CHARACTERIZATION AND COMPARISON OF LAYERED DEPOSIT SEQUENCES AROUND THE NORTH POLAR CAP OF MARS: IDENTIFICATION OF A FUNDAMENTAL CLIMATIC SIGNAL. S. M. Milkovich and J. W. Head, III, Department of Geological Sciences, Brown University, Providence, RI 02912. Sarah_Milkovich@brown.edu

Introduction: Layered deposits exist within the northern residual cap of Mars exposed on the walls of the dark lanes or troughs seen cutting into the cap. These deposits consist of extensive lateral layers of ice and dust and are found throughout the polar cap. They were first identified in Mariner 9 images [1, 2] and later studied in detail with the Viking orbiters [e. g. 3, 4, 5, 6]. Recent images from Mars Global Surveyor show that the layers have a range of thicknesses and albedos, and are not continuous throughout the cap [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 [10], although the details of the formation processes remain unknown.

Characterization of the layered deposits is key to understanding the details of the layer formation process as well as understanding the processes which shape the polar regions and the martian climate as a whole. Here we present new work in our continuing effort to quantitatively correlate layers in images in order to assess variations within the layered deposits. Such variations can provide constraints for layer formation; for example, how widespread and how uniform is layer deposition on an individual layer scale, and how well do layers correlate within and between troughs?

Method: Many studies of terrestrial climate change are in the field of paleoceanography. Thus, we have adapted two paleoceanographic techniques for studying correlations and variations between ocean drill cores. The first method, Fourier analysis, is used to examine a stratigraphic column for cycles and patterns. The second method matches distinctive shapes in two data sets to establish correlations and to get a sense of the correlations and changes in accumulation rate between the two sites. By adapting these methods to study the stratigraphy of the polar layered deposits we are able to assess patterns and correlations as well as get a sense of the variations between locations within the cap.

Profiles of grayscale intensity, or digital number (DN), taken from MOC images are compared using Match 1.0, a program developed by Lisiecki and Lisiecki [11] to compare sets of paleoceanographic data. This program uses dynamic programming to minimize the square of the differences between the data sets in order to adjust one data set to fit as close as possible to the other set. The Fourier analysis is accomplished using a Fast Fourier Transform (FFT) program in Matlab on image profiles.

Prior to comparing profiles from two images, the images must be calibrated and corrected for the slope of the trough wall using the associated MOLA data. The details of this procedure are discussed elsewhere [12, 13, 14, 15] The data from an overhead image is adjusted to be more like the data from a core sample perpendicular to the cap surface.

Previous Results: An earlier analysis near 280˚W [12, 13, 14, 15] found that 7 images in a region of $1.6x10^4$ km^2 or 3.9% of the cap have a ~30 m wavelength, indicating a characteristic deposit thickness which may be due to a climatic process. Visual examination of these images indicate approximately 6 to 12 layers per 30 m layer packet. Six images in a region of 1.3×10^4 km^2 or 3.3% of the cap match, indicating a laterally broad deposit of similar layers. The remaining image located at a lower elevation does not match the others but has the ~30 m wavelength. The layers contained within this image were likely deposited in another portion of polar history. This indicates, however, that the 30 m cycle has occurred several times in polar history despite the difference in details of the layers.

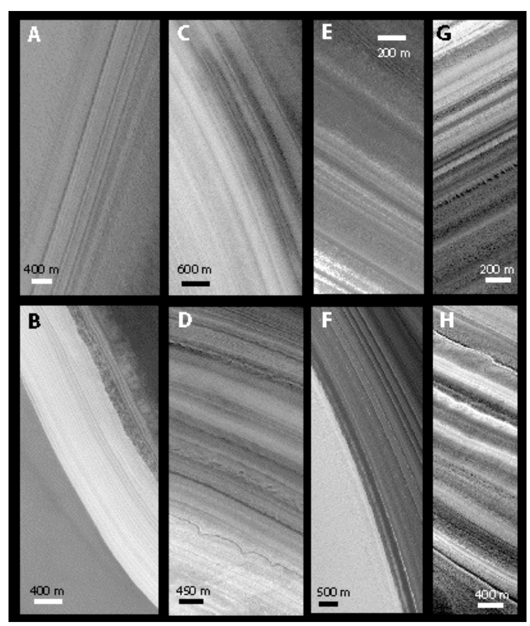

Figure 1: MOC images used in this analysis. A) M21-00236 B) E02-01438 C) M03-01690 D) M02-04286 E) M00-01733 F) E02-01540 G) M00-02100 H) M00-03037.

