LONG-TERM MONITORING OF MARTIAN GULLY ACTIVITY WITH HIRISE. C. M. Dundas[1], S. Diniega[2] and A. S. McEwen[3], [1] Astrogeology Science Center, U. S. Geological Survey, 2255 N. Gemini Dr., Flagstaff, AZ, 86001 (cdundas@usgs.gov), [2]Jet Propulsion Laboratory, California Institute of Technology, Pasadena, CA, [3]Lunar and Planetary Laboratory, University of Arizona, Tucson, AZ.

Introduction: Martian gully landforms with an alcove-channel-apron morphology were first described by Malin and Edgett [1]. These features have generally been taken as evidence for recent near-surface water. Work to define the source for such water has focused on release from aquifers [e.g., 1-4], or melting snow or near-surface ground ice, most likely in a different past climate [e.g. 5-7]. Alternatively, it has been suggested that gullies could be the result of dry processes [8-9], release of liquid CO_2 [10] or seasonal CO_2 frost processes [11-13].

Evidence for present-day gully activity was seen as support for aquifer discharge [14]. However, the observed flows were consistent with dry granular flow [15], leading to the suggestion that current activity was merely the dry degradation of older water-formed features [16-17]. Further observations demonstrated more widespread examples of current activity, including formation of complete dune gullies, and demonstrated that activity is seasonal [18-22]. The timing of the best-constrained events places activity around the time of removal of seasonal frost [22].

Ongoing monitoring of gullies with the High Resolution Imaging Science Experiment (HiRISE) has revealed many additional changes. We present evidence for extensive activity and gully formation in the southern hemisphere of Mars.

Gully Monitoring: We used before-and-after HiRISE observations of several hundred gully sites in the northern and southern hemispheres to look for changes. HiRISE data allows observation of topographic effects and detection of small or subtle changes. For this work, we focus on activity in non-dune gullies, primarily on crater walls. Dune gully activity is extensive [20-21] and likely caused by the same processes [22]. We exclude observations of RSL [possible summer liquid flows, 23] or defrosting activity [22] and focus on flows through channels onto aprons.

More than 60 flows have now been observed, including many with substantial topographic effects. These effects include deposition of lobate flows as well as substantial channel incision (Fig. 1). We observe flows that are bright, dark, and neutral relative to their surroundings; in some cases flows are distinct relative to seasonal frost, but almost undetectable on the defrosted surface. All definite examples of activity to date are in the southern hemisphere, although more than a quarter of our monitoring sites are in the north.

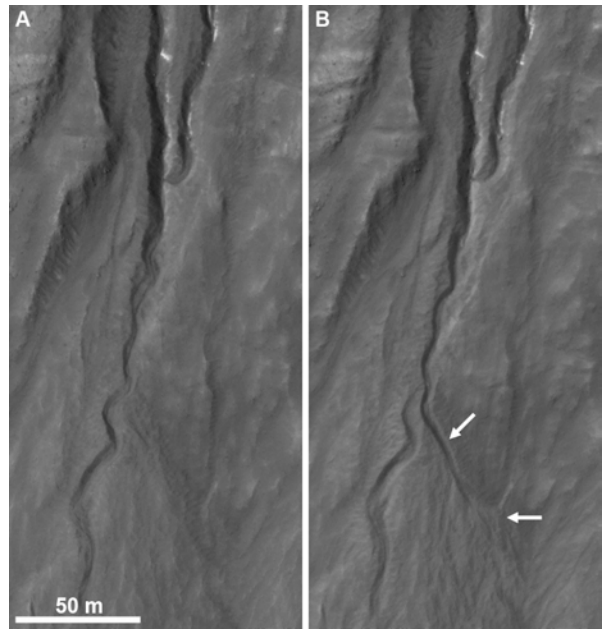

Figure 1: Channel incision (upper arrow) and deposited material (lower arrow) in a crater-wall gully. (A: HiRISE image ESP_013115_1420. B: ESP_032011_1420. Light from left.)

We classified gully sites into degraded, intermediate and fresh based on the apparent freshness of the channels and aprons. This qualitative classification was based on the freshest-looking gully at each site. Based on this assessment, sites classified as fresh are much more likely to be active (23%) than those classified as degraded (2%), a difference which is statistically significant based on the Fisher-Irwin test [24]. Northern hemisphere sites were more likely to appear degraded.

