Ice preservation and landscape erosion during glacial retreat on Earth and Mars

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Introductory points:

Understanding how climate, ice dynamics, and environmental conditions control the evolution of ice-rich and ice-remnant landforms on Mars is an interdisciplinary research goal.

We planned to discuss aspects of what we know about glacial landforms on Earth, in particular about debris-covered glaciers, and to address some ways that this knowledge may be applied when interpreting the history of ice-rich and ice-remnant landforms on Mars.

Here we raise three points that hopefully generate discussion.

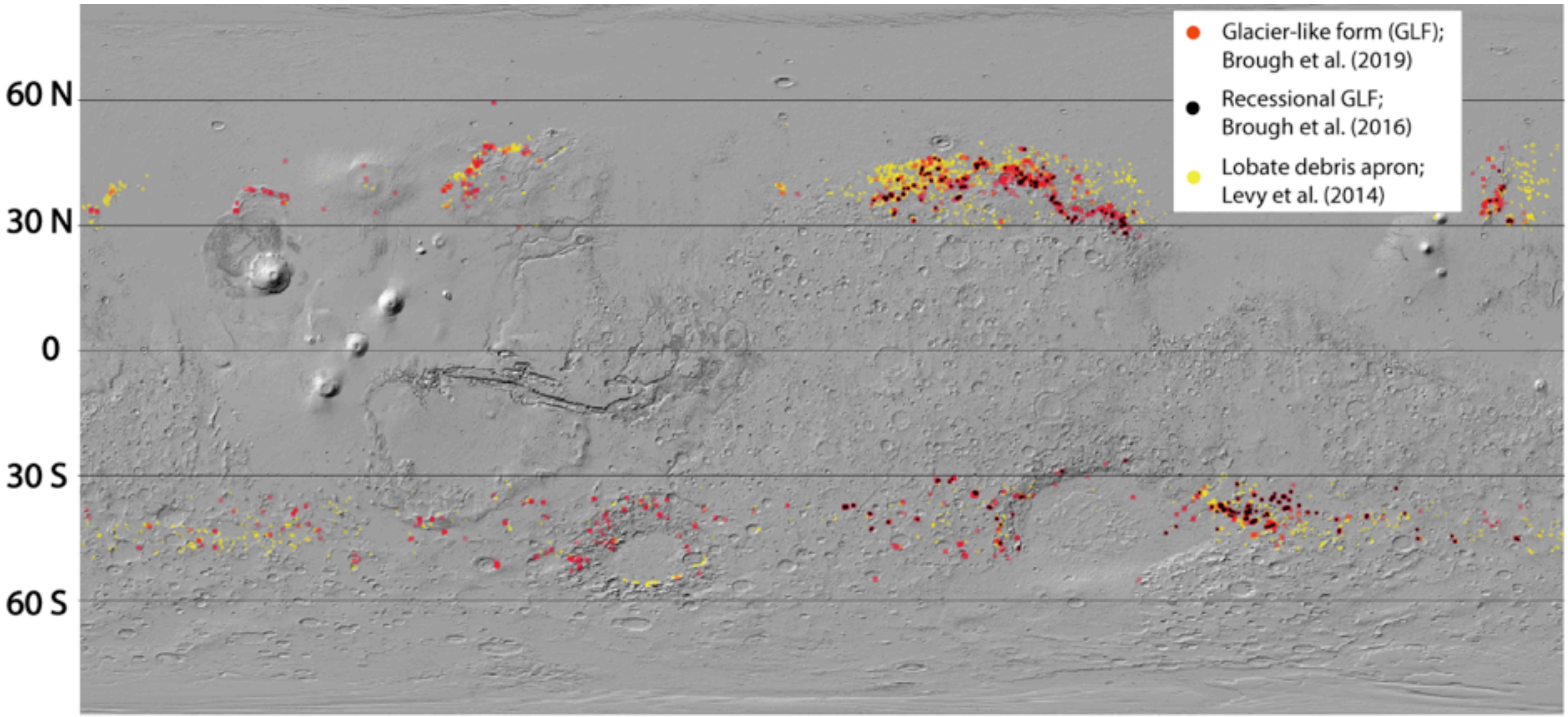


Figure 1. Distribution of select viscous flow features on Mars. Background is the High Resolution Stereo Camera (HRSC) Mars Orbiter Laser Altimeter (MOLA) blended global DEM (Fergason et al., 2018). Red dots show the locations of mapped glacier-like forms (Brough et al., 2019), black dots show recessional glacier-like forms (Brough et al., 2016), and yellow dots show the locations of mapped lobate debris aprons (Levy et al., 2014). All of these features are primarily found within 30-60° north and south latitudes.

1) Martian landforms that are physically similar to terrestrial periglacial, glacial, and paraglacial landforms have been identified since the 1970s. Understanding past and present processes that drive landform evolution on Mars is more challenging, but extending our understanding from Earth can help to identify process-based progressions that may also occur on Mars.

As an example, understanding debris-covered glaciers and landform development associated with transitions from clean-ice to debris-covered to rock glaciers is an active area of research on Earth; what we learn comes from a diversity of landforms found in different environments. Some of this understanding may apply to Mars, and some may not.

How can we continue to best constrain Martian surface processes that control the evolution of surface landforms on Mars that appear similar to surface landforms on Earth?

2) Using the CTX global mosaic (murray-lab.caltech.edu/CTX) we have identified landforms that appear to be shaped by ice action and/or ice recession in select study regions on Mars that were not previously categorized (or mapped) as glacier-like forms or lobate debris aprons.

Our initial mapping has been done in the Hellas region (32-48°S, 88-120°E), where we have found ~190 uncategorized landforms. For context, in this study region ~200 glacier-like forms have been mapped (Souness et al., 2012; Brough et al., 2019).

How should all identifiable ice-rich, ice-remnant, and ice-associated landforms be categorized?

