GULLIES IN THE EASTERN HELLAS REGION OF MARS.

D.A. Crown, L.F. Bleamaster III, and D.C. Berman, Planetary Science Institute, 1700 E. Ft. Lowell Rd., Suite 106, Tucson, AZ 85719, crown@psi.edu.

Introduction. The eastern Hellas region of Mars is characterized by an extensive history of volatile-driven activity, although the style, spatial extent, and magnitude have varied considerably over time [1-5]. Highland volcanoes and cratered terrains dissected by fluvial valleys, extensive sedimentary plains, and the prominent canyons of Dao/Niger, Harmakhis, and Reull Vallis illustrate the widespread and then more localized influence of volatiles, potentially associated with climate change. The regional geology of E Hellas is overprinted with a suite of geologically recent features indicative of contained ice, melting of ice, or its release to the atmosphere. These include lobate debris aprons [e.g., 6] and lineated valley fill, noted as geomorphic indicators of ground ice in analyses of Viking images, as well as ice cemented soils [7], characteristic of the Martian mid-latitudes, and numerous gullies and small flow lobes [8-10]. Gullies in the E Hellas region are found along the walls of the circum-Hellas canyons and along the interior rims of impact craters. The present investigation synthesizes a series of independent analyses of gullies in E Hellas to address their occurrence and potential modes of formation.

Promethei Terra/Eastern Hellas Crater Survey. Part of the E Hellas region (30-60°S, 110-150°E) is being examined (along with other mid-latitude zones [11-12, Berman et al., this issue]) in order to assess the distribution and nature of a suite of degradation features known to be concentrated on crater rims, including gullies, arcuate ridges, and small flow lobes. Numerous, well-developed gully systems are evident on the walls of craters in this region. Gullies and arcuate ridges tend to be found on the walls of craters ~2-30 km in diameter, with small flow lobes found in clusters on the walls of some craters with diameters > 20 km. As in other regions, Berman et al. [11-12] have found gullies, arcuate ridges, and flow lobes on both pole- and equator-facing crater walls, with pole-facing orientations typically between 30 and ~45° latitude and equator-facing orientations typically between ~45 and 60° latitude. These variations have been attributed to cycles of ice deposition, sublimation, and erosion by ice-rich mass wasting and melting of ice. In some cases, pitted and lineated deposits were found to slope away from the base of a gullied crater wall across the crater floor. This work suggests that the occurrence and/or preservation of ice-rich geologic landforms is significantly influenced by insolation history.

Gullies Associated with Dao and Harmakhis Valles. Dao and Harmakhis Valles are parallel canyon systems extending for a combined length of > 2400 km; each extends from ~30 to 45°S and exhibits 5 km of relief from head to terminus. Dao Vallis was described in the initial report on Martian gullies [8] as a location with a significant population and where filled alcoves were common [8, 13]. The vertical distribution of gullies along Dao Vallis was also cited as evidence in support of gully formation involving subsurface aquifers [14]. Relationships between ice-rich mantling deposits, gullies, and viscous flows along Dao Vallis have also previously been noted [9, 13].

Evaluation of MOC narrow-angle images has allowed a systematic characterization of the walls of Dao and Harmakhis Valles [10]. Vallis wall morphology was classified on the basis of the presence and preservation of mantling deposits and occurrence of gullies into the following three types: exposed, mantled, and incised. Gullies are exposed by the removal of semi-competent mantling deposits. Observations suggest a sequence of progressive development from mantled walls to incised mantle and, with further degradation, to walls that display exposed gullies. Analysis of latitude, elevation, and wall orientation for 420 representative sites along vallis walls shows preferential spatial clustering of end-member morphologies: exposed gullies are favored at lower latitude, higher elevation, and on east facing walls, and mantled walls are favored at higher latitude, lower elevation, and on south and southwest facing walls. The observed morphologies and spatial patterns are consistent with the hypothesis that gullies emerge from beneath an ice-rich mantle that is degrading in response to local variations in total solar insolation. These results do not directly address the mechanism of volatile accumulation nor the specific gully formation process, but do suggest that the ice-rich mantling deposits are directly linked to gully formation [see also 15-16], either as 1) the source of volatiles that carve gulles or 2) an insulating layer that allows volatiles to accumulate and act as an erosional agent prior to evaporating or refreezing.

Contemporary Gully Activity in Centauri/Hellas Montes. The discovery of abundant, geologically recent gullies has been a major contribution of the MGS mission [8], and the recent evidence for surface changes along two gullies is especially intriguing, given the interpretation of contemporary flow of liquid water [17]. Comparison of MOC images taken in 1999 and in 2004/2005 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. 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. [17] 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.

The crater exhibiting evidence for contemporary activity is located south of a degraded, rugged highland massif in western Promethei Terra and north of Reull Vallis. Global and regional geologic mapping studies characterize this area as variably degraded highland terrain of the Hellas rim [5, 18-19]. Detailed mapping studies of eastern Hellas [1-3, 20] define the unit containing the crater as pitted plains material, with numerous exposures of younger lobate debris aprons nearby, including the prominent elongate “tongue-shaped” apron featured in studies of volatile-rich mass-wasting on Mars [e.g., 6, 21-23]. 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 [2-3, 20]. Pits were attributed to removal of volatiles.

The crater has interesting morphologic attributes reflecting its geologic setting and history [24]. It has a well-defined rim with the exception of its NE margin. High-resolution images do not show a distinct ejecta blanket [23] but rather pitted, lineated, and possible deformation textures typically associated with debris aprons [6, 22-23] are observed, particularly to the E and N. To the S, subdued topography consistent with a former lobate ejecta blanket is apparent. Scarps stepping down away from the crater rim indicate significant erosion; layered, smooth deposits confined to local depressions suggest burial by and extensive degradation of surface mantling deposits.

The relief of the crater rim (except to the NE) and exposure of rocky outcrops along the S and SE interior rims suggest that the crater formed in highland bedrock. The crater is inundated by ice-rich debris flows from the N. We interpret the topographic and morphologic characteristics to be due to collapse of the NE crater rim and flow of ice-rich debris into the crater interior. The hummocky nature of the floor is consistent with collapse and infilling. Destabilization of the NE rim likely continued, as rocky outcrops are absent here and the present scarp defining the crater wall cuts ridges that characterize the debris apron surface.

The crater walls, floor, and small topographic depressions in the surrounding surfaces suggest the presence of partly degraded mantling deposits. The north crater wall contains gullies incised into mantling deposits; several filled alcoves are observed. On the NE rim, gullies appear to have redistributed debris apron materials along the crater rim slope. The SE crater wall exhibits faint narrow, shallow lineations, or poorly developed gullies, extending from rocky rim materials. The characteristics of the N (pole-facing) and SE (equator-facing) walls are consistent with observations of the NW and SE walls of Dao and Harmakhis Valles [10]. The highly digitate nature of the light-toned deposit in this crater 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.

Implications. In E Hellas, gullies occur in a variety of different geologic settings at different latitudes, elevations, and orientations; they dissect different geologic materials. They appear to be the most recent manifestation of an extensive history of volatile-driven erosion. There is a clear spatial correlation with mid-latitude mantling deposits, suggesting significant influence of insolation history. Further study is required to determine the amounts of water needed, water flow history, and the ultimate source of the water.

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