# THE MARTIAN NORTH POLAR LAYERED DEPOSITS AT HIGH RESOLUTION WITH THE MARS RECONNAISSANCE ORBITER HIRISE CAMERA

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**Goals of This Study:** Layers within the martian north and south polar layered deposits (PLD) have been reviewed in several previous publications [1-9]. Since then, images from the HiRISE camera are revealing unprecedented detail of polar layers which may be the most complete existing record of recent climate change on Mars. This first stage of our study of polar layers at high resolution is descriptive, but already we are finding possible repeating layer sequences which could be linked to climate signals. Later stages will delve into the possible processes which have created the various layer types and the climatic controls on layer deposition.

To begin this descriptive phase, we have chosen to analyze, in an example HiRISE image, layers which have been previously identified and correlated in MOC images [9], providing a context for our observations. Fig. 1 shows an example of the Upper Layer Sequence, as identified by [9], with the major layers labeled. The Marker Bed (MB in Fig. 1) is a layer first identified by [10] owing to its distinctive knobby texture and has been previously thought to be unique.

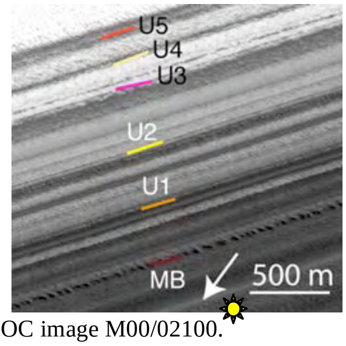

**Figure 1.** Portion of MOC image M00/02100.

**Initial Observations of Layer Morphology:** We begin with HiRISE image, PSP_001488_2665, which lies near the MOC image in Fig. 1. Figs. 2-4 show portions of this image. All layer thicknesses are approximate and absolute. In the interest of brevity for the abstract, we describe only a selection of the layers labeled in Figure 1.

The MB itself appears as a relatively dark, massive bed (thickness ≈ 8.5 m) with a faintly-visible drape-like texture (Fig. 2), which could be erosional in nature or it could indicate barely visible layering within the MB itself. Superposed on the bed are thin, linear grooves which might be made up of chains of tiny pits. These lineations extend into the surrounding material, but they are more pronounced within the MB itself; thus, the MB is particularly susceptible to whatever type of erosion is creating these lineations. Bounding the MB at the top are just visible, tiny pits. The characteristic knobby texture of the MB as seen in MOC images [10, 8] is apparently caused by fingers of the layer below reaching into it. This could be consistent with the idea that the MB represents a major lag deposit [7]; as the surface of the PLD ablated, it did so in an irregular fashion, leaving a hummocky surface contemporaneously filled-in by lag.

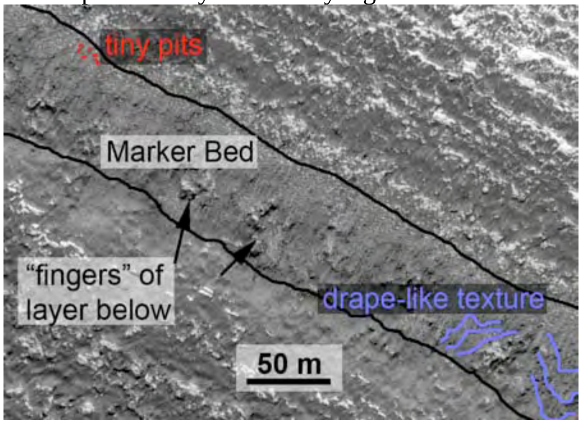

**Figure 2.** Portion of HiRISE image showing the MB. Illumination is from upper left.

The U2 layer has now been revealed as merely the topmost boundary of a massive layer (~15 m thickness) that is similar in appearance to the MB in that it is relatively dark and has a drapy texture, more pronounced here than in the MB. Again, faintly visible lineations cover the layer.

The U3 and U4 layers are now revealed as the topmost boundaries of two package of thinner layers. (Fig. 3). Each layer is ~0.8 –10 cm in thickness in the U3 set and ~10-40 cm in the U4 set. Keeping in mind that this is speculative, if we assume a deposition rate of 0.5 mm/yr [11], then one 10 cm layer would represent 200 years of deposition and the entire U3 package 20 Kyr. These layers grow thinner and thinner towards the top of each stack (down to the limit of resolution), because: they are indeed thinner, the lack of contrast there makes it difficult to distinguish layers, or the bright material is frost which is obscuring the layers. It is possible that the U3 and U4 layers sets, separated by ~18 m (36 Kyr at 0.5 mm/yr constant accumulation rate), represent the same type of depositional/erosional environment, a repeated climate signal. One could play with these numbers further and assume, for example, that the 18 m separation corresponds to the perihelion cycle, giving a deposition rate of 0.36 mm/yr or to the long-term oscillations in eccentricity, giving a rate of 0.009 mm/yr.

