LACK OF MELTWATER MAY PREVENT RADAR SOUNDING MEASUREMENTS OF SUPRAGLACIAL DEBRIS THICKNESS IN THE MARTIAN MIDLATITUDES.

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Introduction: Lobate debris aprons (LDA) are among the purest reservoirs of water ice in Mars' mid-latitudes. Furrow and ridge morphology suggests viscous deformation akin to compressional features observed on terrestrial rock/debris-covered glaciers, where ice ablation is prevented due to an insulating debris layer[1-3]. Depth-corrected orbital radar sounding detections of LDA bases consistently constrain their bulk dielectric properties to that of cold, high-purity water ice with thicknesses on the order of hundreds of meters [4-6]. Due to their relatively low latitude, high purity, and large volume, LDA may be among the strongest candidates for targeting martian water and life resources for future exploration.

A significant challenge in targeting sites with low risk and high scientific return for mission planning is understanding the distribution of supraglacial debris thickness in relation to ice concentration. To date, no near-subsurface radar returns have been interpreted as reflections from a debris-ice contact; either the dielectric contrast is negligible or the contact is too shallow to distinguish from the side-lobes of the compressed pulse [7]. While the theoretical vertical resolution of SHARD is approximately 10 m for the dielectric permittivity of ice [8] and the lack of an internal reflection could signify relatively thin debris, a graded contact or surface scattering could also contribute to the non-detection of a debris layer upwards of 30 m thick.

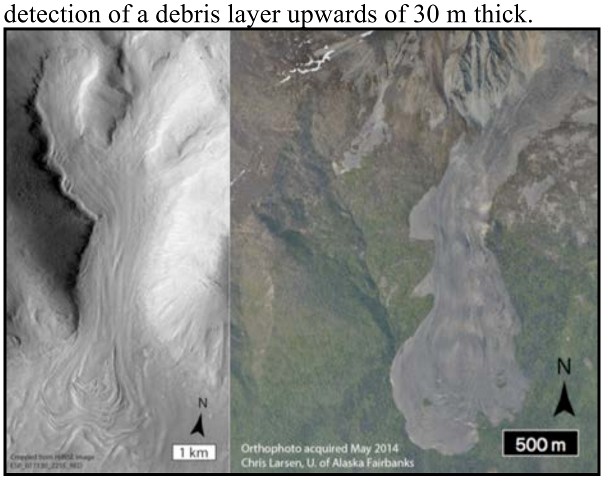

Figure 1: Rock glaciers observed on Mars with HiRISE (left) and in Alaska with airborne photogrammetry (right), showing analogous furrow/ridge morphology.

CTX and HiRISE imagery provide important information regarding the surface morphology of LDA, but terrestrial debris-covered glaciers are also active and accessible laboratories to study the processes that govern debris-layer evolution on Earth which can be used to infer the contributions of similar processes under Mars midlatitude conditions (Figure 1).

North American Analog Sites: We visited four ice-cemented/ice-cored rock glaciers (Gilpin Peak, Colorado; Galena & Sulphur Creek, Wyoming; Sourdough, Alaska) with the objective of using a Sensors & Software PulseEKKO ground-penetrating radar (GPR) to image glacier geometry and structure. These rock glaciers range from 34°N to 62°N latitude, and the minimum elevation decreases with increasing latitude from 3400 m to 500 m a.s.l. Although the interpreted origins of these rock glaciers range from glacial to periglacial [9, 10], we detected distinct near-surface reflectors which were interpreted as debris-ice contact at each site, both with winter snow cover and during the summer melt season. The upper bound on measured debris thickness from GPR is 5 m, and for all of the sites the mean thickness is approximately 2 m.

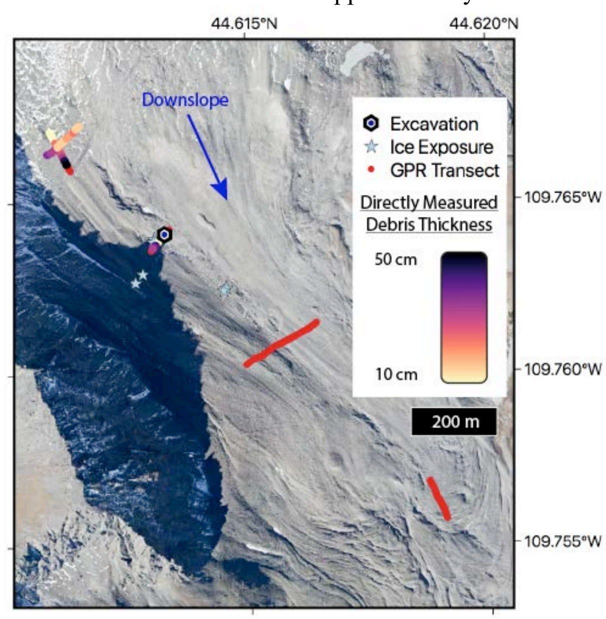

Figure 2: Map view of Sulphur Creek rock glacier showing locations of GPR surveys and directly sampled debris thicknesses along with subaerial ice exposures. Field data collected August 2019, aerial image acquired September 2016 .

