FREQUENCY AND MORPHOLOGICAL CONSEQUENCES OF MARTIAN GULLY ACTIVITY.

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Introduction: The origin of recent gully landforms has been one of the key debates in Mars science over the last two decades, with important implications for habitability and climate. At the time of discovery, gullies were interpreted as evidence for groundwater release [e.g. 1-4]. Subsequent analysis favored melting of snow or near-surface ground ice [e.g. 5-9]. Either of these hypotheses implies the frequent occurrence of near-surface liquid water in geologically recent time, although they markedly diverge in their climate implications: regular melting and runoff implies surface conditions much wetter than the present cold desert.

However, the discovery of ongoing activity in gullies [10] has significantly changed this picture. Early observations of seasonality [11-13] have developed into strong evidence that seasonal CO_2 frost is the major driver of current flows in gullies [14]. This has lent new support to the hypothesis that CO_2 frost-driven flows are not merely a secondary process, but are in fact the primary and perhaps the only cause of gully formation [e.g. 15-17]. Distinguishing between these three hypotheses is thus fundamental for Mars climate science and habitability: CO_2-driven gully formation points to a cold, dry recent climate with limited scope for near-surface habitability. By contrast, wet models are more promising for life, and melting of snow or ice would have strong implications for recent climate.

Survey of Gully Activity: Extensive repeat image coverage from the High Resolution Imaging Science Experiment (HiRISE) enables the detection of new flows in gullies. Previous surveys have demonstrated widespread activity, including formation of many of the morphologies once attributed to liquid water [16-17]. This work presents an extension of that survey for non-dune gullies encompassing additional data. This accomplishes several objectives: detection of new examples provides more case studies of the largest, rarest events which have the greatest geomorphic impact, and expands the set of gullies empirically shown to be active. It also provides a stronger data set for comparison with models for the distribution and properties of gully activity under various scenarios.

Results: At the time of writing, activity has been documented at 22% of 514 southern-hemisphere monitoring sites with long-baseline HiRISE coverage, in most cases with before-and-after HiRISE images. (For these purposes, one site is treated as one set of overlapping HiRISE images. Sites may be adjacent and include variable numbers of gullies.) Among the subset of sites examined by [17], the portion with observed activity has risen from 20% to 25% with the addition of more monitoring data. Many sites, and some individual gullies, have been active repeatedly.

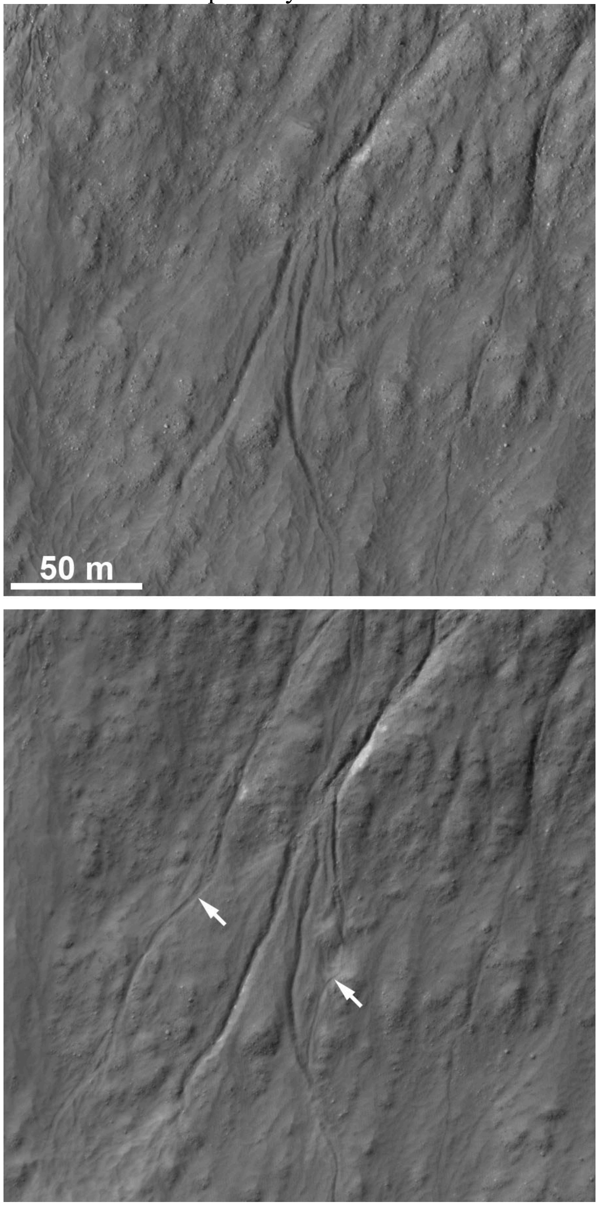

Figure 1: Example of a gully flow event with significant incision of multiple channel segments (arrows). HiRISE images PSP_003094_1430 and ESP_050538_1430. North is up and illumination is from the left.

