particles, since these are most easily mobilized by wind [8]. Laboratory experiments indicate that saltating sand grains on Mars are an effective erosional agent, as they should have about three times higher velocity than their terrestrial counterparts [9]. Thus we propose that the ID may be a residue of vast, migrating sand sheets, whose emplacement may have eroded the polar troughs within the LLD.

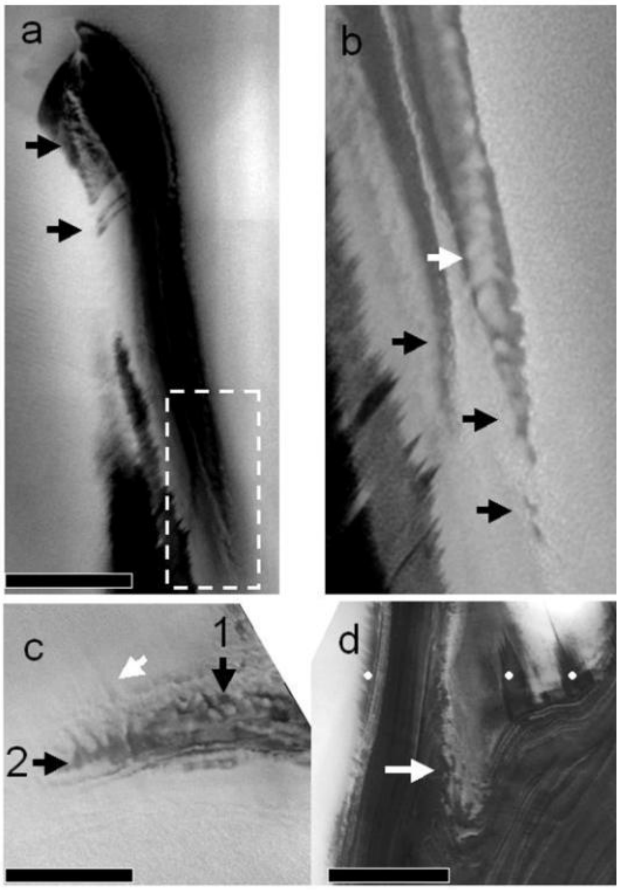

Fig. 3. *Views of polar troughs in Planum Boreum, Mars All scale bars are 5 km.* ***(a)*** *This trough contains ID material mobilized into veneers (black arrows). (Part of THEMIS VIS 13274005 centered at 1.4° E, 80.3° N.)* ***(b)*** *Close up of zone in panel (a) outlined in box. Notice how differential ULD retreat has resulted in the formation of surface grooves (black arrows) and a knobby ridge (white arrow). ULD retreat is possibly related to surface abrasion by the mobilization of ID particles into veneers and to enhanced insolation-driven sublimation produced by decreased surface albedo from veneer deposition. (Part of THEMIS VIS 13506006 centered at 1.8° E, 80.2° N.)* ***(c)*** *Differential ULD retreat has resulted in the formation of a knobby surface (black arrow 1), which contains low albedo materials (black arrow 2) from which faint veneers source (white arrow). The shape of the ULD eroded zone suggests that differential erosion has taken place over ULD materials that overlie a polar trough. (Part of THEMIS V12924005 centered at 252.0° E, 85.1° N.)* ***(d)*** *Note etched margin of receding ULD material (arrow) within a polar trough and associate veneers (dots). (Part of THEMIS V13341002 centered at 87.2° E, 82.2° N.)*

4. Upper layered deposits (ULD): The ULD unconformably overlie the LLD and consist of at least three or four layers detectable in MOC images (e.g., MOC image E20-00005). ULD layers also display irregular pitting. The residual ice cap forms the top layer of the ULD, has an etched surface [10], and locally appears unconformable to the LLD and underlying layers of the ULD [11]. Deposition of the ULD may be linked to a climatic stage of low obliquity during the past 4 to 5 million years [3] during which volatile accumulation in the northern polar region was the dominant process for the emplacement of layers. ULD emplacement does not appear to have led to cementation in the ID, suggesting that there has been little or no vertical volatile exchange between these upper polar strata.

5. North polar veneers: Veneers represent discontinuous sedimentary mantles over the ULD, including the residual water-ice cap (e.g. Fig. 2), and thus comprise the youngest perennial materials of the north polar plateau. They commonly occur along the margins of polar troughs that contain the ID, which suggests that they are depositional lags (Figs. 2 and 3). The occurrence of the ID and veneers within polar troughs is associated with significant erosion and preferential retreat of the ULD, which has led to the exhumation of buried sections of polar troughs (e.g. Figs. 2 and 3). In the absence of other processes, the current climate epoch of low polar insolation might be expected to result in little to no erosion and perhaps deposition of polar layered deposits [1-2]. However, the formation of the veneers, the exhumation of the LLD polar troughs, and the surface degradation of the ULD (including pits and widespread grooves (e.g. THEMIS V13506006, MOC m0001424) indicate that the north polar plateau has been recently undergoing net erosional degradation. Moreover, we propose that the erosion rate for the relatively friable ULD may have been increasing during the current epoch because of the increasing volume of abrasive sedimentary particles released from progressive erosion of the ID.

References. [1] Tanaka K.L. (2005), *Nature 437*, 991-994. [2] Milkovich S. M. and Head J. W. III (2005) *J. Geophys. Res., 110,* E01005. [3] Laskar J. et al. (2002) *Nature, 419,* 375-377.[4] Picardi G. et al. (2005) *Science, 310,* 1925-1928. [5] Pathare A.V. et al. (2005) *Icarus, 174*, 396-418. [6] Johnson C.L. et al. (2000) *Icarus, 144,* 313-328. [7] Heggy E. et al. (2001) *Icarus, 154,* 244-257. [8] Edgett K. S. and Christensen P.R. (1991) *J. Geophys. Res., 96,* 22765–22776. [9] Greeley R. (2002) *Planet. Space Sci., 50,* 151-155. [10] Thomas P. et al. (1992) In *Mars* (H.H. Kieffer et al., Eds.), pp. 767-795. Univ. Arizona Press, Tucson. [11] Skinner J.A. et al. (2006) *Fourth Mars Polar Science Conference*, Lunar and Planetary Institute, Houston, Abstract #8083 (CD-ROM).