RECENT GULLY ACTIVITY ON MARS: IMPLICATIONS AND OBJECTIVES FOR FUTURE EXPLORATION. C. M. Dundas[1], A. S. McEwen[2], S. Byrne[2], S. Diniega[3], and C. J. Hansen[4], [1]Astrogeology Science Center, U. S. Geological Survey, 2255 N. Gemini Dr., Flagstaff, AZ 86001 (cdundas@usgs.gov), [2]Lunar and Planetary Laboratory, University of Arizona, Tucson, AZ, [3]Jet Propulsion Laboratory, Pasadena, CA, [4]Planetary Science Institute, St. George, UT.

Introduction: Recent gully landforms on Mars have been seen as evidence for recent, near-surface liquid water since their discovery [1]. Theories of gully formation by melting snow or ground ice [e.g., 2, 3] imply that liquid water was annually available in certain locations in the recent past. An alternative source of liquid is groundwater [e.g., 1, 4-5], which could tap into possible habitable environments at depth. Much recent work [e.g., 6-10] has favored snow or near-surface melting, but suggestions of groundwater remain [e.g., 11]. If gullies form mainly by flow of liquid water, they would be of great interest for astrobiology, and in situ study or returning samples from gullies would be a high priority for future exploration. They would also be or have recently been “Special Regions” (as defined by [12]), and would warrant a high level of planetary protection. However, recent discoveries have made a role for liquid water less likely.

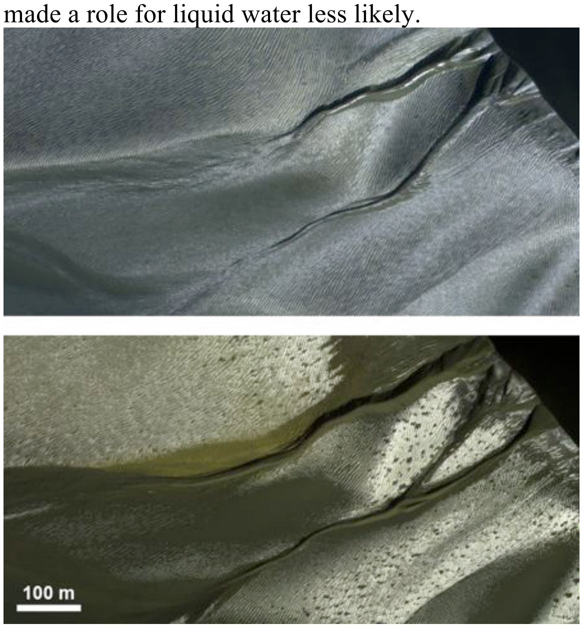

Figure 1: New alcove and channels (HiRISE images ESP_019069_1300 and ESP_019636_1300.)

Recent Activity: Over the past several years, extensive activity has been observed in dune and non-dune gullies on Mars [11,13-17]. Current activity is not simply degradation of older landforms by mass wasting; channel incision and even formation of complete dune gullies has been observed [14-17] (Fig. 1), although the most easily detected change is generally a deposit on a gully apron. Gully formation is ongoing, driven by currently active processes.

An important aspect of the current activity is that it is seasonally controlled, with a preference for winter or early spring activity [13-17]. It is possible that some activity is due to dry, volatile-free flows [18], but in general such activity cannot account for the observed seasonality. Instead, this timing is associated with the presence and removal of seasonal CO_2 frost, which has lent support to suggestions that such frost could play a major role in gully formation [19-23].

The Role of Water: Since current activity is likely driven by CO_2 frost and contributes to ongoing gully formation, it is possible that gullies develop without significant amounts of liquid water. However, extensive current activity without water does not rule out a major role for water in some or all gullies in the past, and some gully landforms occur on slopes where little or no CO_2 frost currently forms. It is necessary to test CO_2 models more extensively in order to understand whether, applied over Mars’ history, they can account for the distribution and properties of all gullies.

Even if liquid water has not controlled gully formation, small amounts could occur annually by melting water frost that is preferentially cold-trapped in alcoves [24, 25]. Recurring Slope Lineae (RSL) also occasionally occur in Martian gully landforms or small channels (gullies in the terrestrial sense), which might also reflect the seasonal presence of water [26, 27]. Future exploration of RSL is discussed by [27].