The properties of individual flow events are highly varied. Their deposits can be brighter or darker than the surroundings, and roughly half have minimal albedo contrast. Most (>80%) reshape the morphology within the channel at scales visible to HiRISE, although the extent varies greatly, ranging up to debris-flow-like deposits that transport boulders and are likely >1 m thick. Morphology within channels is commonly reworked, with local incision and deposition of lumpy bar-like deposits. Less commonly, the outer edges of sinuous curves are modified, altering the channel sinuosity.

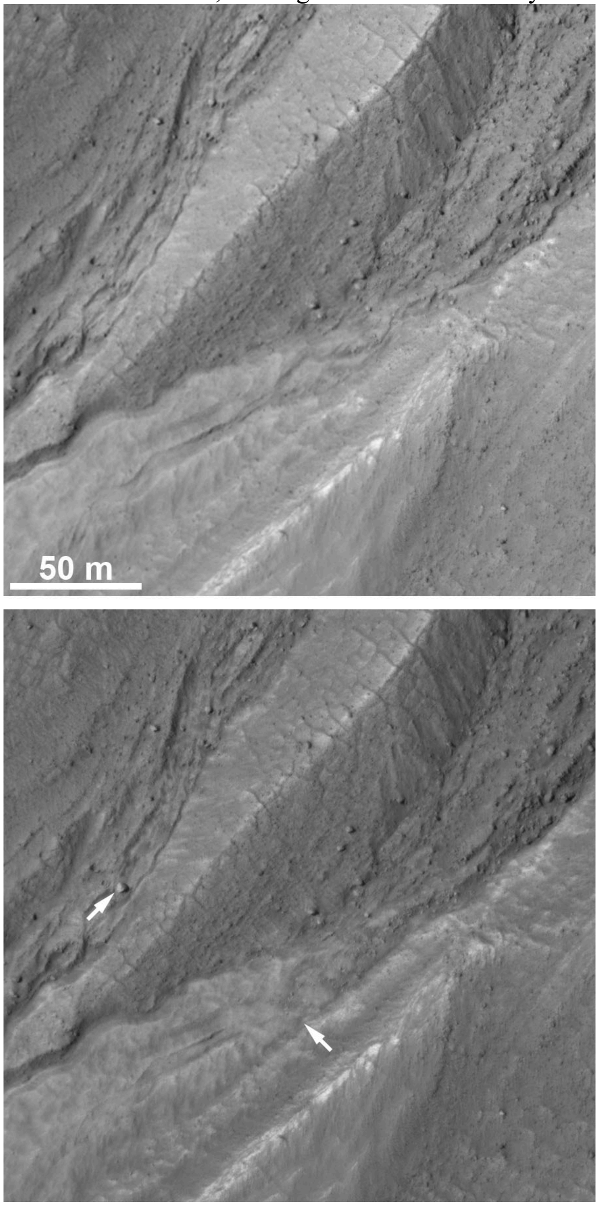

Figure 2: Multiple flow events have occurred in this gully system. At left, note movement of a ~5 meter boulder. At right, deposition has infilled part of the channel system (arrow), while erosion occurred up-slope. HiRISE images ESP_013941_1420 (top) and ESP_057839_1420 (bottom). North is up and illumination is from the left.

Discussion: The geomorphic effect of current activity in gullies is significant. As channel extension and burial is not uncommon, and flows frequently rework the interior morphology of channels, the fine-scale features of gullies represent the effects of modern processes in most cases.

The increase in percentage of active sites at previously surveyed locations is due to two factors: longer time baselines, and the acquisition of more monitoring images that closely match the lighting and viewing geometry of older data. This both improves detections in new images and permits recognition of changes that were present in older data but not readily observable; only events considered definite are included, and manual surveys of poorly matched images can miss subtle changes. Both of these factors indicate that the observed activity rate is a lower bound. The substantial increase in activity detected at the sites from [17] demonstrates that these effects are important. This has both scientific and operational implications: further acquisition of well-matched data is productive, and over a long time baseline, it is likely that a large fraction of gully sites will show activity. This supports the hypothesis that gully formation is ongoing via CO_2 frost processes, as the process is occurring under the cold dry modern climate. While the Martian climate system has varied over time, gullies should not be used as evidence for past liquid water, and variations in gully activity over time may reflect variations in the CO_2 cycle.

Complete results from the survey will be presented at the conference. In future work, these results will be used in conjunction with topographic data to constrain the fluidization of gully flows and compare the new flow slopes with the overall topography of gullies [cf. 18-19].

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