EPSC Abstracts
Vol. 13, EPSC-DPS2019-1913-1, 2019
EPSC-DPS Joint Meeting 2019
© Author(s) 2019. CC Attribution 4.0 license.

EPSC-DPS Joint Meeting 2019
15–20 September 2019 | Geneva, Switzerland

Morphologic, Slope, and Volume Studies of Several Martian Gully Systems

Virginia C. Gulick (1), Natalie H. Glines (1, 2)
(1) NASA-ARC/SETI Institute, NASA Ames Research Center, Moffett Field, CA 94035, USA (vgulick@seti.org), (2) University of California Santa Cruz, 1156 High St, Santa Cruz, CA 95060.

Abstract

We have carried out systematic studies of gullies at a diverse set of locations on Mars. Here we report on morphologic and morphometric trends among similar type gullies, and a volumetric distinction between presently-active dune gullies and classic type gullies. We discuss the role of volatiles in forming these features and suggest that the classic type gullies formed under different climatic conditions than are prevalent today.

1. Introduction

The role of liquid water in the formation of gullies in Mars' recent geological history continues to be actively debated. Numerous global studies have provided information on gully distribution and have inspired numerous hypotheses to explain their formation (e.g., [1, 21]), and the variety of gully morphologies has led many to conclude that gullies likely formed by multiple processes. To understand the relative importance of various gully formation and modification processes, we have been conducting detailed morphologic and morphometric studies of gullies in a variety of environmental settings on Mars using HiRISE and CTX images and HiRISE DTMs. Here, we summarize some of our findings based on study of several gully sites. Sites include: the slopes Palikir [12, 13, 14], Corozal [18], and Moni [19, 20] craters, the central peak of Lyot crater [3, 4, 5, 6], the western rim of a polar pit gully (Sisyphi Cavus), the central peak and southwestern rim of Hale crater [2, 16], and the central pit and western rim gullies of Asimov Crater [15, 22]. For comparison, we studied gullies on the Kaiser dunes and a large gully on the Matara dunes [17], and at a terrestrial site in Iceland.

2. Drainage Systems

Using HiRISE and CTX images, we produced detailed drainage maps of gully systems in all our study regions (Figure 1 for example). Close-ups of these maps reveal that gully systems on the crater slopes and on the central peaks form more complex, highly integrated and ordered, tributary systems in the source regions with fingertip tributaries merging into progressively larger tributaries, and eventually converging into the main gully channel (Figure 2), which is incised along the mid-sections. Similar integrated drainage patterns found on Earth are characteristic of water erosion and fluvial activity.

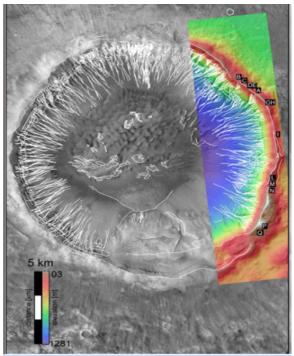

Figure 1: *Drainage map of gully systems on Palikir Crater.*

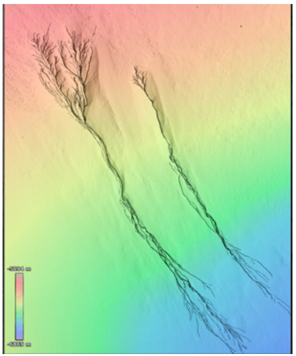

Figure 2*: Lyot Crater gullies mapped using HiRISE images and overlaid onto DTM.*

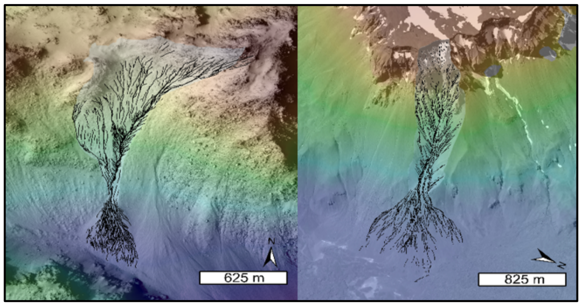

Figure 3: *Map (left) shows extensive tributary networks in the upper reach and complex distributary systems on the debris fan on Hale Crater's central peak, Mars (left) and on the Icelandic Tuya of Herðubreið. (right, 2-m ArcticDEM).*

Additionally, we note that many of the debris aprons are heavily dissected by channels with levees. This is consistent with fluvial activity on Earth where flow transitions from confined to unconfined and is associated with a sudden decrease in slope. As flow spreads out on the apron, water infiltrates and evaporates, sediment concentration increases and flow behaves more like a debris flow. Figure 3 compares drainage maps of a gully system on the central peak of Hale Crater, Mars and of a gully system on the Icelandic Tuya of Herðubreið. Note the integrated tributaries in the source regions and distributary systems on the debris aprons.

