Morphological Diversity of Glacier-Like Forms on Mars G.Driver[1], M.R. El-Maarry[2], B.Hubbard[3], S.Brough[4], [1]Birkbeck University of London, UK [2]Space and Planetary Science Center, and department of Earth sciences, Khalifa University, Abu Dhabi, UAE, [3]Department of Geography and Earth Sciences, Aberystwyth University, Wales, UK, [4]School of Environmental Science, University of Liverpool, UK.

Introduction: Many ice-rich landforms have been observed on the surface of Mars [e.g.1-3]. Glacier-Like Forms (GLFs) are a distinct sub-group of landforms occupying Mars' mid-latitudes and are similar to terrestrial valley glaciers or rock glaciers [e.g. 4-6].

An overview study of the global GLF population reveals that GLFs appear in a variety of morphologies. Using existing and new geometric data, along with visual examination, this study aims to classify GLFs into distinct morphological forms to reveal regional trends in GLF geomorphology and further our understanding of their formation and evolution, along with Mars' climate history.

Methods: Using a recently compiled database[5] 250 GLFs (~20% of the total number of GLFs identified) was selected for the study. The database was arranged by area (km^2) with a variety of GLFs being selected to provide a representative view of the population. Analysis was performed using ArcGIS software to examine CTX and HiRISE images of the sites of interest. Data from the original database [5] was used along with new sinuosity measurements to provide geometric data to aid GLF classification.

Observations: Seven morphological types of GLF were identified, the distributions of which are summarized in *Figure 1*. While most GLFs were similar to terrestrial debris-rich valley glaciers, others displayed notable contrasts in morphology:

Valley GLFs (76.8%) are visually similar to debris-covered valley glaciers or rock glaciers found on Earth. This subgroup is the most numerous and also the most varied type of GLF, having diverse geometrics and distributions. *Figure 2[A].*

Scarp GLFs (10.0%) occupy terrains with medium/high slopes and medium/high relief, allowing the material to easily flow downslope. The features are generally unconstrained and linear, appearing similar to landslides where the material has slowly flowed from steep headwalls. *Figure 2[E].*

Lobate Debris Apron GLFs (4.0%) are defined by being somewhat adjoined to already existing ice-rich Lobate Debris Apron deposits and other ice-rich flows, merging with or within them, making it hard to define their boundaries e.g. GLF flanks. *Figure 2[D].*

Sinuous Valley GLFs (4.0%) are valley GLFs that are highly sinuous, and often multi-lobed. They are commonly found in regions rich in fluvial and dendritic channels. E.g. Arabia Terra. *Figure 2[B].*

Crater Confined GLFs (2.4%) occupy impact craters and are similar to Concentric Crater Fill deposits. They differ as they display GLF geomorphology and are often flowing into/out of the craters via gaps in the crater rim, creating glacial directional flow structures. *Figure 2[G].*

Lineated Valley GLFs (1.6%) appear to occupy rift or tectonic valleys and therefore are of very low sinuosity. They are located in regions where rifts are common e.g. Tempe Terra. Their appearance is similar to that of Lineated Valley Fill but differ by having definitive glacier-like morphologies, such as flow structures. *Figure 2[F].*

Debris-Rich Avalanches (1.2%) are GLFs that are geomorphologically similar to debris rich avalanches observed on Earth such as flow bands and lobate or digitate depositional morphologies. These GLFs are located on crater rims and have heavily sublimated blocky lower (traditional ablation) zones. *Figure 2[C].*

Discussion: Most GLFs are similar in appearance to debris-covered valley glaciers or rock glaciers on Earth although other morphologies exist. The spatial distribution and clustering of different types of GLF suggest that they may have evolved differently and that local geological setting is important to that evolution. The northern hemisphere GLFs show more morphological variation than the south, suggesting that elevation may play a role in GLF evolution, affecting the emplacement and flow of ice, and/or the preservation of such features.

There is a noted difference in GLF source areas, where gradients vary between low relief (e.g. Sinuous Valley GLFs) and high relief (e.g. Scarp GLFs) suggesting topographic control and accumulation processes shape GLF morphology. It is possible that some GLFs in mountainous regions are carving out their topography, while others could simply be exploiting existing topography (e.g. Linear Valley GLFs).

Some GLFs display steep terminus, suggestive of recent movement. This is not specific to any one classification, suggesting that despite their morphological similarities, some processes are not universal across any one category of GLF. There is some room for overlap within the classifications, mostly due to valley GLFs being such a varied group.

As this study only covered ~20% of the full dataset, further insight may be gained from reviewing and classifying each GLF within the whole dataset.

There is also an argument for having sub-classifications within the valley group, due to its geomorphological diversity.

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References: [1] Milliken R.E. et. al. (2003) JGR,108, 6. [2] Souness C. and Hubbard B. (2012) *PPG: Earth and Enviro*., 36(2), 238-261. [3] Galofre, A. G. (2021) AAS, 53(4). [4] Hubbard B. et al. (2014) *The Cryosphere*, 8, 2047-2061. [5] Brought S. et al. (2019) *EPSL*, 507, 10-20. [6] Koutnik M. R. and Pathare A. V. (2021) PPG: *Earth and Enviro*, 45(2), 130-186.