Net accumulation rates vary between images10s to 100s of km apart, from factors of 0.5 to 5.0 but less than a factor of 2 for a vast majority of the profiles. The highest changes in net accumulation rate (greater than 2) occur as spikes over 20 m or less elevation. This implies the importance of local scale effects on layer accumulation, such as the influence of the distance from the pole, trough geometry and trough orientation on insolation and wind patterns.

As part of this analysis, we wish to examine how these results compare with those from elsewhere on the cap in terms of lateral continuity and vertical variations.

Current Analysis: The six new images selected for this analysis (Figure 1) were chosen to cover the same elevation range as the initial study (represented by the right-most two images in Figure 1). They were taken in the same Ls range (northern summer) to minimize the effects of seasonal frost. The images were designed to be from locations at 90˚ intervals around the cap. Due to the availability of images containing layer exposures at the correct elevations and season, the actual locations are 80-95˚ apart. For this analysis, profiles were constructed by averaging across 200 pixels along the layers to provide more robust DN values.

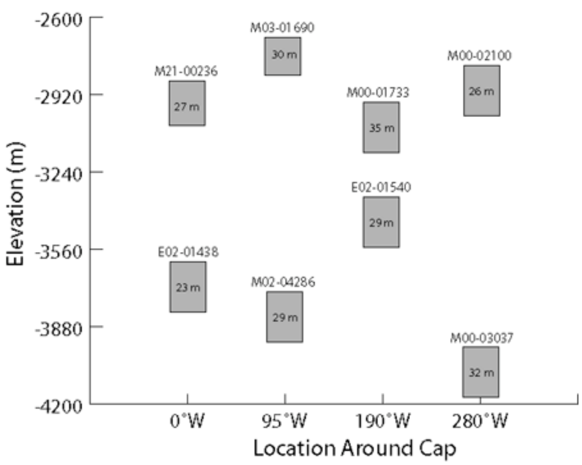

Figure 2. Results of FFT analysis. Boxes indicate elevation of image profiles with respect to elevation and longitude; numbers inside indicate dominant wavelength.

FFT analysis. Five of the six images examined have dominant wavelengths ranging from 27 to 35 meters. These values fall within the range of dominant wavelengths found in the previous analysis of seven images located around 280˚W (24 to 33 meters) [13, 15]. The sixth image has a dominant wavelength of 23 meters; this value is far enough away from the others that it may indicate a unique and different result.

Matching analysis. A preliminary matching analysis was carried out matching images M03-01690 and M02-04286 with M00-02100 using a single, non-averaged profile from each image. Both images display a high level of match with M00-02100, with coefficient of determination (r^2) values of 80.62% and 80.78% respectively. This value indicates how much of the variation within one dataset is related to the variation within the other; thus, the images match well.

This analysis is being refined and extended to include the remaining images using the 200-pixel average profiles. In addition, the data will be filtered to remove the general trend from light (top of the trough) to dark (bottom of the trough) observed in every image in order to improve the quality of matches.

Discussion. The results of this analysis indicate that the deposit characterized in [13, 14, 15] at 280˚ W continues laterally around a majority of the cap. In addition, the fact that the ~30 meter dominant wavelength found at 280˚ W is found throughout the cap indicates that this wavelength is likely a signature of the driving climatic processes forming this deposit.

Implications. The identification of a climatic signature across the pole combined with the high match between three images around the cap indicates that the deposition of layers is on a cap-wide scale rather than a trough scale. This result implies that layer formation mechanisms involve more than simple local redeposition of material sublimated from exposed trough walls. The high level of match additionally implies that the layer accumulation rates of 0.01 cm/yr calculated by Laskar et al [16] for M00-02100 may also apply to the areas at 190˚W and 95˚W.

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