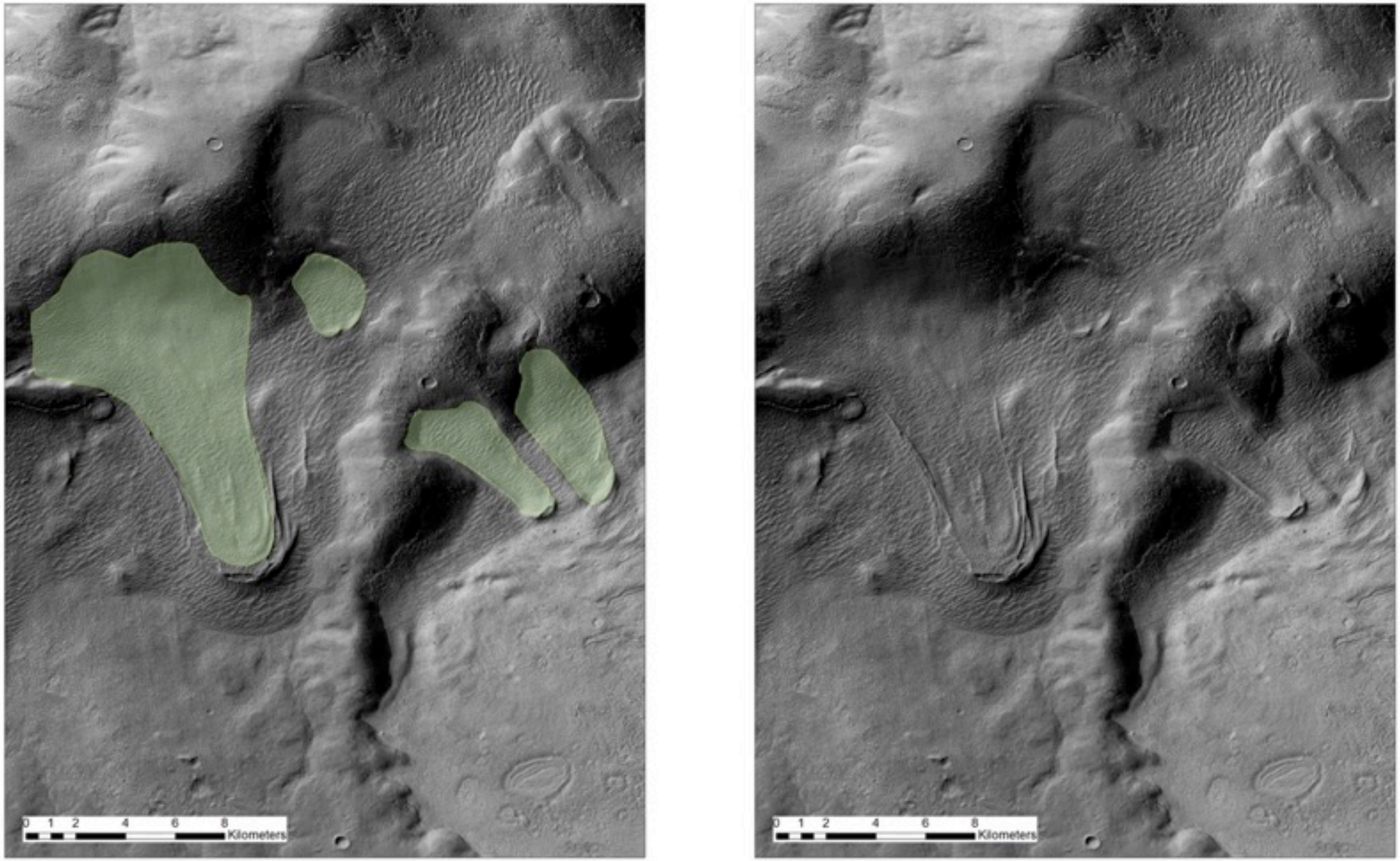


Figure 2. Newly identified landforms near 37.646˚S,105.379˚E, where the termini of putative past ice masses appear preserved as possible moraine assemblages.

