RECENT HIGH-LATITUDE RESURFACING BY A CLIMATE-RELATED LATITUDE-DEPENDENT MANTLE: CONSTRAINING AGE OF EMPLACEMENT FROM COUNTS OF SMALL CRATERS.

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Introduction: A surficial mantling deposit composed of ice and dust blankets Mars at high and mid-latitudes (Fig. 1). The emplacement and evolution of this deposit is thought to be driven by astronomical forcings akin to, but more extreme than, those responsible for Earth's ice ages. In order to test predictions about the age of this deposit, more than 60,000 superposed craters were counted on terrain near the rims of 16 young craters using sub-meter resolution images [1]. A chronology for the deposition of the latitude-dependent mantle is revealed by these data and shows that: (1) the overall age and age trend of mantling deposits is consistent with first-order control by obliquity variations; (2) mantling processes are substantially younger than some equatorial rayed craters which have crater retention ages of ~20-30 million years; (3) the mantle is younger by a factor of two to three at polar latitudes compared to its furthest equatorial extent (~30°) [1].

Latitude-dependent Mantling: The Mars Orbiter Laser Altimeter (MOLA) revealed progressive topographic smoothing in trends of surface roughness from mid- (~30°) to high- (>60°) latitudes, interpreted as the effect of a meters to tens of meters thick blanketing deposit pervasive at high latitudes and degraded at mid-latitudes [2]. Morphological observations based on Mars Orbiter Camera images of both intact (smooth) and dissected (pitted and/or knobby) terrain are interpreted as evidence of a surficial, meters to sub-meter thick, ice-rich deposit that mantles pre-existing terrain and was recently subject to degradation [3] These and related observations led to a model of mantle formation from dusty snow deposited during an obliquity controlled ice age [4], a hypothesis consistent with the observation of internal stratigraphy in erosive margins of the mantling deposit at mid-latitudes [5]. Additional remote sensing measurements and geomorphic evidence for an atmospherically deposited ice-rich mantle have accumulated over the past few years [6]. These include gamma-ray and neutron spectroscopy, polygonally patterned ground, observations by the Phoenix lander, observations of fresh ice exposure by impact craters and subsequent sublimation, mid-latitude gullies, and visible/near-infrared observations of carbon dioxide frosts. Collectively, these observations provide significant evidence in support of widespread and relatively young ice-rich mantling deposits that blanket mid- and high- latitudes [6], but they do not constrain the absolute age of the deposits, or episodes of emplacement. Models of vapor diffusion [e.g., 7,8] can characterize the present-day stability of buried ice, but also cannot directly shed light on the age or origin of buried ice deposits.

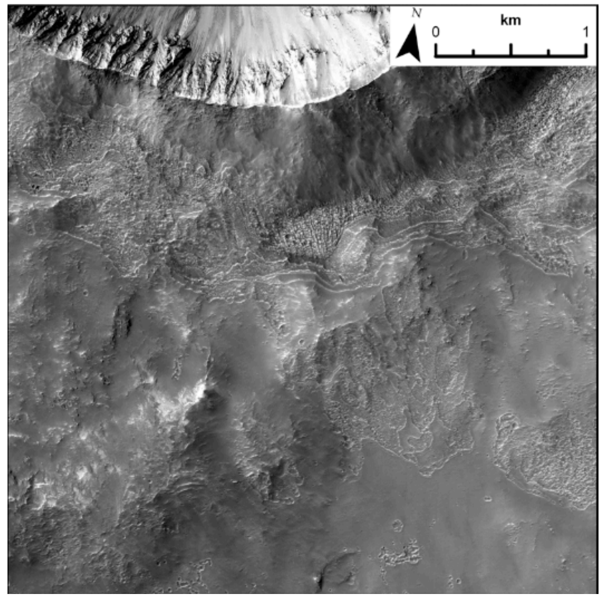

Fig. 1: An unnamed 6.5-km diameter crater is found in Terra Sabaea (27.4°S, 59.1°E). Prominent geomorphic evidence of multiple layers of remnant latitude-dependent mantling (e.g., Schon et al., 2009a) is observed. Portion of HiRISE: ESP_014400_1525. A crater count revealed 865 craters on 12.6 km2 of smooth near-rim mantling material; isochrons of Hartmann (2005) indicate a best-fit age of 7.9 Ma.

Approach: In this investigation we use new sub-meter resolution data from HiRISE to investigate the age and chronology of the ice-rich latitude-dependent mantle at both high latitudes (>60°) and the mid-latitude margin (30°). As part of our study, we date several equatorial rayed craters, which provide additional confirmation regarding the applicability of using small craters to date young surfaces and the validity of the crater chronometry system [e.g., 9].

