STRATIGRAPHY OF YOUNG DEPOSITS IN THE NORTHERN CIRCUMPOLAR REGION, MARS.

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Introduction: High-resolution MGS MOC images [1] showed that all terrains in the north polar region of Mars lack fresh impact craters and, hence, are geologically young. Malin and Edgett [1] noted "the relatively thin, plain-covering materials observed in the northern plains (and southern highlands at comparable latitudes)" and suggested that they are "the result of latitude depended processes". Earlier we [2] noted the latitudinal trend of subkilometer-scale topographic roughness and suggested that smoothing at high latitudes is caused by a climate-controlled high-latitude surface layer (HLL) having a specific decameter-scale surface pattern [2, 3]. A specific dissected pattern interpreted as a result of desiccation of a several-meter-thick ice-rich layer [4] has been observed in a latitude band at the peripheral part of the smoothed area. Recently, a high concentration of hydrogen has been detected by Odyssey spacecraft at high latitudes [5, 6]. These measurements refer to an uppermost layer of ~1 m thick. Thus, the ice in the HLL material is responsible for the detected high ice concentration [7].

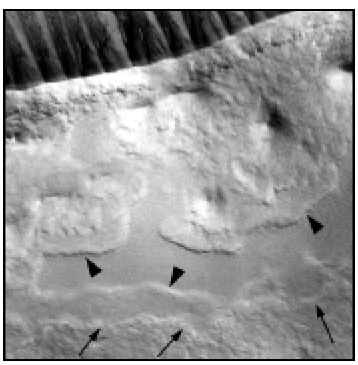

Fig. 1. Rim and southern outer wall of a crater at 69.5°N 86°W. Short arrows show edges of the uppermost layer within HLL, long ones show that of the second layer. Portion of E04/00537, 1.8 x 1.8 km. Illumination is from lower left.

To understand the properties and the origin of the HLL, we are carrying out a systematic survey of the textures and features observed in the HLL in the northern hemisphere of Mars in the high-resolution MGS MOC images. In the northern hemisphere the HLL covers homogeneous, topographically smooth northern plains. These "boring" geological settings allow us to focus on intrinsic characteristics of the HLL itself, in contrast to the southern hemisphere, where in each place we encounter steep topography and a unique set of geological settings. Details of the survey and preliminary results are described in [8]. Here we report our observations on stratigraphic relationships between the HLL and other circumpolar deposits and present an initial synthesis.

Stratigraphic observations: The uppermost part of the *HLL* is the most recent formation in a vast area of the northern plains. This layer is mostly contiguous at higher latitudes (> 60°N). Signs of erosion are observed at rare steep topographic slopes (e.g. **Fig. 1**). At high latitudes the steep slopes of any orientation are the warmest areas in summer, and erosion of the HLL at the steep slopes is consistent with the as the cementing agent.

The HLL itself has a complex stratigraphy. This can be seen where the HLL is disrupted (**Fig. 1)**. In several cases, where individual MOLA profiles cross the layer edge, we obtained an estimation of the uppermost layer thickness. It turned out to be ~ 3 m.

Southward from ~60°N in some (but not all) locations small fresh pits are observed. In some places they are collapse features, in other they look like an accumulation population of small fresh impact craters of uncertain age on the order of a Myr (see [8] for details). Further to the south, the HLL is eroded and dissected. We observed clear examples showing that the dissection from [4] is the dissection of the HLL. At these latitudes (~55°N), the HLL is often preserved on north-facing local slopes, which is consistent with desiccation as the cause of dissection [4].

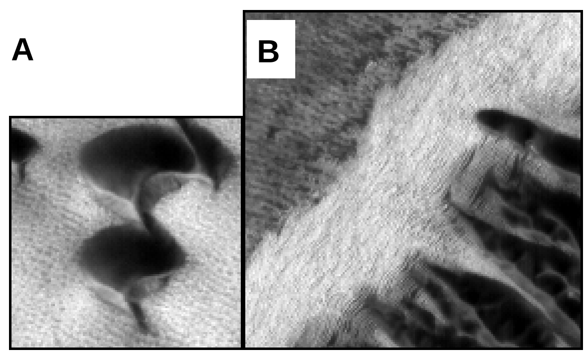

Fig. 2. A. Dark barchans travel on the HLL with basketball texture. Portion of E01/02916, 1.3 x 1.3 km. **B**. Bright material forming ripples covers both the HLL and the sand sea dunes. E01/00652, 1.8 x 1.8 km. Illumination is from lower left in both frames.

At high latitudes the HLL is overlain by *wind-blown material*, mostly dark dunes. **Fig. 2A** shows one of the numerous examples of the dark barchan dunes that travel over the HLL. The barchan passage leaves no observable trace on the HLL, which says that the HLL is strong. It is not clear if movement of the dark dunes occurs at the present epoch. All attempts to identify such movement during one martian year have failed [1]. In many locations the local lows in the dunes are filled with bright wind-blown material forming small dunes or ripples (e.g., **Fig. 2B**). This material is not abundant and probably is more easily mobilized than the material of dark dunes. There are a few examples where dust devil tracks cross the HLL, dark dunes, and bright ripples. The dust devil tracks result from removal of a thin dust film [e.g., 1]. Thus, neither dark nor bright sand experiences any saltation after the last dust storm in the region.

