ALL OUR APRONS ARE ICY: NO EVIDENCE FOR DEBRIS-RICH "LOBATE DEBRIS APRONS" IN DEUTERONILUS MENSAE

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Introduction: Lobate debris aprons (LDAs) are numerous in the mid-latitudes of Mars and are thought to be composed of a mixture of debris and ice similar to rock glaciers or debris-covered glaciers [1-5]. These features are thus targets of high interest for In-Situ Resource Recovery (ISRU) of water ice, as well as a record of Amazonian climate.

The Shallow Radar (SHARAD) sounding instrument onboard Mars Reconnaissance Orbiter (MRO) detects the base of many LDAs and has been used in previous studies [3,4] to constrain the bulk composition of several LDA (>80% water ice with surface debris 1-10 m thick), but no study has been published examining LDA at regional scales.

In this study we used SHARAD to survey the interior of numerous LDAs across the region of Deuteronilus Mensae to understand the regional distribution of their bulk properties, i.e. ice purity. Are all LDAs debris-covered glaciers, or are some composed of debris with interstitial ice?

Methods: *Radar Mapping:* We used our previous results on 507 SHARAD tracks mapping radar reflections from the surface and subsurface (basal contact between apron and bedrock) of LDAs in the northern dichotomy boundary region of Deuteronilus Mensae (Figure 1) [6].

Dielectric Constant: The dielectric constant is dependent on composition and determines radar wave speed. For LDAs it can be constrained by converting measured two-way travel time t between surface and basal reflectors to expected LDA thickness. In this work we used a linear regression to extrapolate the elevation of the plains material beyond the toe of the LDA and assumed this as the elevation of the glacier bed z_{bed}. We then prescribed the necessary dielectric constant at each point to obtain z_{bed}:

$$\epsilon' = [\frac{ct}{z_{srf} - z_{bed}}]^2 \quad (1)$$

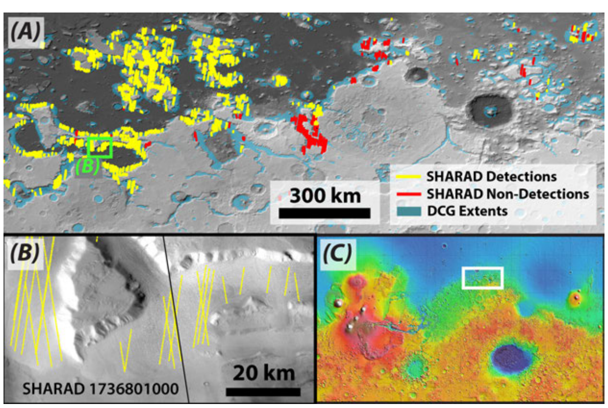

Figure 1: *(A) Map of Deuteronilus Mensae LDAs with mapped basal reflections. LDAs with no detections are also mapped; many of these are due to the effect of surface roughness [6]. (B) CTX image of LDA with SHARAD ground track. (C) Mars MOLA map with location of study site.*

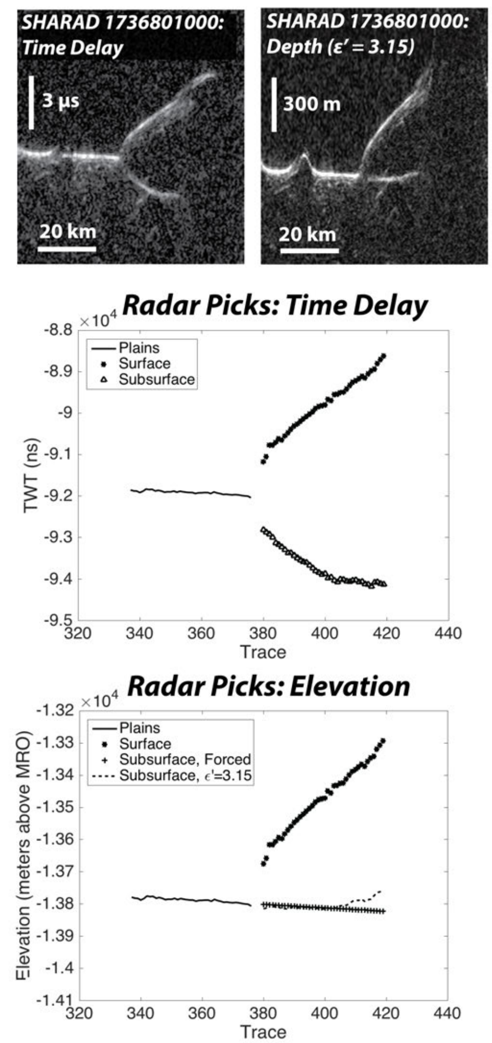

Figure 2: *Illustration of method for depth conversion. (Top panels): radargram of LDA in (left) time delay and (right) depth assuming ε′ = 3.15; north is to the right and ground track is mapped in Figure 1B. (Middle panel): Reflectors in time delay. (Bottom panel): reflectors in elevation; subsurface picks are forced to align with the outlying plains reflector.*

