STRATIGRAPHIC ANALYSIS OF THE NORTH POLAR CAP OF MARS: RECENT CLIMATE HISTORY. Sarah M. Milkovich and James W. Head, Department of Geological Sciences, Brown University, Providence, Rhode Island 02912 USA Sarah_Milkovich@brown.edu.

Introduction: The northern polar cap of Mars is characterized by spiraling troughs cutting through the cap surface. Horizontal and subhorizontal layers exposed on the walls of these troughs are thought to contain varying ratios of water ice and dust. These polar layered deposits (PLD), first observed in Mariner 9 images [1, 2] and later studied in detail with the Viking orbiters [e. g. 3, 4, 5, 6], extend throughout the cap.. Recent images from Mars Global Surveyor (MGS) show that the layers have a range of thicknesses and albedos [7, 8]. Formation theories regard the layers as products of climate change due to orbital cycles [9, 4, 5], similar to climate changes caused by Milankovitch cycles on Earth [e.g., 10], although the details of the formation processes remain unknown.

As a first step in unraveling the relationship between the polar layered deposits and climate, it is necessary to understand and quantify the characteristics of the layers themselves in individual sections. Then it is necessary to establish whether there are any correlations between adjacent sections as well as any regional or cap-wide correlations. Finally, it is important to establish if and how such correlation is consistent with depth in the vertical sections representing changes with geological time. Once the signals encoded in the layers and their lateral and vertical correlations are known, then their relationships to climate change can be assessed. The results reported here are part of an ongoing effort to characterize quantitatively the layers both vertically, by looking for patterns in vertical stratigraphy, and horizontally, by examining variations in layer continuity on local (trough-wide) and regional (cap-wide) scales and build upon work reported elsewhere [11]. The results are then used to assess models of polar history and climate. We also combine images of layer exposures with altimetry measurements of the Mars Orbiting Laser Altimeter (MOLA) to examine the geometrical orientation of the PLD.

Method: Many studies of terrestrial climate change are in the field of paleoceanography. We use two techniques commonly employed in paleoceanography for the study of deep-sea sediment cores on Earth to establish the characteristics of layers in individual cores (Fourier analysis) and to determine the correlation between cores (curve-shape matching algorithms).. These techniques are described in more detail in [11]. By adapting these methods to study the stratigraphy of the polar layered deposits we are able to assess patterns and correlations between locations within the cap.

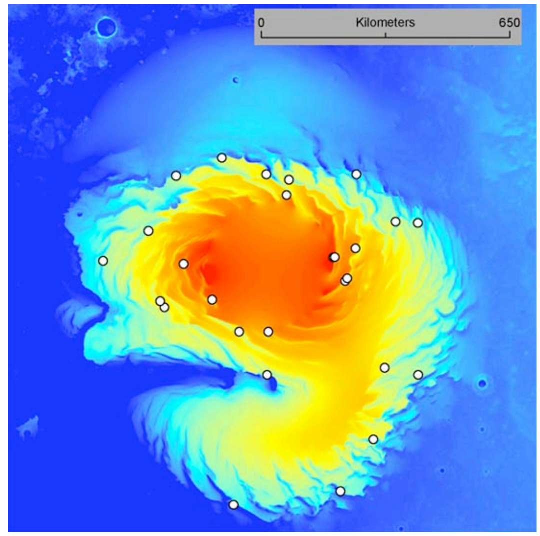

Fig. 1. Locations of 27 images analyzed to date on top of MOLA topographic map of the north pole.

Results: In our recent analysis [11], application of these techniques to "cores" (vertical sections) of the north PLD from 13 images around the cap revealed several fundamental properties of north polar cap stratigraphy. Results of our current analysis of 14 additional images around the cap are consistent with these properties: 2) Application of curve-shape matching algorithms demonstrates that layers correlate across the cap in 23 of the 27 images analyzed to date (Fig.1). Three of the remaining four images are of lower resolution and thus likely do not contain enough data for the matching algorithm to be successful. 2) Fourier analysis of the layer vertical sequences reveals a characteristic and repetitive wavelength of ~30 m thickness throughout the upper ~ 300 m (Zone 1) of all 27 sequences analyzed. 3) Examination of layers located deeper in the stratigraphic sequence than Zone 1 provides evidence for a unit less than 100 m thick (Zone 2) in which the fundamental ~30 m sequence is not detected (Fig. 2). 4) The layers immediately below Zone 2 again contain a repetitive dominant wavelength of ~ 30 m.

We interpret these results as follows: 1) The lateral correlation and broad distribution of these layer sequences strongly imply that layer accumulation processes are widespread across the cap, rather than confined within a single trough or region. 2) The fundamental ~30 m signal in Zone 1 is interpreted as a climate signal that may correspond to a 51 kyr insolation cycle [11]. 3) The underlying Zone 2 is interpreted as a deposit formed during a recent high-obliquity phase of Mars, during which time polar volatiles underwent mobilization and were transport equatorward, leaving a polar lag of dust-rich material. The most recent "ice age" (~0.5-2 Ma) offers a plausible candidate for this period of ice cap removal and lag formation (Fig. 3).