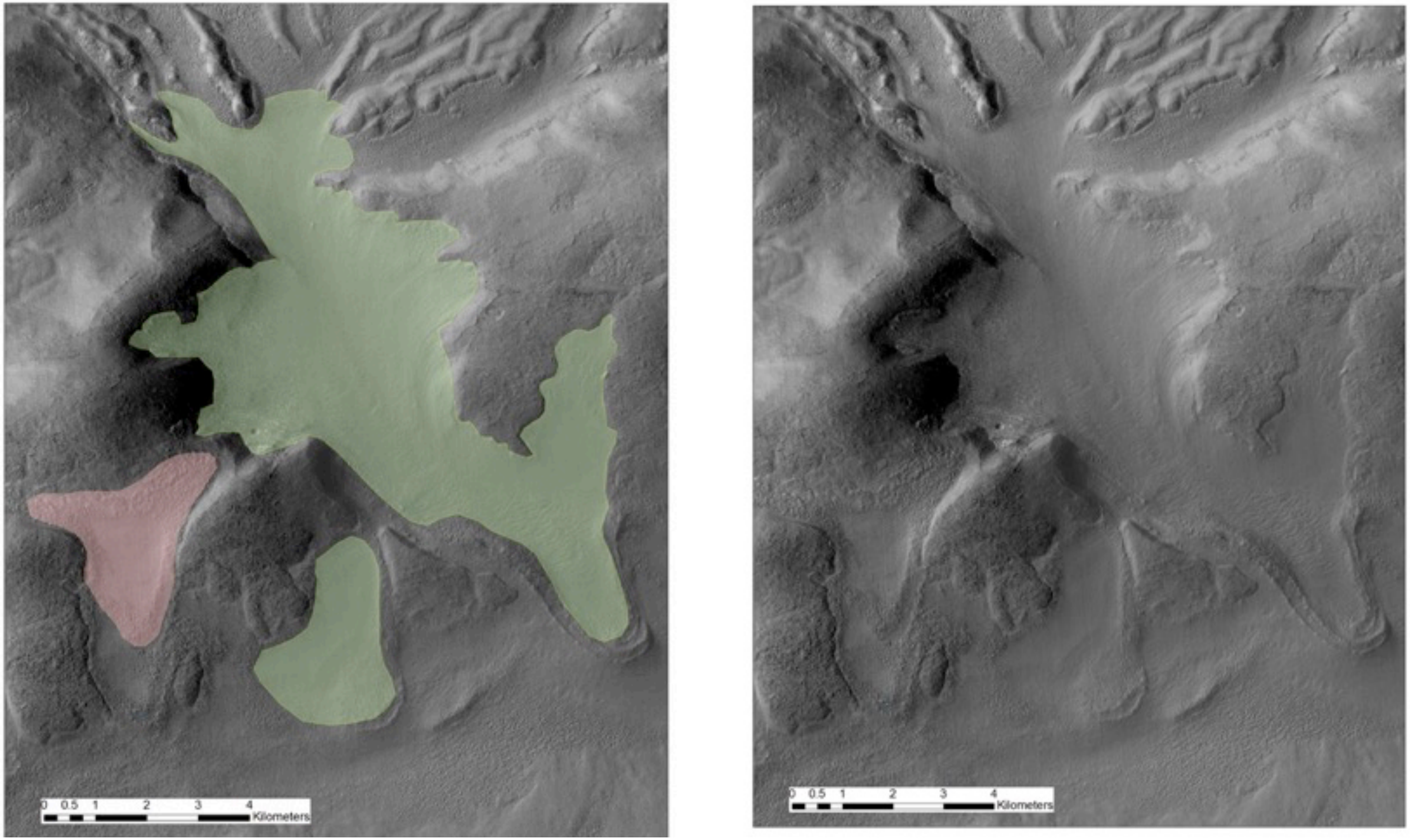


Figure 3. Landforms on the north rim of crater Greg at 38.21°S, 112.83°E, where the feature area in red is a glacier-like form mapped by Brough et al. (2019) and the feature area in green is an unmapped / uncategorized form.

