SULPHUR CREEK AND GALENA CREEK, WYOMING: LABORATORIES FOR UNDERSTANDING THE PRESERVATION OF DEBRIS-COVERED GLACIERS ON MARS

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Introduction: Large, extensive debris-covered glaciers are found in the mid-latitudes of Mars at the bases of escarpments, in valley systems, and filling craters [1-6]. They likely preserve ice deposited during previous high spin-axis obliquity "ice ages," and are thus a record of ice transport between the polar and mid-latitude regions of Mars [7-8]. Understanding the processes by which debris-covered glaciers accumulate and are preserved will help us decode Martian climate history.

A terrestrial analog for Martian debris-covered glaciers are ice-cored rock glaciers, which contain buried ice covered entirely by talus debris. Many, such as Galena Creek Rock Glacier in the Absaroka Mountains, Wyoming, are known to preserve cores of pure ice from past alpine glaciation [9,10]. However, few studies examine the process of transition from alpine glacier to rock glacier [11]. We examine this transition by presenting a case study comparing Galena Creek Rock Glacier with the complex glacial system at Sulphur Creek ~3 km distance away.

Methods: This work integrates field observations with geomorphic mapping of a 24 cm/px orthophoto and DEMs produced from airborne photography acquired in September, 2016 and October, 2019.

Ground-penetrating radar (GPR) at 100 MHz and 50 MHz was also acquired at select locations across the features, in order to measure the thickness and purity of buried ice as well as image internal structure.

Results: *Site Geomorphology:* Galena Creek Rock Glacier has been previously mapped into a number of rock glacier lobes by [12] (Figure 1a). The upper 2/3 of the system is known to be cored by up to 20 m of pure glacier ice under 0.8-1.0 m of continuous debris cover, while the lower 1/3 of the system is composed of ice-cemented rock beneath 2-3 m of surface debris [9].

At the Sulphur Creek system we mapped the following three geomorphic regimes (shown in Figure 2a) based on traits seen in the photogrammetric products, as well as ground-based observations:

(1) A partly debris-covered alpine glacieret extending ~300-600 m from the headwall, ~3120-3500 m.a.s.l., exhibiting crevasses, debris-covered hillocks, and ending in a raised moraine. A snow pit dug in August, 2019 measured 138 cm of seasonal snow. Debris thickness increases towards the terminal moraine, from discontinuous ~10 cm debris in the lower accumulation zone to 20 cm continuous debris 110 m from the moraine to > 50 cm within 20 m of the moraine.

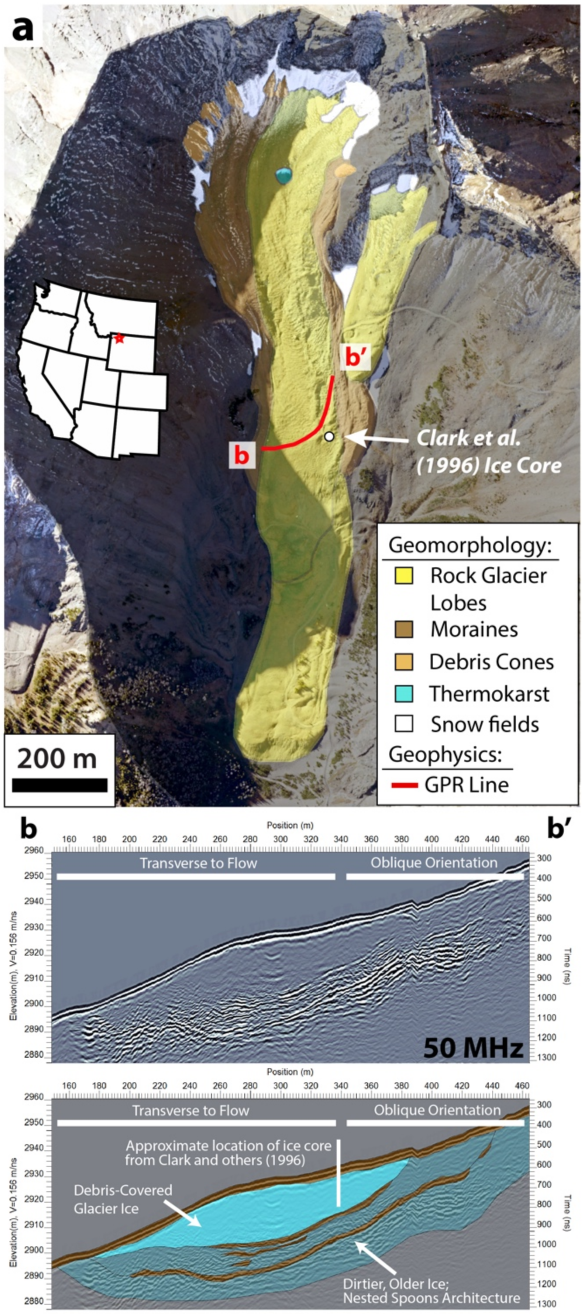

Figure 1: *(a) Map displaying orthophoto of Galena Creek Rock Glacier with gross geomorphic regimes and GPR surveys displayed. Inset indicates location in western USA. (b) GPR data across the rock glacier mid-section; 20-25 m thick core of glacier ice along with underlying nested spoons architecture is revealed. Note the convex-up surface topography.*