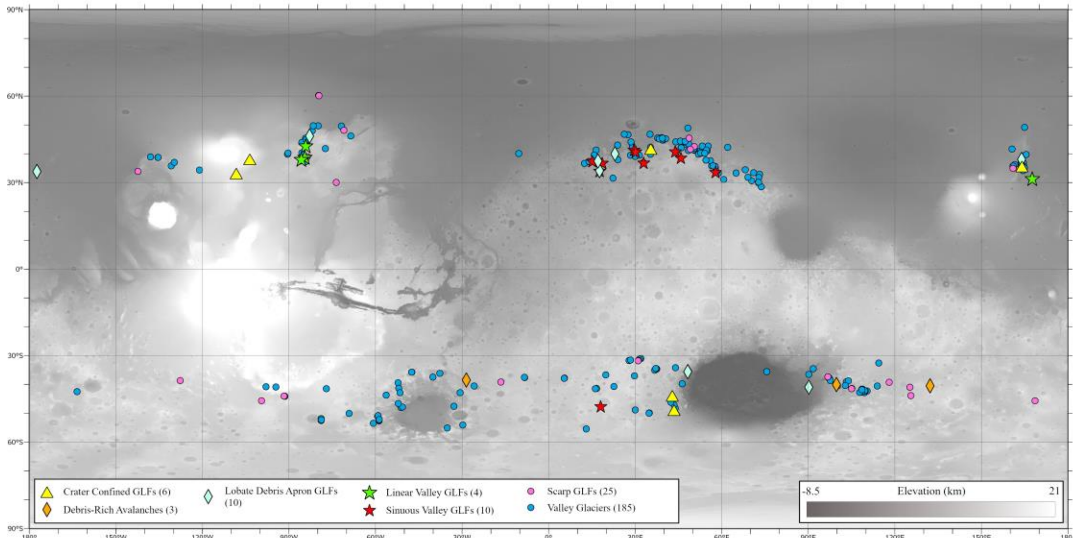

Figure 1: A Mars Orbiter Laser Altimeter (MOLA) topography map of Mars showing the distribution of different GLF morphologies observed in this study.

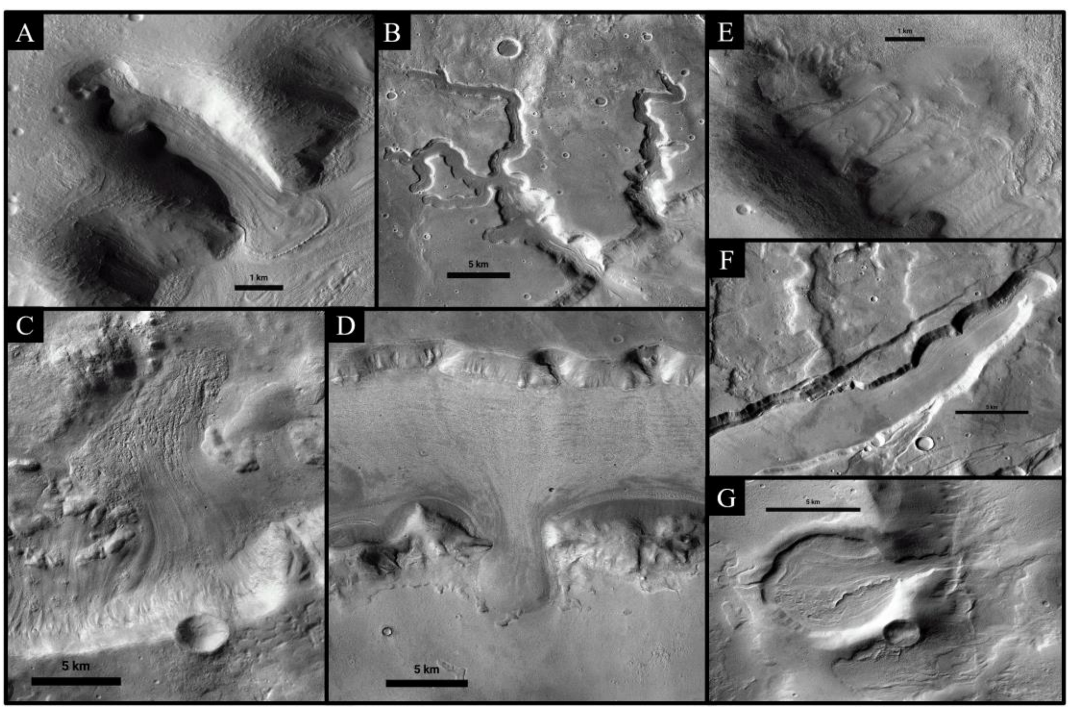

Figure 2: A mosaic of CTX images showing the various GLF morphologies observed in this study. [A] Valley GLFs [B] Sinuous Valley GLFs [C] Debris-Rich Avalanches [D] Lobate Debris Apron GLFs [E] Scarp GLFs [F] Linear Valley GLFs [G] Crater Confined GLFs.