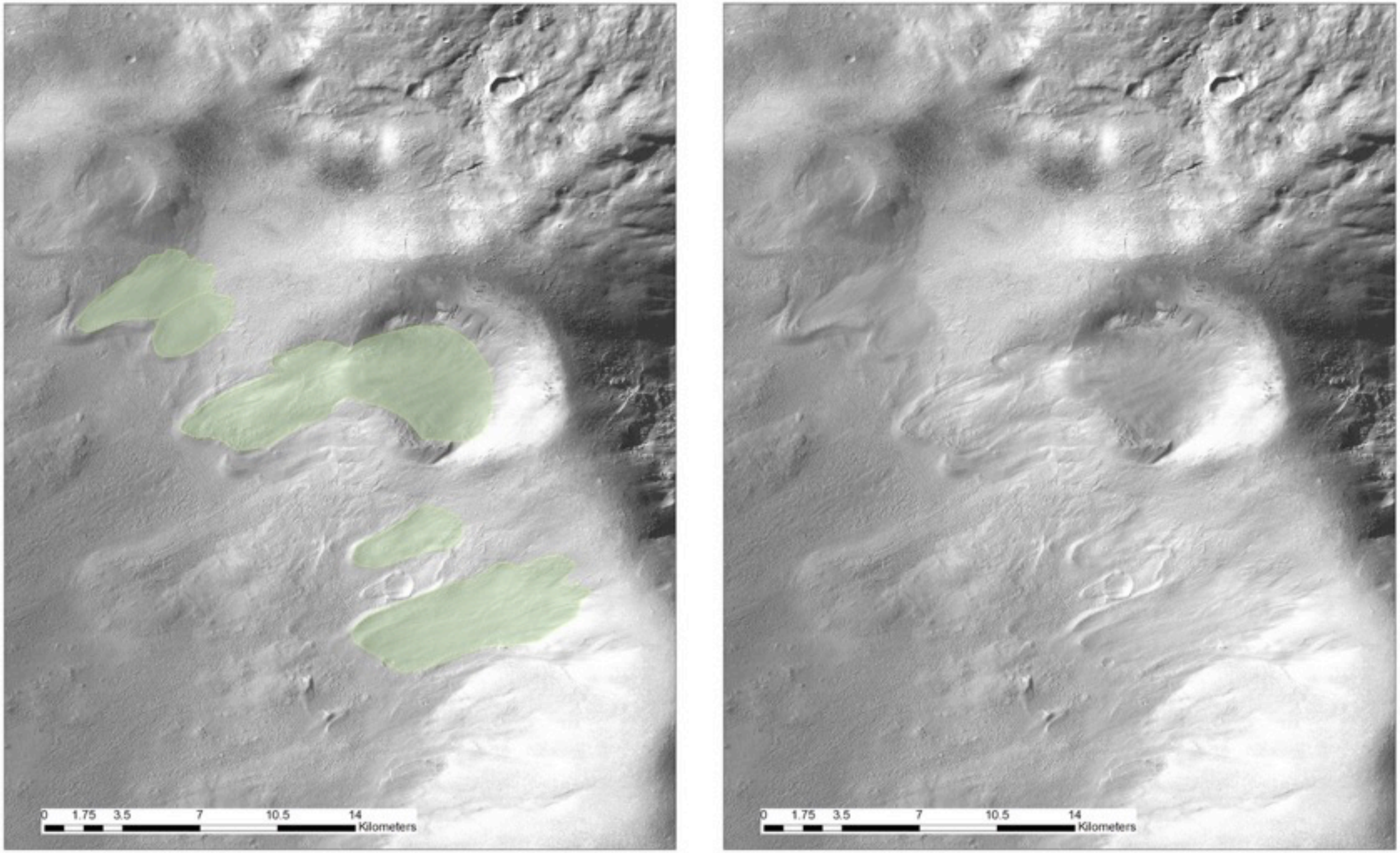