Future Observations Needed: Understanding the roles of water and CO_2 in gullies is vital to assess the role gullies should play in future exploration and falls under Challenge Area 1 for this meeting. Several observations would lead to significant advances.

It is not clear how observed activity applies to gully landforms as a whole, over space and time. Widespread activity has been seen in images from the High Resolution Imaging Science Experiment (HiRISE), but this data set has a distinct bias because areal coverage is very low: images (particularly monitoring series) are concentrated at sites thought to be active or known to appear fresh in other data. The Context Camera (CTX) data has much less bias (due to wide spatial coverage), but has a lower resolution and signal-to-noise ratio (SNR) and lacks color, all of which may lead to activity going undetected (Fig. 2). The first observed new deposits were relatively bright [11], but relatively dark deposits and changes that are most visible in color images also occur [15, 17].

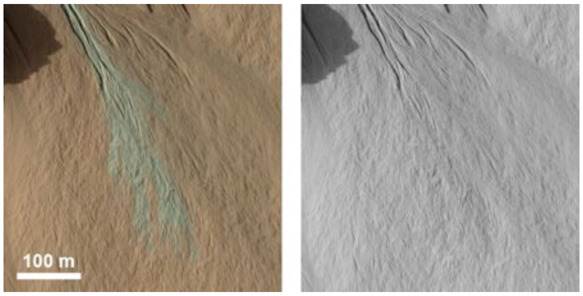

Figure 2: (Left) New gully deposit in a HiRISE RGB color image using only data from the red and blue-green filters. (Right) In the red band alone (HiRISE red filter) the deposit is hard to discern. (HiRISE image ESP_020661_1440).

An unbiased, broad-scale assessment of current activity is needed to understand how similar activity would have been distributed in the past. This can be achieved by repeat imaging of a significant fraction of the mid-latitudes in color, with high SNR and moderate resolution (5-10 m/pix). Coverage at latitudes as high as ~75° is desirable but most gullies are at lower latitude [e.g., 8]; CO_2 frost is less abundant in the mid-latitudes, so learning its role there would aid understanding of higher latitudes. Topography from stereo imaging would aid in understanding data on frost (below). Data should be collected for at least two Mars years to study seasonality and characterize the environmental conditions of observed active gullies in the second year. Alternatively, these goals could be achieved by radar interferometry [28] if similar coverage and resolution can be obtained. Volumes of larger events (especially in dune gullies) could be estimated with stereo imaging at high resolution; this is of interest to study rates of change but is not required to assess the distribution of activity. Likewise, high-resolution imaging of frost activity would be informative but is not required to understand the distribution of changes.

The second necessary component is a better understanding of volatiles in active and inactive gullies. The distribution of CO_2 frost can be assessed by thermal- and near-infrared spectroscopy. Thermal imaging can identify surfaces at the CO_2 frost point (~145 K), while near-IR spectra would allow both CO_2 and H_2O frost to be identified. (Color images can show frost but cannot distinguish CO_2 and H_2O.) Existing thermal-IR data in particular has low spatial resolution (100 m/pix); better data (10-20 m/pix) would resolve variations in gully alcoves. Near-IR data must contend with shadows in winter and would be best acquired near local noon.

With this data, we can answer several questions: What is the frequency of activity of all Martian gullies? How does it vary with latitude and gully morphology? What is the thermal environment in a gully alcove at the time of activity? A complete assessment of changes will let us understand the characteristics of active gullies. Frost observations constrain environmental conditions driving activity. We can then assess whether environments conducive to present-type activity have existed for all gullies at some time. If it is not possible to explain all gullies in this way, other drivers (such as liquid water) would be required.

With models for the thermal environment of gullies that are well-constrained by observations, we can better assess coldtrapping and potential melting of water frost [24, 25]. If this process is significant, gullies would be "Special Regions" even if water does not drive their formation. We can then determine which sites would have been most conducive to occurrence of seasonal liquid water over long periods of time.

A better understanding of the roles of H_2O and CO_2 in gullies thus contributes to each of the Decadal Survey science goals for Mars [29]: determining whether life ever arose, understanding the processes and history of climate, determining the evolution of the surface, and ultimately determining their role as targets for sample return or human exploration.

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