CHARACTERIZING AND DEFINING LAYERS IN THE MARTIAN NORTH POLAR DEPOSITS USING HIRISE: IMPLICATIONS FOR CLIMATE CHANGE. K. E. Fishbaugh[1], S. Byrne[2], K. Herkenhoff[3], P. Russell[4], R. Kirk[3], A. McEwen[2], and the HiRISE Team. [1]Smithsonian Institution, National Air and Space Museum, Center for Earth and Planetary Studies (CEPS), P.O. Box 37012, MRC 315, Washington, DC 20013-7012, fishbaughke@si.edu. [2]Lunar and Planetary Laboratory (LPL), University of Arizona. [3]U.S. Geological Survey, Flagstaff, AZ. [4]Physikalisches Institut, Universität Bern, Switzerland.

Introduction: Since their discovery in Mariner 9 [e.g., 1] and Viking images [e.g., 2], layers within both the north and south polar layered deposits (PLD) have been characterized broadly as alternating bright and dark stripes. This "striping" has been suggested to be linked to changing relative amounts of dust and ice in the atmosphere as a result of changing orbital parameters and, hence, changing climate [1, 3-5]. Here, we use high resolution image and topographic data from MRO's HiRISE to better characterize layering within the NPLD, to take a new look at how "layer" could be defined, and to examine the implications of these analyses for global climate change. Since the PLD likely contain the most complete record of relatively recent climate change on Mars, it is crucially important to obtain a realistic understanding of what a "layer" is and what its characteristics and stratigraphic position tell us about the contemporary martian climate.

What is a Layer?: The way one defines a layer depends on the method being used to detect layers. When using images, layers are delineated by their brightness and morphology, characteristics that are influenced by a myriad of factors. Layers defined this way do not necessarily correspond directly with layers identified, e.g., in radar data [6]. While both types of layers may tell us something about climate change, can either alone necessarily be linked directly to changing orbital parameters?

Scale is also important. Layers revealed in Viking images actually constitute packages of MOC-scale layers. If one used a method similar to [4] or [5] and attempted to tie Viking-scale layering (defined by brightness) directly to changing obliquity and then did the same for MOC-scale layering, the results could likely be quite different. Surprisingly, HiRISE has not revealed even thinner layering than MOC, but rather has highlighted much more detail of layers of the same scale as visible (some just barely) in MOC; the thinner layering that certainly exists is obscured by younger, surficial deposits of frost, ice, and dust and by slumping of this material and possibly of material inherent to the layers themselves. The thinnest layers visible from orbit are ~0.3-1 m thick, as measured in a 1m/pix, sub-meter vertical accuracy HiRISE DEM created from the stereo pair, PSP_001871_2670 and PSP_001738_2670.

In this abstract, we summarize what we have learned so far about the properties of NPLD layers from HiRISE data, which constitutes an initial step toward clarifying the complexity of layer definitions and their implications.

Layer Brightness: HiRISE has confirmed that apparent layer brightness is not necessarily indicative of the bulk composition of the layer [7]. Surficial, younger deposits of ice, frost, and dust and illumination angle can mask inherent layer brightness. New analysis of the HiRISE DEM shows that surficial frost/ice deposition and/or retention depends on meter and sub-meter scale surface roughness (Fig. 1), aspect, and slope. But since surface roughness is determined at least partially by erosion, and since a layer's resistance to erosion is determined by its inherent composition, apparent brightness can be used to make a general, first order definition of a layer, keeping in mind all the corresponding caveats. However, as discussed below, stratigraphic studies are greatly enhanced by characterizing layer morphology and by the use of DEMs, rather than by observing apparent brightness alone.

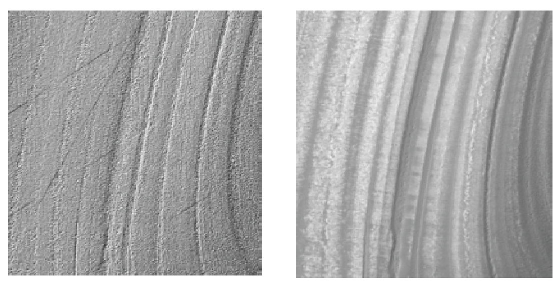

Fig. 1. (L) Portion of shaded relief map created from HiRISE stereo DEM. (R) Portion of HIRISE image. Width = ~2 km. Smoother areas have more frost.