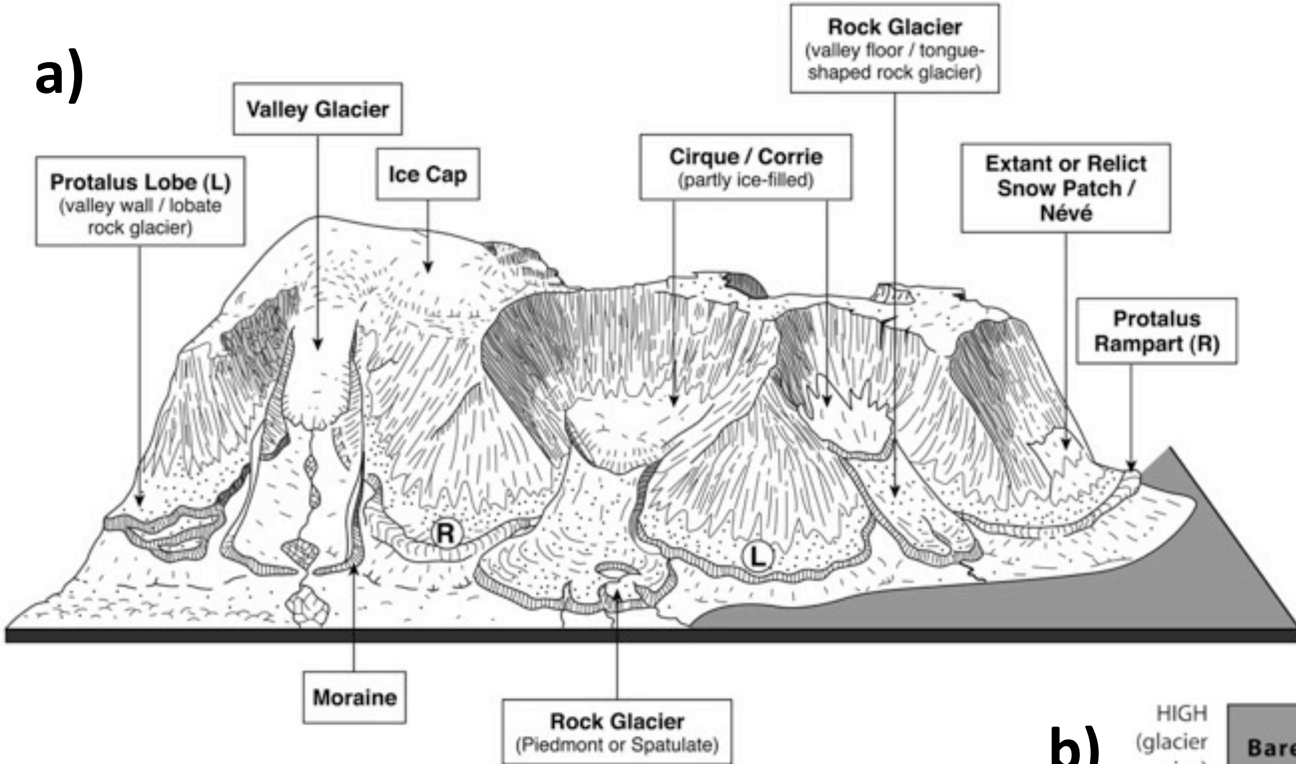


