MULTI-SCALE CHARACTERIZATION OF SUPRAGLACIAL DEBRIS IN DEUTERONILUS MENSAE, MARS.

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Introduction: Much evidence supports a debris-covered glacier origin for a suite of features in the mid-latitudes of Mars, including lobate debris aprons (LDA), lineated valley fill (LVF) and concentric crater fill (CCF) [e.g., 1]. These "glacial deposits" are significant non-polar ice reservoirs that have been preserved beneath a layer of supraglacial debris for millions of years [2]. Characterizing this supraglacial debris is important for understanding the long-term preservation of glacial ice, the resurfacing, modification, and climate history recorded by the glacial deposits, and the accessibility of these ice reservoirs for future unmanned and manned missions. Here, we more fully assess the physical characteristics of the near-surface layers of glacial deposits in Deuteronilus Mensae (36-48.5ºN, 13-36ºE), using radar sounding data and derived roughness values from the Mars Reconnaissance Orbiter (MRO) SHAllow RADar (SHARAD) instrument, integrated with a suite of other orbital datasets.

Data and Methods: A full-resolution (6 m/pixel) mosaic of MRO CTX images was produced for regional mapping using USGS ISIS tools. Glacial deposits were mapped based on their topographic and textural characteristics at 1:50,000 scale in ArcMap. The glacial deposits were identified based on their typical 100-meters of vertical relief and unique stippled and "brain-terrain" textures and flow lineations [1-4].

SHARAD nightside radargrams and geometry files (US Team, PDS archive) were used for the radar analysis. The vertical resolution of SHARAD is 15 m in free space with a horizontal footprint of ~0.3-1 km along-track and ~3-6 km cross-track. A roughness parameter (ς) was calculated for each column in the radargram based on the methods of Campbell et al. [5], where $\varsigma = P_i/P_0$ and P_i is the integrated power over 20 samples of two-way time-delay (0.713 μs) and P_0 is the peak echo power. While the roughness parameter can be used as a proxy for topographic roughness at the 10-100 m length scale [5], it can also be enhanced by the presence of near-surface reflectors or volumetric scattering. For the glacial deposits, such shallow reflectors may include interfaces between rocky supraglacial debris and underlying glacial ice. We also attempt to correct for the contribution of roughness to the peak echo to assess possible near-surface density variations.

A mosaic of Mars Express HRSC DTMs, resampled to 100 m/pixel, was also produced to calculate root mean square (RMS) height as a measure of topographic roughness for comparison with the SHARAD data.

Mapping Summary: Glacial deposits cover 22% of the region and always occur adjacent to steep slopes (Fig. 1). A variety of surface textures at the tens of meters scale are present, which result from a combination of primary flow-related terrain and secondary resurfacing textures, including mantling and inherited topography from preferential fracturing and aeolian erosion [2-4]. Typically, the surfaces consists of relatively fine-grained, sub-meter scale material based on HiRISE imagery (~0.25 m/pixel resolution).

SHARAD Roughness Parameter: Consistent with CTX mapping, glacial deposits are generally rougher compared with the adjacent plains (Figs. 1,2a), but have a similar frequency distribution as the entire region (Fig. 2a). The highest roughness values for the glacial deposits are attributed to the effects of adjacent steep slopes of plateaus. Features such as crater ejecta also have higher roughness and have distinct boundaries with the surrounding plains (Fig. 1).

There is a direct correlation between ς and average RMS height at the 100-m scale over a footprint of 1 km along track and 8-km cross-track (Fig. 2b). We detrended ς for track footprints falling completely within the glacial deposits to examine anomalously high values that might be the result of near-surface reflectors. Several enhanced areas within the glacial deposits are found that could potentially be attributed to the presence of near-surface interfaces. Visual analysis of individual radargrams show possible near-surface reflectors, but the complicating effects of sidelobes and deterministic clutter [5] require more detailed analyses to verify these observations.

Peak Echo Variations: Peak echo has an inverse relationship with ς (Fig. 2c). Detrending the data to remove the effect of roughness on P_0 narrows the distribution and shifts it toward higher values (Fig. 2d) [5]. Overall, the glacial deposits have lower peak echo power relative to the plains and region, possibly indicating a low-density near-surface composition, consistent with recent fine-grained mantling [2,3]. Alternatively local slopes, such as the convex profile of the glacial deposits, could be affecting these values as they are not accounted for in batch processing of SHARAD radargrams.

Conclusions and Future Work: Glacial deposits show enhanced SHARAD roughness at the 10-100 m scale that is consistent with imagery and topography and attributed to the unique surface textures of the features. Anomalously high SHARAD roughness values not attributed to steep slopes and topographic roughness variations require further assessment for potential near-surfacing layering. This will include more detailed analyses of individual radargrams and clutter simulations. Additional integration with thermal inertia datasets and CTX DEMs will also help to more completely characterize supraglacial debris in glacially modified regions on Mars.

References: [1] Head, J.W., et al. (2010) *Earth Planet. Sci. Lett.* 294, 306–320. [2] Baker, D.M.H. and Head, J.W. (2015) *Icarus* 260, 269–288. [3] Mangold, N. (2003) *J. Geophys. Res.* 108, 8021. [4] Chuang, F.C. and Crown, D.A. (2005) *Icarus* 179, 24–42. [5] Campbell, B.A., et al. (2013) *J. Geophys. Res.* 118, 436–450.

