CONTEMPORARY GULLY ACTIVITY ON MARS: INSIGHTS FROM REGIONAL GEOLOGY. David A. Crown, Daniel C. Berman, and Leslie F. Bleamaster III, Planetary Science Institute, 1700 E. Ft. Lowell Rd., Suite 106, Tucson, AZ 85719, crown@psi.edu.

Introduction: The discovery of abundant, geologically recent gullies on the surface of Mars has been a major contribution of the Mars Global Surveyor mission [1]. The morphologic characteristics, distribution, and geologic settings of Martian gullies continue to be the subject of intense research by numerous investigators, with significant implications for the abundance and distribution of near-surface and subsurface volatiles on Mars as well as climate change. The recent identification of surface changes along two gullies on Mars between 1999 and the present [2] adds intriguing new information to incorporate, given the interpretation of contemporary flow of liquid water. Here, we discuss the geologic settings of the gully systems that show recent surface changes, placing these compelling discoveries into their regional geologic contexts.

Martian Gullies: Global-scale analyses have shown tens of thousands of gullies on the Martian surface that are predominantly located in mid-latitude zones (i.e., 30-60°) [1, 3]. Some studies note that gullies occur in regional clusters [4-6]. Gullies were interpreted to be geologically recent features based on a lack of superposed craters, superposition of gully aprons on geologically recent landforms, and their relatively pristine appearances [1]. Most gully channels originate several hundred meters below their associated local topographic high and typically include an alcove, one or more channels extending from the alcove, and a depositional apron that may exhibit mutiple distributary channels and flow lobes [1].

Although alternative hypotheses have been proposed [7-8], most investigators have interpreted gullies as the result of downslope flow of water or water-rich debris flows. Considerable debate continues to center around whether there was a subsurface or surface source for the water [e.g., 9-10]. Proposed models include: surface runoff fed by subsurface aquifers [1, 11], discharge of saline groundwater or brines [12], melting of ground ice [11], and melting of snowpacks [14-16]. Several recent studies [17-19] demonstrate a linkage between exposure/emergence of gullies and degradation of ice-rich mantling deposits [20] due to solar insolation effects. These observations are consistent with snowpacks or volatile-rich mantles as the source of the water that carves gullies and/or indicate that gully formation is favored by the presence of an insulating layer that allows volatiles to act on the surface prior to sublimating or refreezing.

Evidence for Contemporary Gully Activity: Comparison of Mars Orbiter Camera (MOC) images taken in 2001 and 2005 shows a new light-toned deposit on the NW wall of a 3.8 km diameter crater in Terra Sirenum (near 36.5°S, 161.8°W) [1]. The deposit is located on the floor and banks of a gully channel and terminates in a digitate lobe near the base of the crater wall. Comparison of MOC images taken in 1999 and in 2004 and 2005 shows a new light-toned deposit on the SE wall of an ~10 km diameter crater between Centauri and Hellas Montes (near 38.7°S, 263.3°W) in Promethei Terra [1]. This deposit has digitate lateral and distal margins that appear to have been influenced by small topographic obstacles on the crater wall. Malin et al. [1] attributed the observed morphology to short duration, highly fluid flows of a mixture of water and debris, perhaps triggered by failure of ice-rich rock dams on the crater wall. The light tone was interpreted to be due to frost, fine-grained sediment, or salts.

Centauri/Hellas Montes Gully-Geologic Setting: The crater exhibiting evidence for contemporary activity is located south of a degraded, rugged highland massif in western Promethei Terra. Global and regional geologic mapping studies characterize this area as variably degraded highland terrain of the Hellas rim [21-23]. Detailed mapping studies of eastern Hellas [24-27] define the unit containing the crater as pitted plains material (AHpp), with numerous exposures of younger lobate debris aprons (unit Ada) nearby, including the prominent elongate “tongue-shaped” apron featured in studies of volatile-rich mass-wasting on Mars [e.g., 28-31]. Pitted plains were observed to fill low-lying regions of the highlands and were interpreted to be water- or ice-rich deposits resulting from coalescence of debris aprons [24-26]. Pits were attributed to removal of volatiles.