Figure 4. Landforms near 37.63°S, 109.42°E. These uncategorized landforms are examples where the role of ice erosion and deposition, compared to other surface processes (e.g., mass wasting), needs to be evaluated.

3) Continued collaboration across planetary geomorphology will be necessary to categorize all small-scale components of the Martian glacial system, and to interpret these landforms as a function of glacial and paraglacial processes on a local-to-regional scale that control their evolution.

How do different Martian landforms constrain past and present climate conditions, ice dynamics, and other environmental controls?

a)



b)

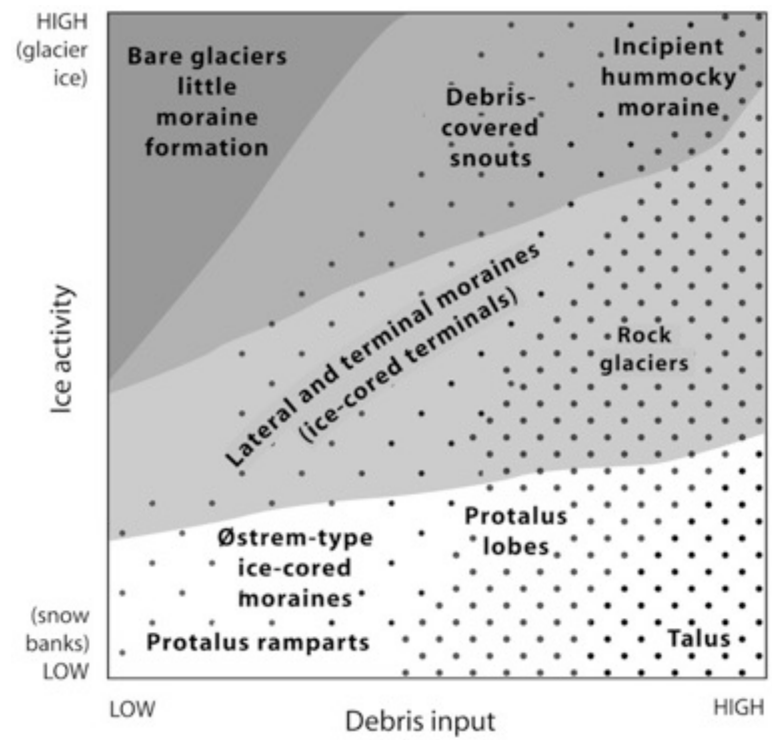


Figure 5. **a)** Cartoon illustrates some significant glacial landforms containing ice and debris that are found in mountainous environments (figure from Whalley and Azizi, 2003). **b)** As an example in a way to relate landforms to surface processes, periglacial and glacial landforms can be evaluated as a function of ice activity and debris input, and additional transitions and landform instability can occur during a paraglacial period (figure from Whalley, 2009).

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