

THE STRATIGRAPHIC RECORD IN THE MARTIAN NORTH POLAR LAYERED DEPOSITS AS MEASURED BY HIGH RESOLUTION STEREO TOPOGRAPHY. K. E. Fishbaugh¹, C. Hvidberg², S. Byrne³, K. Herkenhoff⁴, C. Fortezzo⁴, R. Kirk⁴, M. Winstrup². ¹Smithsonian National Air and Space Museum, Center for Earth and Planetary Studies, Washington, DC, fishbaughke@si.edu. ²Niels Bohr Institute, Center for Ice and Climate, U. Copenhagen. ³Lunar and Planetary Laboratory, U. Arizona. ⁴U.S. Geological Survey, Flagstaff, AZ.

Introduction: We have previously described the detailed morphologic characteristics of layers within the north polar layered deposits (NPLD) [1]. Here, we discuss quantitative morphology gleaned from a high-resolution, stereo DEM, including the production of the most detailed stratigraphic column of the NPLD produced to date and the implications for a quantitative connection with climate.

As discussed previously [1], we have identified many layers within the upper NPLD similar to the erosionally resistant and easily recognizable “marker bed” discovered by Malin and Edgett [2] in MOC images. Many of these marker beds correspond to layers making up the Upper Layer Sequence, correlated across the NPLD by Fishbaugh and Hvidberg [3], using MOC images. Because these layers are erosionally resistant (protrude from surrounding layers), can be correlated from one location to another, and are similar to each other in detailed morphology, we consider them to be key layers in the NPLD stratigraphy and the manifestation of a repeating climate signal. HiRISE images reveal details of these layers not visible in MOC, and, using the DEM, we can measure the thicknesses and separation distances of these layers, a feat not previously possible but crucial to connecting the layers to climate change mechanisms.

Between the marker beds lie sets of thinner layers, just barely visible in MOC images, and previously termed “laminated layers” [4]. The remaining material appears undifferentiated due to erosion; however, it may constitute a third layer type whose boundaries are not clearly visible, due to erosion and later deposition of frost and dust.

Datasets and Methods: To classify layer types and identify layers previously used in MOC correlations [3], we have analyzed HiRISE images at the same locations as the MOC images used by Fishbaugh and Hvidberg [3]. For morphometric measurements, we use a 1m/pixel scale, ~30 cm vertical accuracy DEM, created from the HiRISE stereo pair PSP_001738_2670 (87.1°N, 92.8°E) and PSP_001871_2670 (87.1°N, 92.6°E) [1].

We use a conservative approach for creation of the stratigraphic column: we identify layers as marker beds only if they possess distinct morphology similar to that of the original marker bed; we note the positions of distinct, highly preserved thin layers, but do not

measure their individual thicknesses; we leave as undifferentiated sections that are not clearly identifiable.

We measure layer thicknesses and separations by overlaying the HiRISE images on the DEM and a DEM-derived shaded relief map in ESRI’s ArcMap. We mark layer boundaries using the shaded relief and image (morphology) and extract the elevations of these boundaries from the DEM. The elevation of each boundary is gleaned from an average of multiple elevation measurements along the boundary.

Results: Figure 1 presents a stratigraphic column of layers exposed in the DEM stereo image pair. Orange layers are identified by their morphology as marker beds, green layers are distinctive in topography, but are not obviously marker beds, blue represents sets of thin layers, and gray are undifferentiated sections. Dip is ignored for simplicity.

Thinning with Depth: It appears possible that layers (especially the marker beds) become thinner with depth. Several potential reasons for this are: a lower deposition rate in the past, layer thinning resulting from ice flow, layer thinning resulting from compaction, and/or observational bias due to shallower slopes at depth. To assess these possibilities, we have plotted layer thickness as a function of average slope at a 50 m baseline and find no correlation; thus, decreasing slope is not creating a bias. We also note that the separation distance between thin and marker bed layers does not decrease with depth, making unlikely the possibility of thinning due to ice flow or compaction. Thus, the thinning of layers with depth is a real, primary effect of decreased deposition rate in the past, but the trend does not apply to every layer and is non-linear.

Rhythmic Layer Sequences?: A rhythmic sequence of layer types is not immediately apparent. However, it is possible that the marker beds, and the beds labeled green in Fig. 1 can be grouped into clusters based on their separation distances. The average distances of these clusters lie at ~30.7 m, 21.0 m, 12.5 m, and 6.3 m. Interestingly, the first cluster is similar to the dominant brightness wavelengths (from Fourier analysis) of ~30 m and ~21 m calculated by Milkovich et al. [5] (though the latter number was not called-out as dominant, it is evident in their results). However, since there are only 14 layers used to identify these clusters, and since we have only one DEM for analysis,

it is perhaps too early to definitively claim these separation distances as characteristic of marker beds throughout the NPLD. There also appears to be no clustering of or repetition in marker bed thicknesses (1.6 m – 16.0 m +/- 2m), no correlation between separation distance and marker bed thickness, and no correlation between the thicknesses of the thin layer sets and the separation of the marker beds between which they lie.