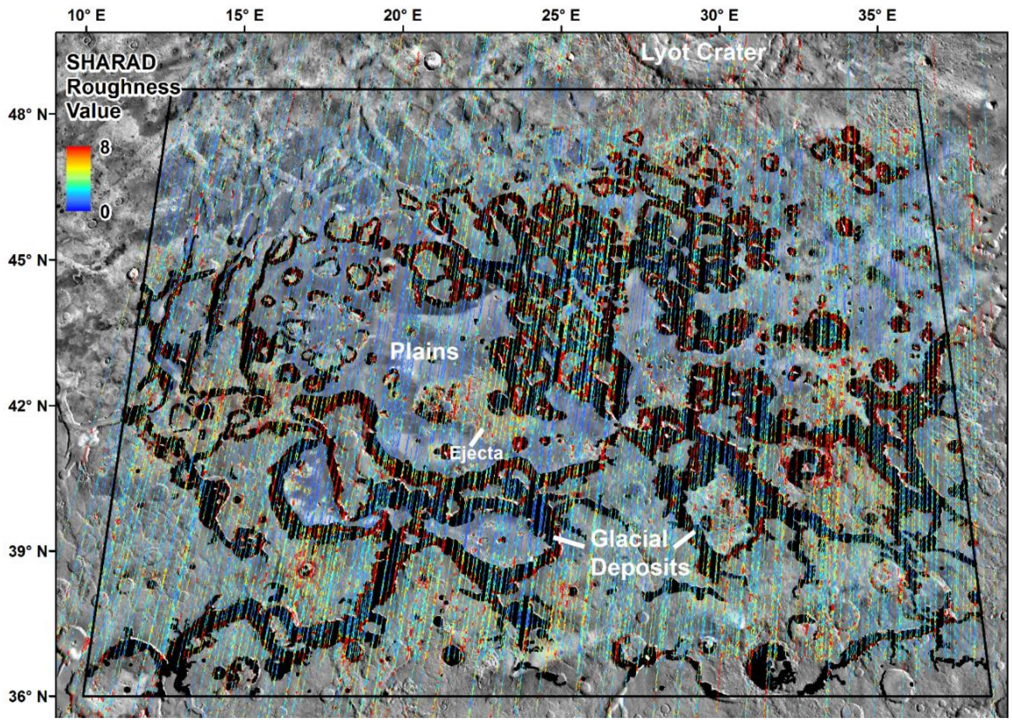

Figure 1. Map of SHARAD roughness values (1-km cells) in Deuteronilus Mensae (black outline), showing mapped glacial deposits (shaded unit). Sinusoidal projection with THEMIS daytime IR image mosaic.

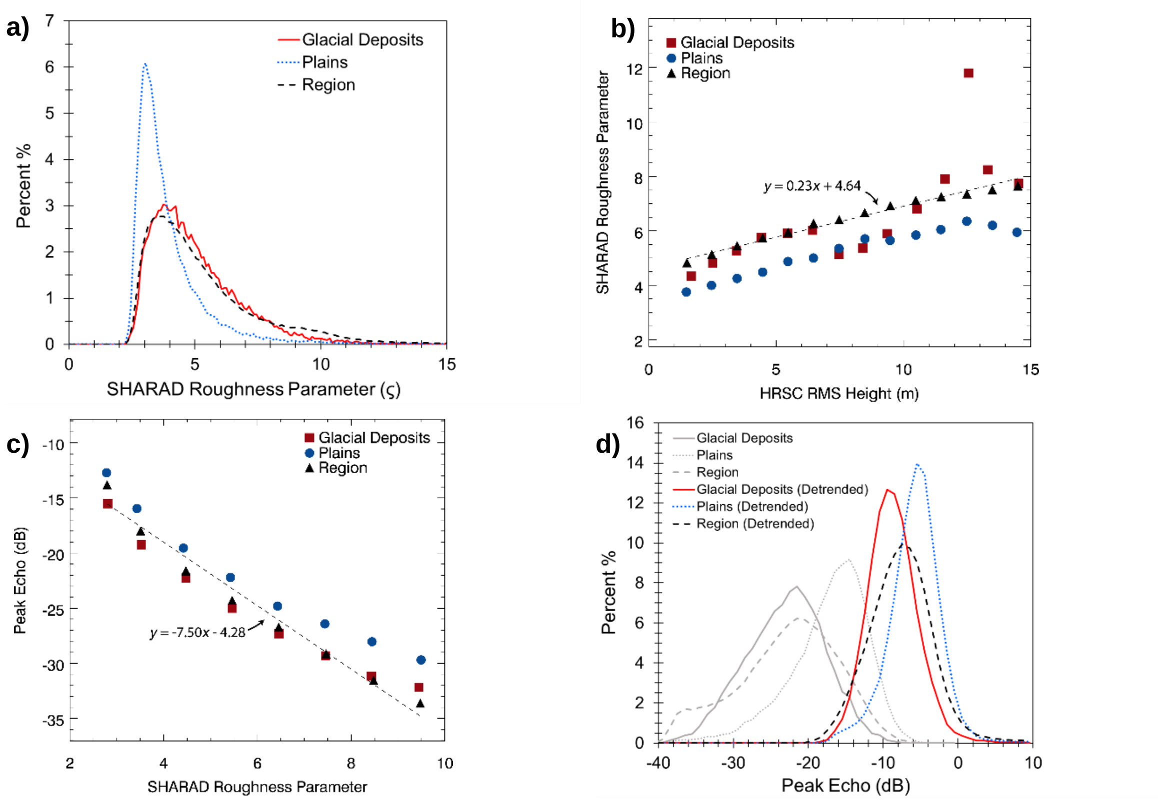

Figure 2. a) Histogram of SHARAD roughness parameter values for units in the study region. b) Roughness parameter as a function of HRSC RMS height (average values in 1 unit bins), with linear-fit to the regional data. c) Peak echo as a function of roughness parameter (average values in 1 unit bins), with a linear fit to the regional data. d) Histogram of SHARAD peak echo power, with data detrended for roughness.