The crater has interesting morphologic attributes reflecting its geologic setting and history. The crater has a well-defined rim with the exception of its NE margin. High-resolution images do not show a distinct ejecta blanket [31] but rather pitted, lineated, and possible deformation textures typically associated with debris aprons [29-31]. We interpret the topographic and morphologic characteristics to be due to collapse of the NE crater wall and flow of ice-rich debris into the crater interior (Fig. 1). The hummocky nature of the crater floor is consistent with collapse and infilling. The crater walls, floor, and small topographic depressions in the surrounding surfaces suggest the presence of partially degraded mantling deposits as have been proposed for Martian mid-latitudes [20]. The north crater wall contains gullies incised into mantling deposits; several filled alcoves are observed. The south crater wall exhibits faint narrow, shallow lineations, or poorly developed gullies. These characteristics are consistent with observations of the NW and SE walls of Dao and Harmakhis Valles located to the east [17]. The highly digitate nature of this light-toned deposit reflects the subdued south crater wall topography and lack of confinement by a well-incised gully channel.

In considering implications of contemporary gully activity at this site for understanding gully volatile sources, it is important to note that the surface containing the gullied crater is geologically young (i.e., Amazonian) and thought to be ice-rich. Ice may have been emplaced by geologically recent flow of ice/rock mixtures (i.e., debris-covered glaciers, rock glaciers, or ice-rich mass movements), thus obscuring the ultimate source (ground vs. atmosphere) and timing of initial deposition of the volatiles. Given typical debris apron thicknesses of 100-300 meters at their fronts, ice may be abundant in the subsurface down to at least these depths. Even younger ice-rich mantling deposits may be an additional source of volatiles for the gullies in this crater. The diverse evidence for abundant volatile-rich materials near and at the surface suggests that this is not an unlikely location for contemporary activity.

Terra Sirenum Gully-Geologic Setting: The crater exhibiting evidence for contemporary activity is located NW of Newton Basin at 36.5°S. This densely cratered region is thought to be representative of the southern highlands [32]. Recent work has characterized degradational morphologies of craters in the Phaethontis Quadrangle that contains Newton Basin [6]: 188 craters with diameters between 2 and 30 km were identified with gullies on some portion of their walls. In this region, gully orientations are latitude dependent, with a change from predominantly pole-facing orientations north of 44°S to predominantly equator-facing orientations south of 44°S [6]. Many craters were also noted to have pitted or lineated floor materials sloping to the south. Some asymmetries in rim heights were also apparent, with lower, apparently degraded northern rims suggesting collapse and infilling of crater interiors preferentially occurring on the pole-facing side. The crater of interest has relatively few gullies; those observed are incised into smooth deposits mantling its northern walls. The crater floor and terrain surrounding the crater also appear to have been mantled, given smooth and pitted textures and partially buried features. The crater, which is 100 meters deep, shows a N-S rim height asymmetry, with the northern rim ~40 meters lower. Its topographic and morphologic characteristics suggest that it is typical of craters in the vicinity of Newton Basin, indicating that continued high-resolution surveys of this region would be important for constraining current rates of surface activity. In MOC images, the crater shows two bright zones: the new light-toned deposit and another that is more diffuse and covers the base of several gullies and part of the crater floor along the northern crater wall. Comparison of available MOC images indicates that this second light-toned patch has not changed during the MGS mission. To date, we have identified only one additional example of a light-toned deposit (R11-02298) on the south wall of a crater near 41.6°S, 157.7°W that is similar (elongate with digitate terminus) to those associated with gullies showing evidence for contemporary activity.

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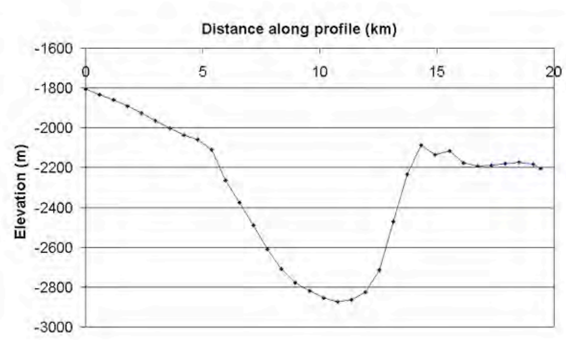

Figure 1. Topographic profile (NE-SW) from MOLA 128 pixel/deg DEM of crater in Centauri/Hellas Montes region showing evidence for contemporary activity. Note lack of defined rim to NE (left) and evidence for infilling of crater from NE.