Layer Morphology: Many previous authors have used apparent brightness combined with layer morphology to identify particular layers in MOC images and to correlate them from place to place [5, 8-13]. Fishbaugh and Hvidberg [10] have shown that the morphology of a particular layer in a MOC image can vary from one location to another. It is evident in HiRISE images that this variation is at least partly due to the location of the image footprint with respect to the trough [14]; an image located on a prominent bend in a trough exhibits more eroded layering than an image located on a straight trough wall, for example, perhaps due to being buffeted more by winds. Even the famous Marker Bed [13] changes appearance dramatically across the PLD in HiRISE images. Because of the variation in morphology, even of a particular layer, [10] concluded that apparent brightness, morphology, and stratigraphic position are needed to identify specific layers and to correlate them across the PLD; the one unifying characteristic of each of these layers is relative resistance to erosion. What these various authors have identified as “layers” in MOC images likely consist of a mix of many kinds of layers that can be defined in many ways: single, massive depositional beds, packages of thinner morphological layers, layers with and without chemical differences from the adjacent layers, morphologic layers and packages of layers that correlate with radar layers, etc. Using HiRISE images, we have been able to discern more details of the MOC layers and thus to make more detailed morphologic/stratigraphic layer correlations [14].

Topographic Expression: The creation of DEMs from HiRISE stereo pairs has significantly improved our ability to determine layer thickness and more accurate layer elevations than was previously possible using MOLA data. However, the topographic expression of morphologically-defined layers is not completely straightforward. Fig. 3 shows several profiles taken across a small portion of a HiRISE image. It is immediately clear that the topographic expression of most of the morphologically visible layers is on the scale of the (erosional) roughness (~≤ 1m). Analysis of profiles along the full image shows that breaks in slope that exist in nearly the same location in every profile (and hence are not erosional “noise”) correspond to particular morphologic/stratigraphic layers previously identified in MOC images [10].

Unraveling the Climate Record: Within one HiRISE image, we have discovered at least four morphologic layers that are similar to the original “marker bed” [14], all of which display a prominent topographic expression. These layers likely represent a repeating climate signal. The next step is to determine possible origins for these layers, given their detailed characteristics in HiRISE images, in order to better place them in the climate history. If, for example, a particular obliquity range would produce a marker bed-like layer of a particular thickness then one cannot just directly link a stratigraphic pattern with the obliquity period; amplitude would also need to be considered. If the marker bed-like layers are massive beds, while some of the other prominent layers are actually packages of thinner layers, then the relationships of each of these to climate would clearly be different.

A close look at the HiRISE DEM shows similar layer thicknesses for the prominent morphologic layers, ranging from ~4m – 5m, with one exception at ~8m. Separations between these layers appear to follow a pattern (24 m, 31 m, 31 m, 23 m, 30 m) and are similar to the dominant brightness wavelength detected by [5]. The next step is to create more HiRISE stereo DEMs to determine whether this pattern repeats across the PLD and to make comparisons of the elevations of these prominent morphologic layers with the elevations of radar layers. If the morphologic layers correspond to radar layers, then we can also determine something about their dielectric properties, in turn helping us to determine their origin and place in the climate history.

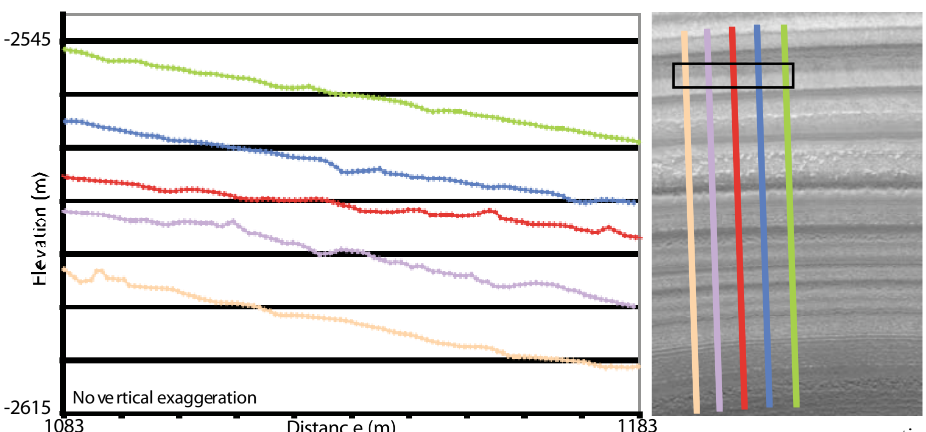

Fig. 3. Topographic profiles across NPLD, coresponding to boxed portion of HiRISE image. Profiles have been shifted horizontally for clarity.

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