Implications for Connections to Climate Change: The results reported above do not at first seem to bode well for connecting the stratigraphic record with theoretical changes in insolation and other climate-change triggers. To first order, the absence of any obvious stratigraphic patterns can be attributed: 1) to erosion of the NPLD and later deposition of frost and dust, erasing some of the thinner layers and wiping out the exposures of layer boundaries in the undifferentiated sections; 2) to the fact that layer deposition depends on the period AND amplitude of the insolation curve, possibly in a non-linear way and with lags in response time; 3) (related to 2) to the fact that particular values are rarely repeated in the insolation curve of the past 20 Myrs [6]; 4) to episodic events, such as impacts, melting, periods of faster ice

flow, and volcanic eruptions; and 5) to changing size and location of water reservoirs contributing to NPLD build-up.

We propose to extract any subtle, first-order connection with climate by concentrating on the insolation curve calculated by Laskar et al. [6]. We will present preliminary results of a new, unique inverse model wherein we assume a non-linear relationship between accumulation/ablation rate and insolation and attempt to match the observed, quantitative stratigraphy in Fig. 1. We will take into account the fact that the NPLD are mostly likely no older than 5My, as insolation conditions would have prevented net buildup before that time [7], assuming any dust lag was not effective at preventing sublimation.

References: [1] Fishbaugh et al. (2009), *Icarus*, in revision, and *EPSC 2008*, abstract EPSC2008-A-00307-1. [2] Malin, M. and K. Edgett (2001), *JGR 106*, 23,429-423,570. [3] Fishbaugh, K. and C. Hvidberg (2006), *JGR 111*, doi: 10.1029/2005JE002571. [4] Milkovich, S. and J. Head (2006), *Mars 2*, 21-45. [5] Milkovich, S. and J. Head (2005), *JGR 110*, doi:10.1029/2004JE002349 and Milkovich, S. et al. (2008) *PSS 56*, 266-288. [6] Laskar et al. (2004), *Icarus 170*, 343-364. [7] Jakosky et al. (1995), *JGR 100*, 1579-1584.

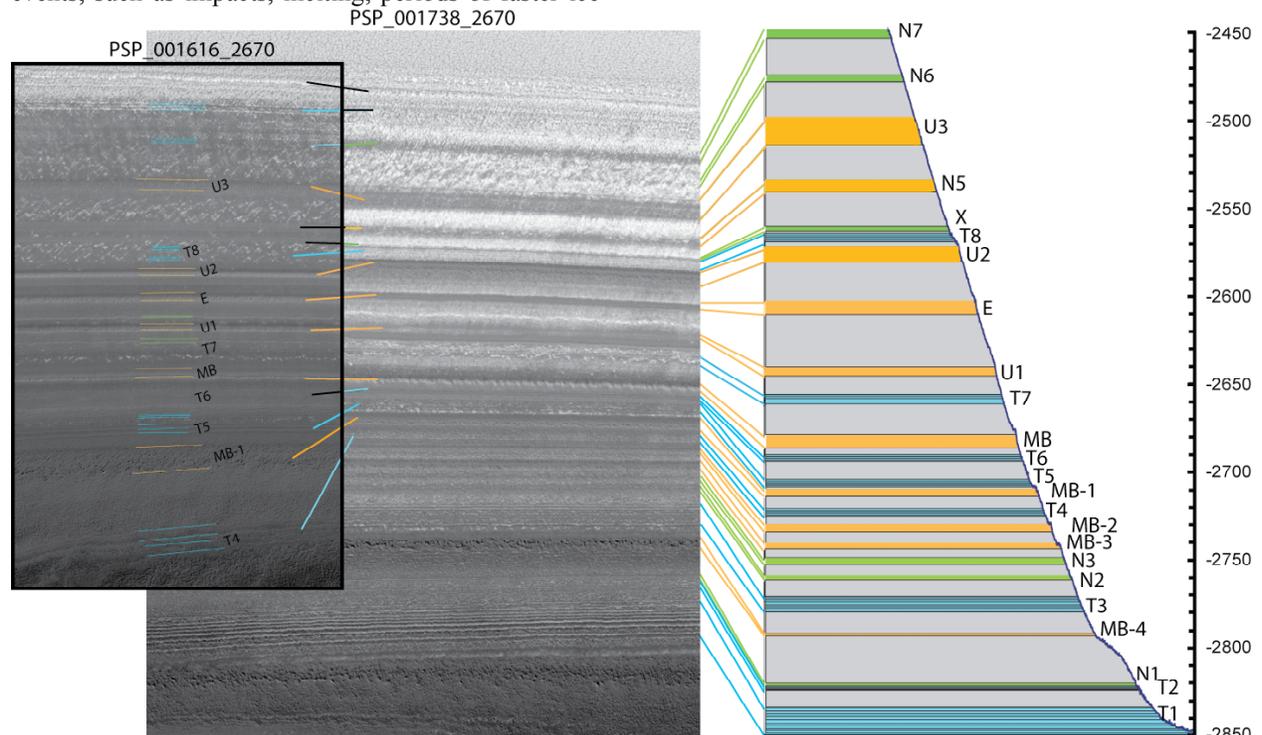


Fig. 1. Center: HiRISE image PSP_001738_2670, one image of the stereo pair used to create the DEM. Left: PSP_001616_2670 (87.0°N, 175.4°E) with correlations to layers in center image. Correlations performed by comparing layer morphologies and placing layers in the stratigraphic context described by [3]. Layers U3, U2, E, U1, and MB were originally identified by [3]. All other layers have been newly identified in this study. Right: Stratigraphic column created from the HiRISE stereo DEM. Topographic profile and elevation scale are taken from the DEM. See text for explanation of colors.