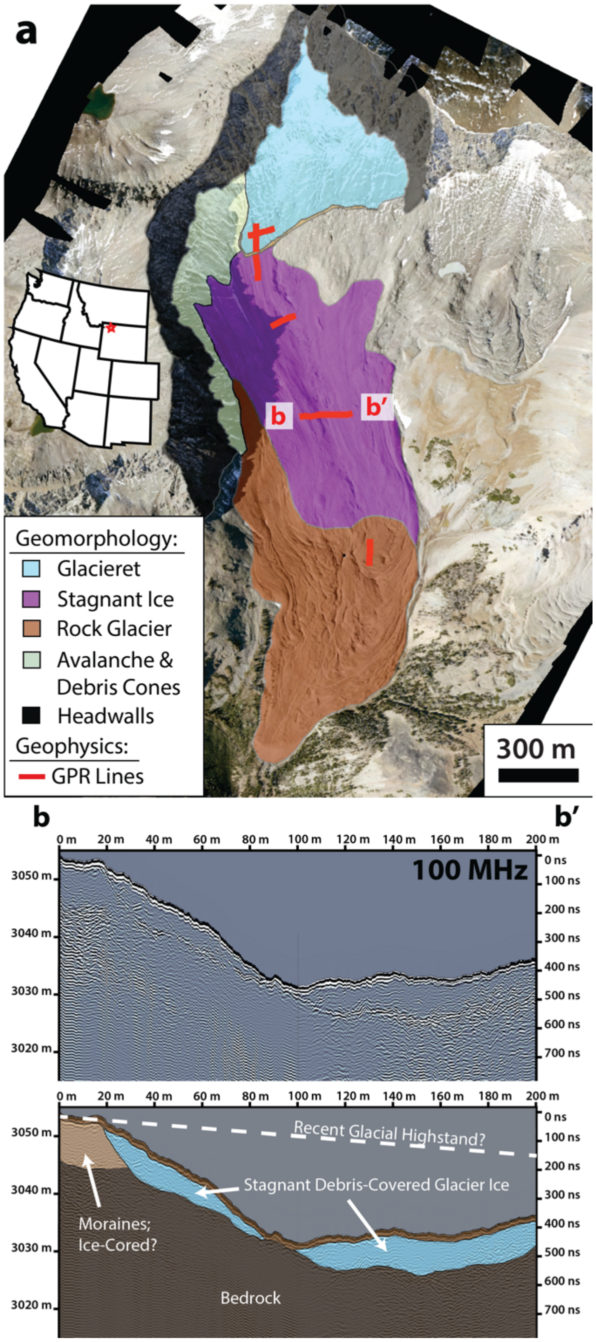

Figure 2: *(a) Map displaying an orthophoto of the Sulphur Creek system with gross geomorphic regimes and GPR surveys displayed. (b) GPR data across the mid-section of the valley; thin (< 10 m thick) ice deposits are revealed. Note the v-shaped surface topography.*

(2) A debris-covered stagnant ice zone ~1.1 km long at ~2880-3120 m.a.s.l. with highly deflated topography and abundant active thermokarst features. This region is cut off dynamically from the glacieret above. Ice exposures are abundant. Debris thickness is highly variable, ranging between 20 cm and ~1 m.

(3) A rock glacier tongue ~900 m long at ~2660-2880 m.a.s.l. with abundant compressional fold morphology, some thermokarst scars and ponds, ending in an oversteepened toe ~50-60 m high. Surface debris is up to 1.8 m thick.

Ground-Penetrating Radar: The results of a 50 MHz radar transect across the mid-section of Galena Creek Rock Glacier are shown in Figure 1b. A debris-covered ice core 20-25 m thick was imaged over a set of reflectors forming a nested spoons architecture.

The results of a 100 MHz radar transect across the stagnant ice mid-section of Sulphur Creek are shown in Figure 2b, displaying localized ice deposits < 10 m thick. The upper glacieret was measured locally at up to 18 m, thickening upslope, while the lower rock glacier was measured at ~30 m thickness.

60 diffraction hyperbolae were measured in radar data on Sulphur Creek, providing statistics on the dielectric constant and composition of measured deposits. The glacieret and stagnant ice zones yielded results that were statistically the same, with mean ε’ = 3.7±0.2 for an ice content of >77%. The rock glacier yielded mean ε’ = 5.8±0.6 for an ice content of ~26-50%.

Discussion: At both Galena and Sulphur Creek we find high ice purity in the deposits in the upper 2/3 of the valley in contrast to a more ice-poor lower rock glacier body. At Sulphur Creek the ice deposits are significantly thinner, more localized, and buried by surface debris up to 4-5 times thinner than the surface debris at Galena Creek.

We hypothesize that both valleys previously consisted of active alpine glaciers overrunning more ancient rock glaciers. At Galena Creek, sufficient debris cover allowed the glacier to be preserved in the form of the 20-25 m thick ice core observed in Figure 1b. However, at Sulphur Creek the debris cover was insufficient to preserve a significant amount of ice; the glacier retreated to its current glacieret state, leaving behind the stagnant ice deposits.

This study highlights the influence of debris availability on the preservation of glacier ice in otherwise very similar geologic settings. We will use these sites to quantify the debris-availability threshold for preserving glaciers and extrapolate our findings to Martian debris-covered glaciers.

References: [1] Squyres, S. (1979), JGR: Solid Earth, 84, 8087-8096 [2] Head, J., et al. (2009), EPSL, 294, 306-320. [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. (2018), GRL 45(21). [7] Forget et al. (2006), Science [8] Madeleine et al. (2009), Icarus 203(2). [9] Potter (1972), GSA Bulletin 83(10). [10] Clark et al. (1998), Geogr. Ann. A: Phys. Geogr. 80(3-4). [11] Jones et al. (2019), Global and Planetary Change 181. [12] Ackert Jr. (1998), Geogr. Ann. A: Phys. Geogr. 80(3-4).