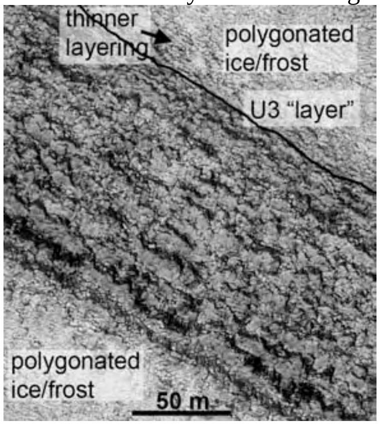

**Figure 3.** Close up of U3 layer set. Some of the ice/frost has polygons on its surface. Illumination is from upper left.

Just below the MB, fine-scale layering is apparent and layers are degraded but traceable. Other layers appear as ridges surrounded by grooves and occur in several packages, again possibly indicating a repeating climate signal.

Below the MB, lies a layer similar in appearance to the MB with a thickness of ~9 m. This layer has a drapy texture and pitting at its top boundary but no "fingers" of the layer below, rather, the bottommost boundary of this layer is difficult to delineate. We have thus identified two layers similar to the MB in addition to the original MB; they range in thickness from ~9 m – 80 m and are separated by 43 and 97 m.

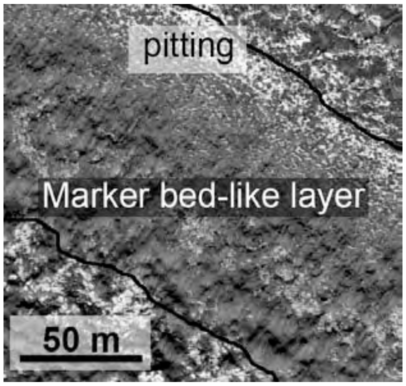

**Figure 4.** Example of a layer similar to the MB but lying stratigraphically below it. Illumination is from upper left.

**Initial Observations of Layer Albedo:** The fundamental albedo of even the exposed surface of any of the layers is not easy to determine. It appears that layers are brightest on the tips of their hummocks and knobs and on the north- (up-trough-wall) facing side of ridges and slopes. In general, layer brightness decreases down-section. These observations are consistent with several possibilities. 1) The layers are inherently dark, but frost collects on north facing slopes and increases in extent (and maybe thickness) further up-section, toward the top of the PLD. 2) The layers are inherently relatively bright, but as they sublimate in the summer, sublimation lag builds up in the hollows and in places protected from winds blowing off of the PLD surface and down the trough wall slope. In this case, the lag also tends to collect at the shallower slopes towards the bottom of the trough as it is removed from upper layers by wind and mass-wasting. 3) Or #2 is true in addition to the fact that frost increases up-section. If the marker-bed-like layers are indeed relatively friable, then they may have a convex configuration, which would allow lag to collect on top of them and could explain their relatively low albedo. Dust lag may also be obscuring thin layers, making them invisible to orbital imaging.

**Summary:** In this preliminary analysis, we have thus far found that many layers which have previously been identified using MOC data [9] appear in higher-resolution HiRISE data as the topmost boundary of a package of thinner layers or as one layer but with more visible detail. For the most part, throughout the image, layer boundaries are not sharp at this scale. Additionally, HiRISE does reveal layering down to the limit of its resolution (<1m thickness), but only in confined places, not ubiquitously. Thus, even at a resolution of 30cm/pix, some layers appear as massive beds. We have also identified several sets of thin layers and several layers which are similar to the "Marker Bed", possibly indicating repeating climate signals. When moving from a description of the layers to identification of a depositional history, one must remember that the morphologies visible today could be highly modified (e.g., eroded) versions of their original selves. One should also keep in mind that without in-situ analysis, such as of drill core samples, we cannot see chemical or isotopic layering; and resolution limits and obscuration by frost and dust prevent us from seeing annual or decadal layer packages. Further analysis will include more images and the use stereo data.

**References**: [1] Murray, B., et al. (1972), *Icarus*, *17*, 328-345. [2] Cutts, J. and B. Lewis (1982), *Icarus*, *50*, 216-244. [3] Howard, A., et al. (1982), *Icarus*, *50*, 161-215. [4] Thomas, P., et al. (1992), in *Mars*, University of Arizona Press, 767-795. [5] Fenton, L. and K. Herkenhoff (2000), *Icarus*, *147*, 433-443. [6] Byrne, S. and A. Ivanov (2004), *J. Geophys. Res.*, *108 E11*, 10.1029/2004JE002267. [7] Milkovich, S. and J. Head (2005), *J. Geophys. Res.*, *110 (E05)*, 10.1029/2004JE002349. [8] Milkovich, S. and J. Head (2006), *Mars*, *2*, 21-45. [9] Fishbaugh, K. and C. Hvidberg (2006), *J. Geophys. Res.*, *111 E06012*, 10.1029/2005JE002571. [10] Malin, M. and K. Edgett (2001), *J. Geophys. Res.*, *106 (E10)*, 23,429-23,570. [11] Laskar, J., et al. (2002), *Nature*, *419*, 375-377.