Rayed Craters: Thila, Naryn, and Dilly craters all preserve crater rays that are visible in thermal infrared data [10]. These morphologically fresh craters are located in the equatorial regions near Elysium. Detailed crater counts on near-rim deposits to date the formation of these craters reveal ages that vary by more than a factor of ten. The crater retention ages of Thila, Naryn, and Dilly are 23.1, 2.1, and 34.4 Ma respectively [1].

All count areas in this study are located on near-rim deposits (typically within 1 crater radius from the crater rim crest) of morphologically fresh craters with diameters between ~1 and several km and for which

HiRISE data was available [1]. The topography of these areas was reset by the crater ejecta. Therefore, the surface is of a homogeneous age and the crater retention age represents either the age of the crater, or any post-crater resurfacing history. In this fashion, crater counts can be performed that confidently date superposed mantle surfaces as well as un-mantled ejecta deposits, which can constrain the emplacement history of the mantle.

Interpretations of LDM Chronology: Obliquity-driven climate change has long been recognized as an important feature of the Amazonian. We present the isochron fits to our crater counts in [1]. Of course using small craters and areas for dating leads to some uncertainties [1, 9] and we thus do not use these values for specific individual age constraints, but rather we base our interpretations and conclusions on multiple crater counts and factor-of-several to factor-of-ten differences in crater retention ages.

In our interpretation, crater retention ages < 1 Ma in conjunction with the pervasive mantling and polygonalization of decameter and larger craters, are consistent with the emplacement of ice-rich latitude-dependent mantling during the most recent ice age (2.1 – 0.4 Ma). Crater retention ages of < 1 Ma and the timescale of polygon formation suggest that thermal cycling could form polygons under current conditions [e.g., 11] The absence of rayed craters from these latitudes also supports our interpretation of geologically recent mantling events.

Our observations indicate that the current equatorial margin of remnant latitude-dependent mantle (e.g., Fig. 1) is variable as might be expected based on regional depositional heterogeneity, weather and climate patterns, and preservation potential. The most equatorial mantle with a crater retention age of ~7.9 Ma is at least a factor of several older than the high latitude mantle terrain. This suggests that the mantle was not emplaced synchronously across the mid- and high-latitudes. The presence of ~1.2 Ma Gasa crater rays and secondaries on mid-latitude mantle surfaces [12] also indicates that mid-latitude LDM is older than high latitude mantle. Although substrate is important for recognizing rays on Mars [10], our data show that crater rays in the equatorial region can persist for tens of millions of years. In contrast, other rayed craters similar to Gasa, are not observed superposed on the LDM, which further supports the young age of the mantle.

Conclusions: Chronologies based on small craters must be interpreted carefully because uncertainties are potentially greater than with larger craters and older surfaces [9]. Our analysis of more than 60,000 superposed craters on the near-rim deposits of 16 young craters [1] supports the following conclusions:

(1) Detailed counts of small craters on geologically young surfaces have size-frequency distributions consistent with the isochrons of Hartmann (2005). (2) Rayed craters in the equatorial regions, e.g., Thila and Dilly, can retain their rays for a period likely to be tens of millions of years. (3) The ages of rayed craters [1, 9] are consistent with the isochron system and exceed the formation intervals expected [9,13]. (4) The ice-rich latitude-dependent mantle is geologically young. The LDM has crater-retention ages approximately a factor of 10 less than the timescale for crater ray retention at low latitudes [1]. The youngest LDM is found at high latitudes where polygonal patterned ground is pervasive and is < 1 Ma [11,14]. (5) Remnant latitude-dependent mantling is limited to the dissected mantle region and is older than high latitude polygonally patterned ground by a factor of several or more. (6) The age and latitudinal age trend of the LDM (younger at higher latitudes) is consistent with suggested control by obliquity variations [1, 4, 15]. (7) The precise extent of remnant LDM is likely to be related to regional depositional heterogeneity [e.g., 16,17] and local preservation potential. (8) Ice-rich LDM was deposited in the region of polygonally-patterned ground during the last ice age [2.1-0.4 Ma, 4]. Polygon development due to thermal cycling of previously emplaced ice is likely to be ongoing [e.g., 11, 14]. (9) Remnant latitude-dependent mantle in the dissected region dates from either earlier in the last ice age (~2.1 Ma) or from the transition from higher mean obliquity at ~5 Ma.

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