3. Slopes

Many of the Martian gullies that we studied have concave profiles, regardless of whether they are located on a crater slope, peak, or pit. Deviations in longitudinal profiles generally correlate to areas where gullies have incised through more resistant stratigraphic layers. Gullies in our study regions formed on alcove slopes < ~23° and on apron slopes < ~16°, values significantly less than the angle of repose required to initiate (~33°) and to maintain dry flows (apex fan slopes >22°) under Mars gravity [7]. For comparison, we measured alcove slopes on the Icelandic Tuya of Herðubreið between 20°-22° and apron apex slopes between 6°-12°. Similar to the classic Martian gullies studied, Herdubreid gullies also have concave longitudinal profiles.

4. Volumes

We also measured gully volumes and found that they are often significantly larger than their associated apron volumes [2]. Some apron volumes (e.g. in Moni and Corozal Craters) were only ~60% of the gully volumes **(Figure 4)**. Volume losses were even higher for gullies on the central peak of Lyot Crater, where apron volumes were only between ~10% and ~40% of the gully volumes (Gulick et al. 2018). This suggests that excess volatiles (CO_2 or H_2O) may comprise a significant portion (~40% - ~90%) of the original pre-gully substrate volume.

However, this is not a universal trend and for other types of gullies, particularly those found on dunes and in a few other locations the opposite is true. For the Kaiser and Matara dune gullies, we find that the apron volumes are generally similar to or larger than their gully volumes, as seen in Figure 4. Likewise, while some Sisyphi Cavi gullies measure ~40-70% volume lost, other Sisyphi gully aprons exceed two or three times their gully volumes.

Repeat imaging of the Matara and Sisyphi sites has documented seasonal flows and changes in gully morphology. Ice/frost-related processes are currently active in both these regions which seem to trigger dry slides, and our data of these volumes suggest that dry or simply present-day surface frost sublimation-triggered processes seem to produce apron volumes that are equal or larger than their gully volumes as opposed to more classic gullies, which we have interpreted to have a significant volatile constituent in their pre-erosional makeup.

We also measured two gullies on Herðubreið Tuya in Iceland and determined volume losses were 58% and 91%, which are similar to our results for the more classic gullies on Mars (Figure 4).

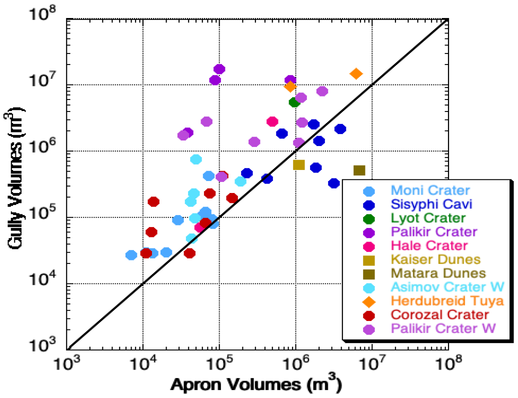

***Figure** 4: Gully vs. apron volumes in studied gully sites. Apron volumes are generally much < gully volumes suggesting that the original substrate was volatile rich. Herðubreið Iceland gullies are shown as orange diamonds.*

5. Summary and Conclusions

Our detailed studies of a selection of Martian gully systems reveal a number of morphologic features that are most consistent with formation by surface fluid flow. The detailed gully morphologies summarized in Section 2 and the gully profiles discussed in Section 3 are most consistent with wet, rather than dry, flows. These gullies formed concave longitudinal profiles, regardless of whether they are located on crater slopes, peaks, or pits. This imply that concavity is a function of the gully forming process rather than of the original slope. Finally, we interpret the volume discrepancy between apron and eroded gully volumes to be a sign of volatiles lost from the subsurface in the gully formation process. The few gullies which show the opposite trend are morphologically distinct, forming on dunes or unusual surfaces.

Acknowledgements Funding for targeting & early gully morphologic analyses was provided by the MRO HiRISE project. Funding for subsequent analysis was provided by NAI Grant # NNX15BB01A.

References [1] Harrison et al. 2015, Icarus 252. [2] Gulick et al. 2017 LPSC #1970. [3] Gulick et al. 2018 GSL, SP 467, https://doi.org/10.1144/SP467.17. [4] Hart S.D. et al. (2010) LPSC #2662; Hart et al. 2009 LPSC #2349. [5] Glines & Gulick 2018 LPSC #2955. [6] Glines & Gulick 2018, Late Mars Wkshp, [7] Kolb et al. 2010, Icarus 208. [10] Gulick et al. 2014, 8th Mars Conf. [12] Narlesky & Gulick 2014. #2870. [13] Hamid & Gulick 2018. LPSC #2644. [14] Luu et al. 2018. LPSC #2650. [15] Paladino et al. 2018. LPSC #2889. [16] Corrigan et al. 2017. LPSC # 2876. [17] Glines & Gulick 2018. LPSC #2825. [18] Hernandez et al. 2014. LPSC #1198 [19] Glines & Gulick 2014. LPSC #2926. [20] Glines et al. 2016. LPSC #2464. [21] Hobbs et al 2017. Geomorphology 295. [22] Langenkamp et al. 2019. LPSC, # 3224.