Icy layered deposits (LD) of polar cap outliers are deposited on top of the HLL. It looks like the HLL texture is kept preserved beneath the LD rather than forming when the LD retreat. Edges of the LD are often erosional exposing the layers. Thus the HLL is much more resistant to erosion than the LD. This may be related to the protective layer with low ice concentration, which preserves the ice of the HLL from sublimation; this upper layer, however, should be somehow indurated to provide mechanical strength.

There are clear examples of dunes that travel from the HLL to the exposed layers in the LD. In this case, dune migration postdates deposition and erosion of the LD. There are also clear examples, where erosion exposes layers and exhumes dunes, that is the dune migration predates deposition of the LD.

The stratigraphic relationships of the HLL with the main body of the polar cap are not clear. The contact at the cap edges is usually hidden. The flat floor of deep troughs has a texture similar but not identical to the typical texture of the HLL, and we cannot be sure that it is the same material.

Synthesis: Stratigraphic observations are summarized in **Fig. 3**. Deposition and removal of very thin films of bright fine dust by the dust storms and dust devils, as well as deposition and removal of seasonal CO_2 and H_2O frost occurs at seasonal time scale. Inter-annual accumulation and removal of dust and water ice films is obvious from inter-annual albedo variations [e.g., 1]. Migration of dunes is either related to anomalously strong winds or occurred under somewhat different climate conditions in the geologically recent past (we have not seen any fresh impact feature on the dune surface).

Deposition and erosion of the LD of the polar cap outliers also occurred in the recent past and was simultaneous or interleaved with dune migration. This process was controlled by climate variations due to astronomical forcing (variations of obliquity, eccentricity, and perihelion longitude) or intrinsic climate instabilities.

Formation of the HLL could be related to the most recent extremes of obliquity [3,4]: those of moderate amplitude (30° 0.4 Myr ago, 34° 0.6 Myr ago) or of high amplitude (42° 4.3 Myr ago; [9]). The observed fresh impact crater density, because of the cratering rate ambiguity, agrees with both cases. Formation of the HLL also can be related to the most recent catastrophic voluminous release of volatiles (the most recent volcanic eruptions and/or outflow event in Cerberus plains, or Chasma Boreale outflow [10]).

At higher latitudes, the formation of the upper sublayer of HLL could occur much later; this would explain the apparent difference in the crater retention age between higher and lower latitudes. Alternatively, the HLL of uniform true age could have been persistently covered at high latitudes by icy deposits similar to the modern polar cap outliers and protecting the HLL from impacts. These icy deposits retreated relatively recently [11]; H_2O from them was redeposit at the polar cap. 50 m thick layer of icy deposits extending down to 60°N being redeposited would add 400 m to the polar cap, which would explain the young crater retention age of the cap. The main body of the polar cap is probably older [12].

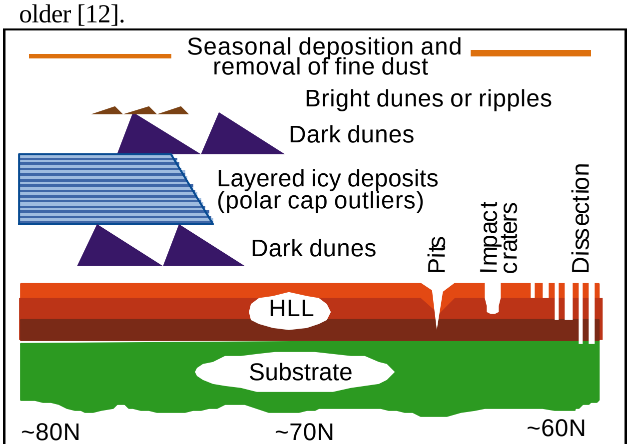

Fig. 3. Stratigraphy and zonality of the north circumpolar region

The sequence of events described seems reasonable and self-consistent. The major unresolved questions are (1) what is the detailed nature and origin of the HLL, and (2) why it is so different from LD.

References: [1] Malin M. C. and Edgett K. S. (2001) *JGR 106*, 23429. [2] Kreslavsky M. A. and Head J. W. (2000) *JGR 105*, 26695. [3] Kreslavsky M. A. and Head J. W. (2002) *GRL 29*, 10.1029/2002GL015392. [4] Mustard J. F. et al. (2001) *Nature 412*, 411. [5] Boynton W. V. et al. (2002) *Science 297*, 81. [6] Boynton W. V. et al. (2002) *Eos Trans. AGU*, *83*(47), P11B-02. [7]. Tokar R. L. et al. (2002) *GRL*, *29*, 10.1029/2002GL015691. [8]. Kostama V.-P. et al. (2003) *LPS XXXIV*, Abstract #1340. [9] Laskar J. et al. (2002) *Nature*, *419*, 375. [10] Fishbaugh K. E. and Head J. W. (2000) *JGR*, *105*, 22455. [11] Fishbaugh K. E. and Head J. W. (2002) *JGR*, *107*, 10.1029/2000 JE001351. [12] Head J. W. and Kreslavsky M. A. *LPS XXXIII*, 1744.