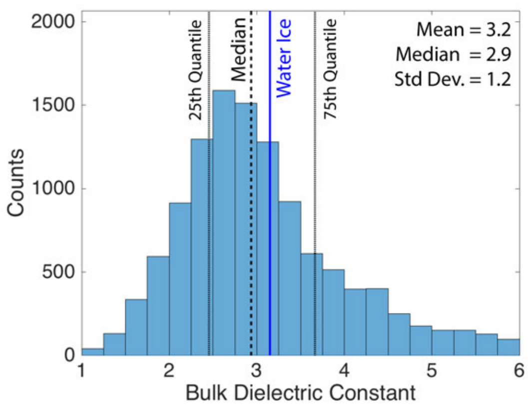

Figure 3: *Bulk dielectric constant values produced by force aligning LDA bases with surrounding plains during depth-correction.*

Loss Tangent: The loss tangent $tan\delta$ indicates attenuation of the material and is a good indicator of ice purity [7,8]. We calculated $tan\delta$ following [7] from measured surface (P_s), and basal (P_b) reflection power, two-way travel time t, SHARAD center frequency f (20 MHz), and assumed surface dielectric constant ϵ'_{srf}:

$$tan\delta = \frac{10log_{10}(\frac{P_t}{P_b})}{0.091ftc} \quad (2)$$

$$P_t = P_s[(\frac{\sqrt{\epsilon'_{srf}}+1}{\sqrt{\epsilon'_{srf}}-1})^2 - 1] \quad (3)$$

Note that ϵ'_{srf} is that of the surface debris and we assume a range of 3-8 consistent with compositions from ice-rich dust to porous basalt.

Results: *Dielectric Constant:* The distribution of calculated ϵ' is shown in Figure 3; mean value is 3.2±1.2. The large standard deviation is likely due to complex basal topography that is not always best represented by a simple linear regression of plains elevation. For example, in Figure 2 there is a steeper basal slope closer to the headwall, leading to low ϵ' estimation. Subglacial basins can similarly lead to high ϵ' estimation. There are no strong spatial trends in dielectric constant variability.

Loss Tangent: Calculated loss tangents are plotted in Figure 4. Variability as a function of ϵ'_{srf} (3-8) is less than the standard deviation of 4×10^{-3}. Values at shallow thickness near LDA toes include increased uncertainty due to relatively thicker debris cover, steeper surfaces, and off-nadir clutter. Filtering out shallow thicknesses decreases the standard deviation of the distribution while retaining a similar mean. Assuming ϵ'_{srf} = 5 for thicknesses >800m yields $tan\delta = (3.2{\pm}1.9){\times}10^{-3}$. There are no strong spatial trends in $tan\delta$ outside of the increase in standard deviation towards LDA toes.

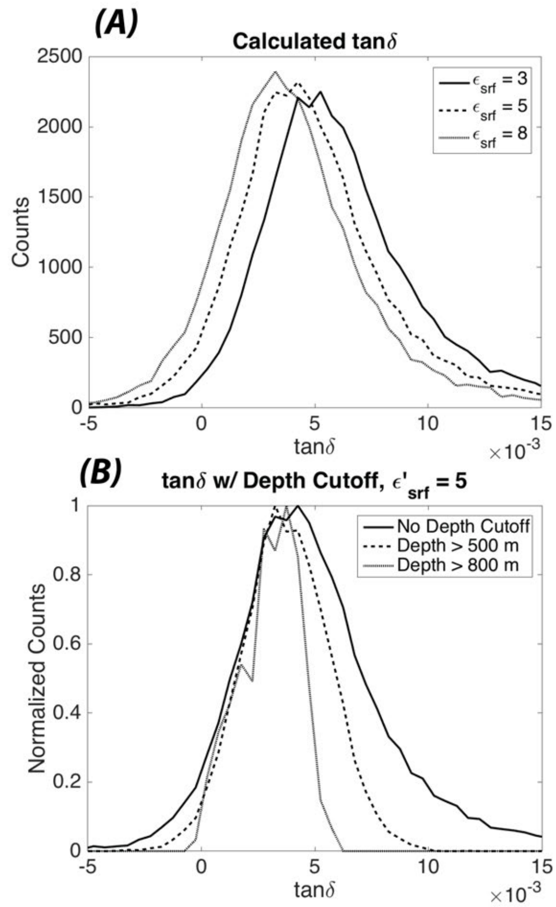

Figure 4: *A) Englacial loss tangent distributions calculated assuming surface ϵ'_{srf} = 3, 5, and 8. (B) Loss tangent distributions calculated with ϵ'_{srf} = 5 and removing data points at depths shallower than thresholds of 500 m and 800 m.*

Discussion and Conclusions: Combining results from the dielectric constant and loss tangent constraints produces a mean complex permittivity of 3.2 + 0.001i. This value is consistent with >80% water ice with dust/basalt inclusions [7,8]. There is no evidence for regional variability or trends in this value. We thus interpret that all LDAs penetrated by SHARAD in Deuteronilus Mensae are debris-covered glaciers.

References: [1] Head, J., et al. (2009), EPSL, 294, 306-320. [2] Squyres, S. (1979), JGR: Solid Earth, 84, 8087-8096 [3] Holt, J., et al. (2008), Science, 322, 1235-1238. [4] Plaut, J., et al. (2009), GRL 36. [5] Levy, J., et al. (2014), JGR: Planets, 119(10), 2188-2196, [6] Petersen et al. (2017), LPSC 48, 2767, [7] Grima, C., et. al. (2009), GRL 36(3), [8] Heggy, E., et al. (2008), LPSC 39, 2471.