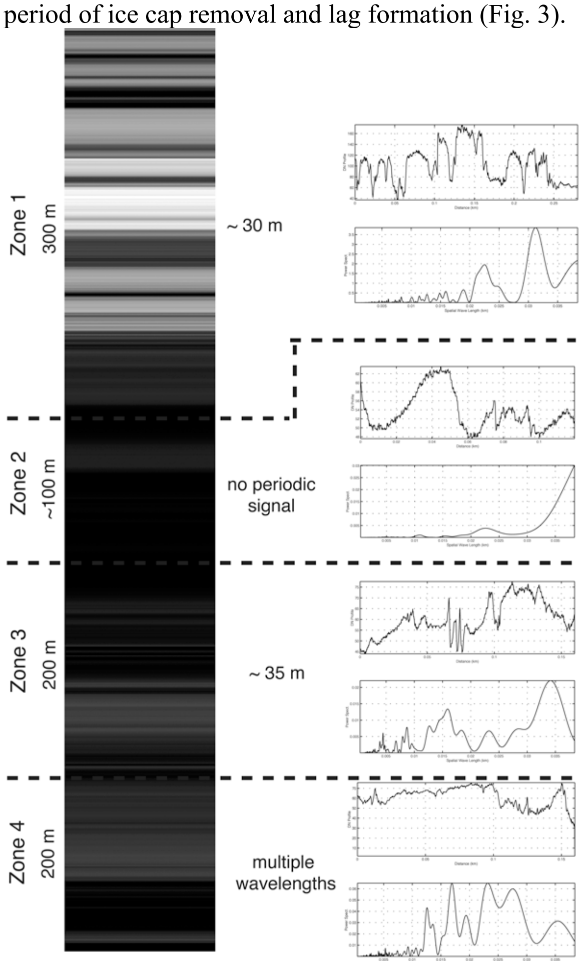

Fig. 2. FFT analysis of a composite stratigraphic column from M00-02100 and M00-01714 exposing deeper layers in the cap with resulting distinctive “zones” identified.

Discussion: These findings support earlier interpretations that orbital parameter variations could cause significant erosion and possibly complete removal of the polar caps [e.g., 12]. This suggests that polar material is accumulated and removed throughout geological history, constantly resetting the crater record. The interpreted crater retention ages of the layered terrain [13] are consistent with the correlations and vertical sequences described here. The matching analysis indicates that local to regional variability in individual layer thicknesses (and thus accumulation and sublimation rates) is typically less than a factor of 2.5, implying the existence of local scale climate effects on layer accumulation.

The south polar cap also contains PLD although images show them to have several distinctive characteristics compared to the north PLD [1, 6, 7]. FFT analysis of layers exposed in image M08-05817 (Fig. 4) reveals a dominant wavelength of 35 m, within the range of results for the north PLD Zone 1. An attempt was made to match this image to the target image in the north cap; no good match could be made. This may indicate that while similar climate forces drive the formation of the south PLD (as evidenced by the FFT results), the timing or conditions at the formation of individual layers are different between poles.

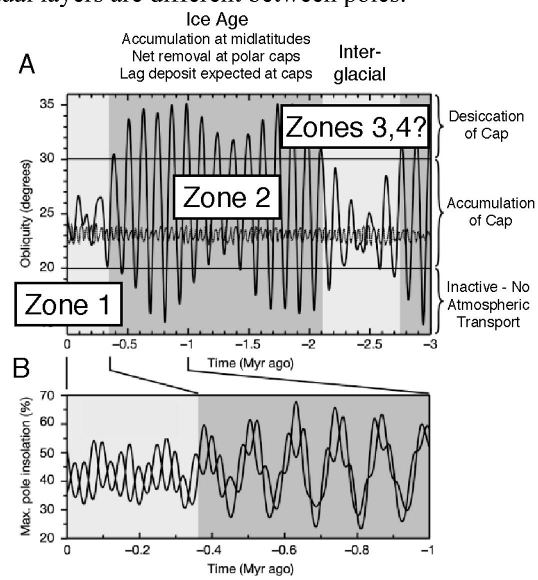

Fig. 3. Recent martian obliquity and insolation. Proposed correlation with zones from FFT analysis of layers is indicated by white boxes.

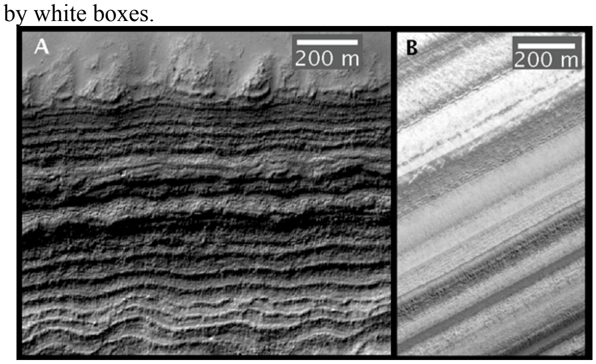

Fig. 4. PLD in the north and south caps. A) M08-05817 from the south. B) M00-02100 from the north.

References: [1] Soderblom, L. A., et al. (1973) *J. Geophys. Res.,78,* 4197-4210. [2] Cutts, J. A., (1973) *J. Geophys Res., 78*, 4231-4249. [3] Kieffer, H. H., et. al, (1976) , *Science, 194*, 1341-1344. [4] Blasius, K. R.,et al. (1982) *Icarus, 50*, 140-160. [5] Howard, A. D.,et al. (1982) *Icarus 50*, 161-215. [6] Thomas, P. et al, (1992) In *Mars*, H. H. Kieffer et al ed. Univ. of Arizona Press. [7] Malin M. C. and Edgett K. S. (2001) *J Geophys Res, 106*, 23429-23570. [8] Milkovich, S. M. and J. W. Head (2001) *LPSC 32*, 1973. [9] Squyres, S. W. (1979) *Icarus 40*, 244-261. [10] Imbrie, J. (1982) *Icarus 50*, 408-422. [11] Milkovich, S. M. and J. W. Head (2005) North polar cap of Mars: Polar layered deposit characterization and identification of a fundamental climate signal, *JGR* in press. [12] Jakosky, B., Carr, M. (1985) *Nature, 315,* 559-561. [13] Herkhenoff, K., Plaut, J. (2000) *Icarus, 144,* 243-253.