LOCAL VARIABILITY IN DEBRIS-COVERED GLACIER EVOLUTION ON EARTH AND MARS. T. M. Meng[1], E. I. Petersen[1], J. W. Holt[1], J. S. Levy[2], and C. F. Larsen[3] [1]University of Arizona, Lunar and Planetary Laboratory (tmeng@lpl.arizona.edu), [2]Colgate University, Department of Geology, [3]University of Alaska Fairbanks, Geophysical Institute

Introduction: Rock glaciers and debris-covered glaciers (DCG) have been observed in regions of high topographic relief on both Earth and Mars [1-6]. DCG consist of a relatively pure glacial ice core and a surficial debris layer, which shields the ice from direct solar radiation and prevents it from completely ablating.

On Mars, DCG are found in a mid-latitude band between 30° and 50° in the northern and southern hemispheres where a surface debris layer allows for stable water ice hundreds of meters thick [3-6]. Since a debris source is required for ice stability, they are located on the slopes of mountains and within valleys and craters. They contain a total volume of ice equivalent to a global layer between 0.9 and 2.6 m thick [6]. Questions remain regarding the link between the emplacement and evolution of these ice units and their surface morphology and internal structure. Answering these questions could help further elucidate the climate history that they preserve.

Morphology, Structure, and Climate: On Earth, analogous rock glaciers in mountainous valleys of Alaska, Antarctica, and elsewhere give insights into the evolution of their martian counterparts. Surveys over multiple terrestrial glaciers have constrained debris/ice thicknesses and suggested a link between surface morphology and internal structure, particularly where internal debris bands create large arcuate ridges and variations in debris thickness [7,8].

It is hypothesized that these internal debris layers can be used as climatic proxies for periods of low ice accumulation, and the surface ridges can indicate the locations of the internal layers in the absence of internal imaging data. In the case of martian glaciers, this could greatly contribute to the understanding of the martian water budget and its latitudinal transport throughout the Amazonian period.

Slope Aspect and Glacier Morphology: One challenge in linking rock glacier surface morphology and internal structure is the variability in glacier evolution due to local or regional climatic factors, such as solar radiation received by glaciers due to differences in their slope aspect. On Mars, numerical modeling indicates that glaciers on the north and south faces of Euripus Mons must have evolved differently to produce their observe topographies, despite being separated only by about 10 km [9]. Orbital images of this unit also show a clear morphological disparity between the poleward and equator-facing slopes (Figure 1).

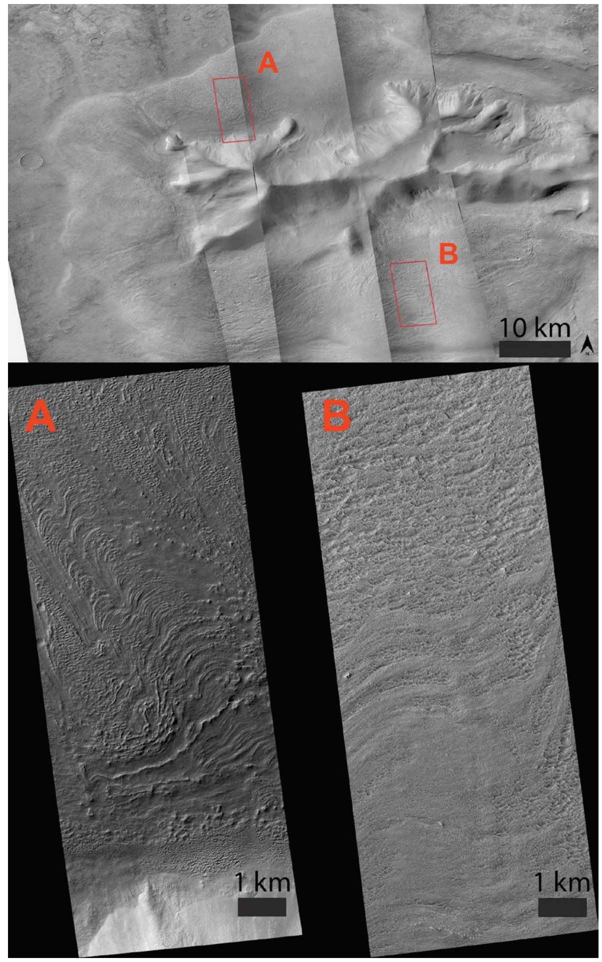

Figure 1: (Top) CTX [11] mosaic of Euripus Mons (105° E, 45° S) showing HiRISE footprints over north and south faces of the lobate debris apron. (Bottom) HiRISE [12] images ESP_045334_1350 (A) and PSP_003639_1345 (B) comparing rock glacier morphologies on each slope of Euripus Mons.

The equator-facing slope, which receives more solar radiation over a martian year, displays finely-spaced ridges with arcuate shapes, while the poleward-facing ridges are much broader, linear, and more continuous [10]. This indicates that the equator-facing slope may have a significantly lower viscosity than its poleward counterpart due to increased temperature. One interpretation is that most of the ridges on the equator-facing slope are produced by viscous buckle folding, while the poleward-facing ridges are more likely due to internal layers.

Alaskan Analog Study: Sourdough Rock Glacier (SRG), which is on an equator-facing (south) slope near McCarthy, AK, has been one of the subjects of a multi-year campaign to investigate rock glacier evolution [7]. Ground-penetrating radar measurements have shown that SRG consists of a ~2 m thick debris layer overlying a ~30 m thick ice unit near the toe of the glacier, with candidate internal reflectors.

Glacier velocity measured from repeat airborne photogrammetry was previously used to show that SRG is frozen to its base, thus a suitable analog to martian rock glaciers. Here, we revisit this velocity data alongside velocity data collected over the nearby McCarthy Creek Rock Glacier (MCRG) and compare the morphology of the two glaciers (Figures 2 and 3).

