THE SIGNIFICANCE OF SUB-MILANKOVITCH SIGNALS IN THE MARTIAN NORTHERN POLAR LAYERED DEPOSITS. J. P. Sotzen[1] and K. W. Lewis[1], [1]Johns Hopkins University, Earth and Planetary Sciences Department (2800 N Charles St, Baltimore, MD 21218)

Introduction: The polar layered deposits (PLD) on the northern polar cap of Mars are identified as varying mixtures of water ice and dust in individual layers, and are thought to contain a record of the recent paleo-climate of Mars [1]. The PLD are observed in outcrop exposures along the spiral troughs of the northern polar cap, which contain bright and dark horizontal layers which extend hundreds of kilometers.

Analogous to Milankovitch Cycles on Earth, orbital cycles (i.e. obliquity, and eccentricity) are thought to affect the intensity and frequency of dust within the atmosphere due to changes in solar insolation and thereby the dust content of the deposited ice on the polar caps [2]. Since the discovery of the PLD, there have been efforts to recover a signal from the layers which could ideally be correlated to orbital forcing [1,2,3,4].

Twelve sites were surveyed across the northern polar cap using stereo HiRISE imagery from the Mars Reconnaissance Orbiter (MRO). Digital Elevation Models (DEM) were also used to reconstruct a three-dimensional representation of the stratigraphy, taking into account outcrop topography and non-horizontal layering.

Prior studies have attempted to make a connection between the stratigraphy and the climate signals [5], and used various signal processing techniques to analyze extracted records [6]. One of the many challenges in identifying layers from overhead imagery is the presence of changing three-dimensional orientation (dip) within the stratigraphy, as well as inconsistent albedo due to topography. We performed a new analysis by attempting to correct for these sources of error to identify signals across multiple sites. We then present a case for measured fine bedding to be considered "sub-Milankovitch", which would imply a causal mechanism which is not due to orbital forcing.

Stratigraphy Reconstruction: Properly reconstructing a stratigraphic column and identifying a periodic signal requires numerous corrections to be accounted for, the primary being slope, dip, albedo, and measured elevation.

The shallow outcrop slope (~ 2°) of the spiral troughs exacerbates the influence of the dip angle on the extracted signal, and an assumption of constant dip throughout the entire column skews the resulting signal and thus spectral signal processing. We measure the three-dimensional PLD stratigraphy and find that it has variable dip (0-6°) which generally increases with elevation. The trend was observed across multiple sites and is consistent with SHARAD observations at larger scales [7].

In order to obtain the inherent albedo of the PLD, we removed the illumination effects due to topography (via varying incidence angles) in the measured (i.e. apparent) brightness of the image.

Previous authors have identified the challenges in identifying layers within the PLD [8], and pointed out that topography is a useful proxy for stratigraphy [9]. In this study, we attempted isolate the influence of varying illumination angles due to topography from intrinsic changes in the brightness of the layers. Assuming a Lambertian surface, we removed the incidence angle effect to identify residual intrinsic albedo and find that the there is a low correlation between the incidence angle and the Lambertian-corrected brightness record, suggesting there may be two separate effects controlling the polar stratigraphy. We are working to better understand the relationship between these two signals, but they potentially represent two independent stratigraphic proxies to understand the climate history on Mars.

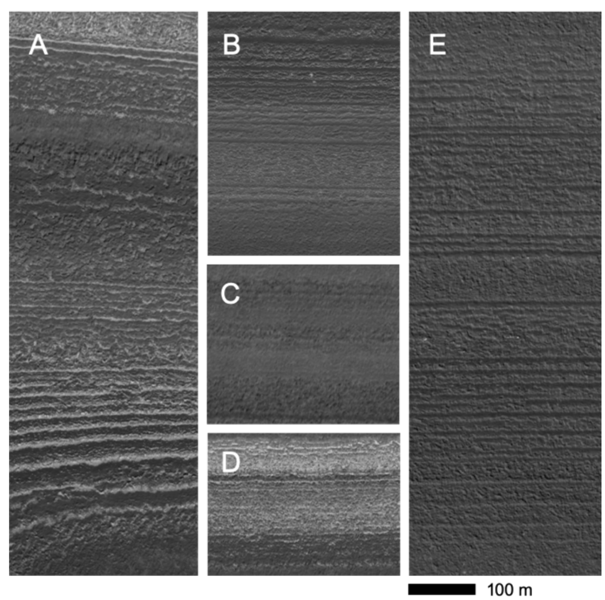

Figure 1: Fine bedding examples in the Martian PLD

Sub-Milankovitch Signal: We measured persistent and cyclic fine-bedding in the PLD throughout the sites surveyed. These fine beds occur in intermittent packages, often with dozens of layers which are distributed throughout all measured depths. There does not appear to be a correlation across the locations as to where the fine bedding is expressed within the columns.

Reconstructed signals were analyzed using wavelet analysis, and with our correction we noted the fine-bedding in the power spectrum as a strong signal at 0.5-1.2 meters, as similarly identified in previous studies [3,10]. There is excess power in the spectrum relative to a red noise background which is above the minimum stratigraphic resolution of 2-10 cm. We also do not observe large variations in the bed thickness throughout the sites.

Modeling suggests that due to the obliquity history of Mars the Northern polar cap cannot be older than 5 Myr [11]. Given nominal estimates for ice accumulation rates, varying from 1 mm/yr to 20 mm/yr [2,12,13], this puts a meter-scale signal on a centennial to millennial timescale. These timescales are significantly shorter than those of changes in the orbital parameters and are thus termed "sub-Milankovitch."

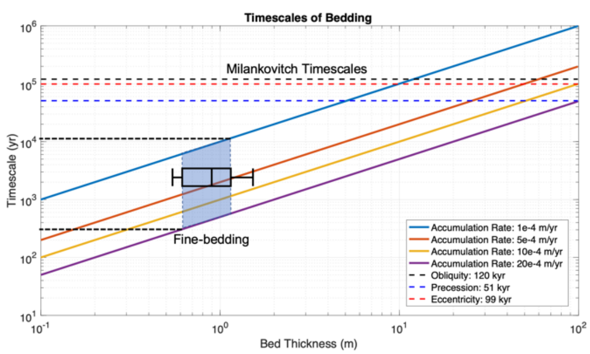

Figure 2: Fine-bedding in the NPLD at 0.5-1.2 m fall well below the Milankovitch timescales, given nominal accumulation rate assumptions, suggesting a cyclic climate mechanism at centennial to millennial timescales.

If the fine bedding is representative of quasi-periodic changes in the Martian climate, it would suggest an unknown climate mechanism which is independent of orbital forcing, and occurs at centennial to millennial timescales. The available outcrops in the troughs access the upper 500 m of the stratigraphy implying the climate variability is captured in the last ~500 kyr. It is unknown what mechanism could be responsible for this forcing and whether they might be exogenic (e.g. solar cycles) or endogenic (e.g. ice/dust redistribution), but this variability appears to be an important component of the recent climate history of Mars.

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