Sulphur Creek Tie Point: The upper cirque of Sulphur Creek Rock Glacier provided the thinnest debris cover, which allowed for direct observation of the debris layer (Figure 2). We dug a trench near the location of a near-surface reflector truncation in the GPR data with the objective of tying the reflection to a physical contact (Figure 3). We excavated 90 cm before reaching glacial ice, and we split the section into four units depicted in Figure 4. This depth to ice, along with the two-way radio wave travel time of 17 ns, suggests a dielectric permittivity of 9, consistent with the observed wet sand. This estimate can constrain our other GPR measurements of debris thickness.

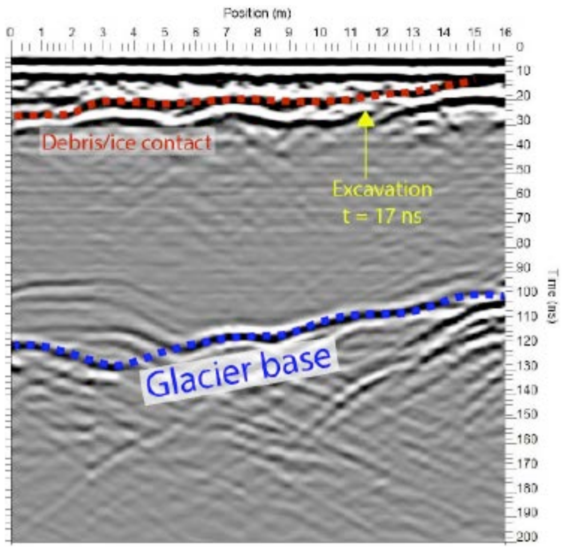

Figure 3: 200 MHz radargram showing the shallow debris-ice reflection that was investigated at the excavation site.

We observed inverse grading in the debris layer, and a notable characteristic of this section was the presence of meltwater and a layer of ice-cemented debris between the graded debris and glacial ice. Other shallow debris measurement sites showed consistent grading and a film of meltwater at the debris-ice contact. While mechanical grading that sorts smaller particles to the bottom of the debris layer could be accomplished by the movement of debris following viscous glacier deformation, the thin layer of ice-cemented debris and the film of liquid water could not have formed without invoking melt, which is an obvious difference between Earth and Mars surface conditions.

Challenges for Orbital Radar Sounding of Mars: Our observations of the debris layers on four North American rock glaciers provide constraints on the debris variability on local and regional scales, but they also warn of issues that may be encountered when exploring their martian analogs. The presence of liquid water in the active layer may be required to create the sharp dielectric contrast observed at the terrestrial sites, so with present-day conditions on Mars, we would not expect to see a strong near-surface reflection, but rather a dielectric gradient. Future radars with higher center frequency or larger bandwidth would aid in further investigation of debris thickness and stratigraphy by increasing spatial resolution.

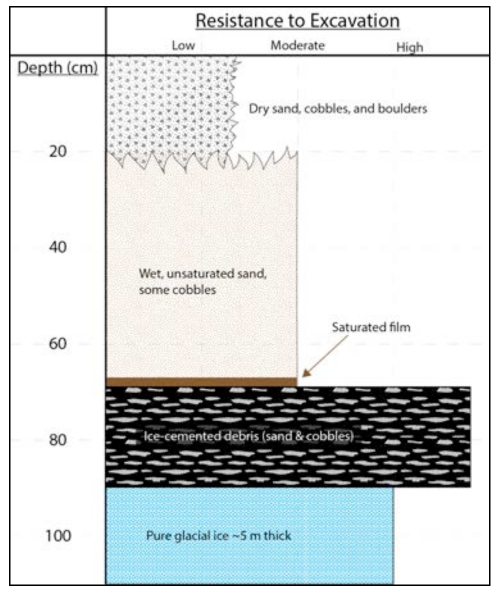

Figure 4: Stratigraphic column interpreted from the Sulphur Creek excavation site. Note the saturated film and ice-cemented debris providing a high-reflectivity contact.

As a corollary, if strong near-surface reflectors are observed on Mars in future missions, this could serve as an indicator that liquid water may have played a role in martian landscape evolution within the time scale of the extant glaciers. With currently available instrumentation, further study of debris layer variability should explore water vapor diffusion and model depths to ice stability for varying slope aspects, insolation, and grain size assemblages in tandem with morphological analysis of compressional ridges and furrows.

References:

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