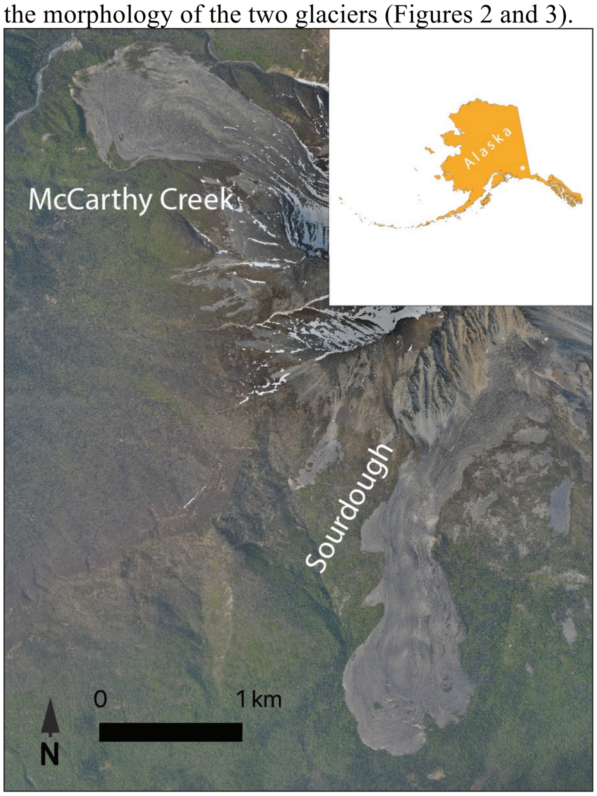

Figure 2: Orthophoto of Sourdough (SRG) and McCarthy Creek (MCRG) Rock Glaciers, showing relative location and size. Location in Alaska shown as white star.

From the orthophoto (Figure 2) we observe a difference in aspect ratio between the two glaciers; MCRG (the poleward slope) is shorter but wider than SRG (equator-facing slope), potentially indicating a higher viscosity. This is consistent with the velocity data (Figure 3), giving a mean of 0.4 m/yr for MCRG and 1 m/yr for SRG, as we expect higher viscosities to deform more slowly given similar basal slopes. MCRG's transverse ridges are more continuous but less lobate than the SRG ridges, similar to the pattern observed between different slopes on the Euripus Mons Debris-Covered Glacier. While the lengths and speeds of the glaciers imply similar ages, it is clear that they evolve quite differently despite their proximity.

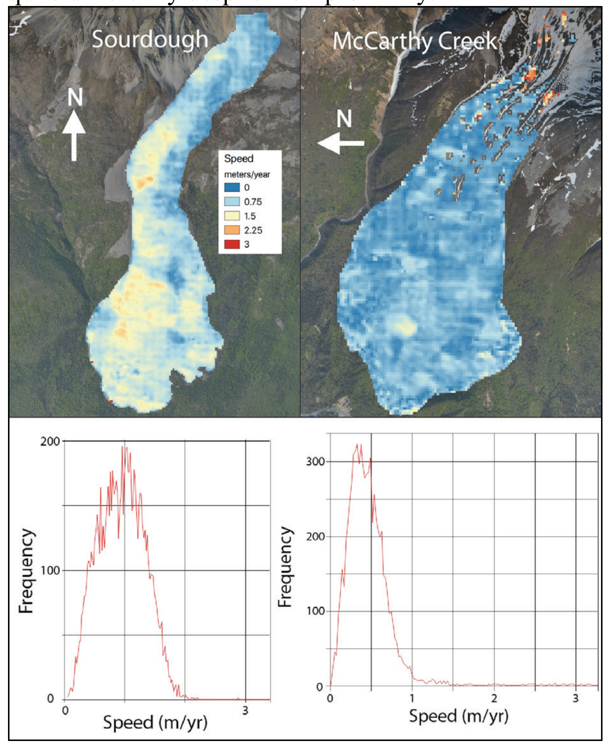

Figure 3: (Top) Glacier velocities collected from repeat photogrammetry surveys in the period of August 2013-August 2014. (Bottom) Histograms of each glacier's velocity field, excluding snow-covered pixels.

Further work is needed to analyze the evolution of each rock glacier in response to the variability of local factors. It is likely that differences between DCG with varying slope orientations also stem from local differences in accumulation rather than solar radiation alone. A field campaign is planned for Spring 2019 with the goal of mapping the thickness of the debris and ice layers for each glacier. Since MCRG is slower and more viscous, and assuming constant debris supply, we predict both the debris and ice layers to be thicker on the poleward-facing glacier (MCRG) compared to the equator-facing glacier (SRG).

References: [1] Warhaftig C. and Cox, A. (1959) *GSA Bulletin, 70,* 383–436. [2] Benedict, J.B. (1973) *Glaciology, 12,* 520-522. [3] Potter et. al. (1998) *Geografiska Annaler, 80,* 251-265. [4] Holt et. al. (2008) *Science, 322,* 1235-1238. [5] Plaut et. al. (2009) *GRL, 36,* L02203. [6] Levy et. al. (2014) *JGR Planets, 119,* 2188-2196. [7] Petersen et. al. (2016) *LPSC XLVII,* Abstract #2535. [8] Mackay et. al. (2014) *JGR Earth Surface, 119,* 2505-2540. [9] Parsons, R. and Holt, J.W. (2016) *JGR Planets, 121,* 432-453. [10] Stuurman et. al. (2017) *LPSC XLVIII*, Abstract #2740. [11] NASA /JPL-Caltech/Malin Space Science Systems. [12] NASA/JPL/University of Arizona.