We examined correlations with other features as well. At sites where possible RSL occur in the same series of images (not necessarily within the alcove-channel-apron gully landforms, but often within fine channels), there is an enhanced likelihood of activity but the statistical significance is marginal. We also examined correlations with albedo, elevation and thermal inertia using the nonparametric Mann-Whitney test [24], which evaluates the likelihood that two populations have the same distribution function. No statistically significant difference in either elevation or albedo was observed. Thermal inertia does show a statistically significant difference, but this is likely due to the anomalously low-thermal-inertia polar pit gullies, which are particularly active. Since latitude rather than

thermal inertia may be the important parameter, we re-tested this parameter using only monitoring sites from 25-60°S and found no significant difference. Northern hemisphere sites have systematically different elevation and albedo, but because of the asymmetry of Mars' seasons, we do not consider this to be evidence of an effect from those parameters.

Discussion: It is now clear that gully formation is ongoing: transport of loose material from alcoves to aprons is observed, along with incision of substantial channels. The correlation between freshness and activity also supports the proposal that current processes form gullies. While it is impossible to rule out past processes like snowmelt contributing to gully formation, it is not necessary to invoke them, and the rate of current activity would likely have erased most features that might uniquely relate to the most recent high-obliquity period. To an order of magnitude, current processes at current southern-hemisphere rates could likely produce the observed population of gullies within a few Ma.

The timing of observed changes remains consistent with the proposed correlation with seasonal frost and defrosting, and hence with a substantial role for seasonal CO_2 in gully formation. The orientation and geographic distribution of gullies are similar to that of seasonal frost. Gullies (including active sites) are found slightly closer to the equator than detections of seasonal CO_2 frost [25]; this could mean that trace water frost facilitates activity, but it is also possible that small or short-lived patches of CO_2 frost have gone undetected, particularly in deep shadow.

Formation of gullies is ongoing today at a geologically rapid pace, so past climates with widespread melting snow are not required. The likely driver of current activity, and perhaps all gully formation, is seasonal CO_2 frost.

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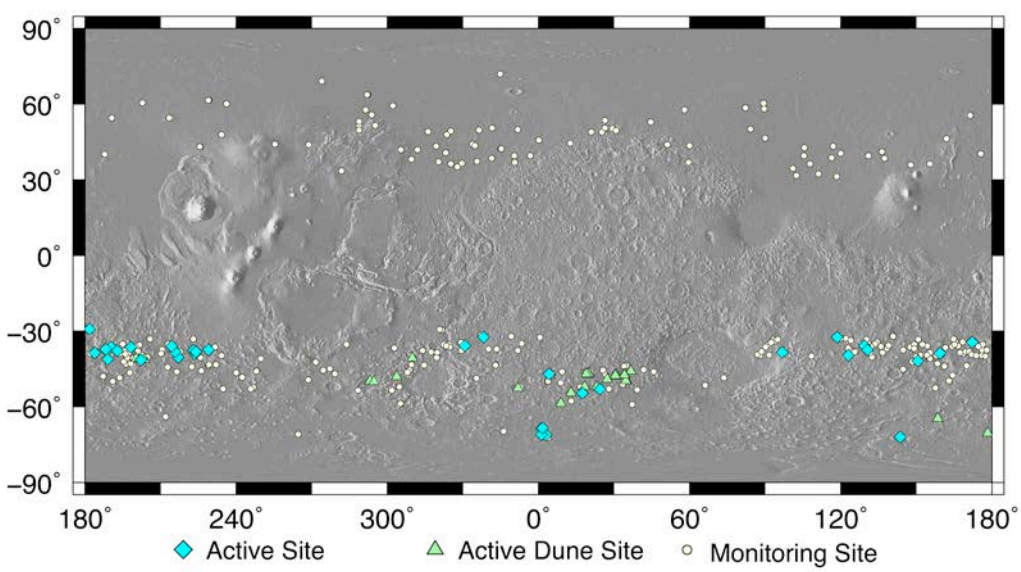

Figure 2: Distribution of HiRISE non-dune gully monitoring sites (yellow). Active sites are shown in blue. Active dune gully locations are shown in green. Background is shaded relief from MOLA elevation.