DEPTHS AND GEOLOGIC SETTING OF NORTHERN HEMISPHERE GULLIES (AND COMPARISON TO THEIR SOUTHERN COUNTERPARTS). Martha S. Gilmore and Naomi Goldenson, Dept. of Earth and Environmental Sciences, Wesleyan University, 265 Church St., Middletown, CT 06459, mgilmore@wesleyan.edu.

Abstract: Gullies are recognized as having an incised (often sinuous) channel, alcove, and apron morphology as defined by [1]. Previous detailed work [2,3] has focused on the characteristics of southern hemisphere gullies; here we examine the distribution, morphology and depth of northern hemisphere gullies. Gully locations (both hemispheres) were compiled from the literature [1,4-6], not a global search, and thus the gullies studied here are the subset of the whole for which corresponding MOLA tracks are available.

We find that the heads of the majority of N. hemisphere gullies commence in a specific cliff-forming layer, and average 250 m below the local surface. This observation suggests that the rock layer has a genetic relationship to gullies and is difficult at present to reconcile with gully formation from snowmelt [7,8], which predicts no correlation to rock layers. Gully locations and depths correspond to specific geologic units. We propose that in addition to ground ice and a melting mechanism, gully formation requires groundwater flow along or within specific rock units.

Gully Morphology and Associations. Twenty-three gully systems were studied using MOC images. They occur from 35°-64°N and all but two occurrences are exposed on (mostly pedestal) crater walls. All but one of the gully systems studied occur with landforms indicative of ground ice (lineated crater fill, polygonal terrain, viscous materials). In 3 instances, lobate material near the crater wall appears to have flowed downslope prior to gully formation leaving toes of material interpreted to be remnants of sublimed rock glaciers [5,9]. In one instance (E03/01847) lobate toes are present on the poleward facing side of the crater and gullies are present on the opposite side. Several images of gully systems have evidence for degraded gullies (and ice flows). This supports the mounting evidence that these gullies may persist and evolve at a given location [5, 9].

In most occurrences, gully heads coincide with a competent, cliff-forming layer 10s m thick in the wall as noted for other gullies globally [1-4]. Two examples (both on knobs) lack a cliff-former; in these instances gullies appear to be related to mantle materials described by [10].

Gully Orientation. Northern hemisphere gullies are oriented equally and predominantly towards the north and the south. This suggests that there is no direct dependence on poleward orientation. The paucity of E or W-facing gullies could be an observational effect as the N-S MOC images often exclude the E or W walls of an imaged crater.

Relationship of Gullies to Geologic Units. The distribution of gullies in both hemispheres is regionally clustered as noted by [2,4,11]. In the North, gullies of this survey lie largely within units of the Vastitas Borealis formation (Hvm, Hvk, Hvg [12,13]) in Acidalia and Utopia Planitae, plains materials (Arcadia Formation, Aa_1[13]) in Acidalia, and on a plains unit interpreted to be flows of Elysium Mons (Ael_3[13]) [12-14]. The Late Hesperian - Early Amazonian materials of the Vastitas Borealis Formation are interpreted by several to have been deposited by a northern ocean and interpreted by most to have experienced a volatile-rich history (see discussion and references in [14]).

Depths of Northern (and some southern) Hemisphere Gullies.

Method. MOC and MOLA data were processed and correlated using ISIS provided by the USGS. Gully depths are calculated by measuring the average slope of the gully using MOLA and measuring the horizontal distance of the gully head (depth at which gully commences) from the local surface on a MOC image. In most cases only the top or bottom of the slope can be directly pinned to a MOLA footprint due to an offset angle between the slope and direction of MOLA track, or due to the limited extent of the image. In that case a height value is extrapolated along strike. Depth errors are calculated to between ±10-20m.

Results of Depth Measurements. The heads of N. hemisphere gullies lie ~-2.5-6 km below the MOLA datum, comparable to gullies in the S. hemisphere at Dao Vallis (Fig. 1a). N. hemisphere gullies are found an average of ~240 m (range 0-500m) below the local surface similar to S. hemisphere gully depths measured by [2, 3; Fig. 1b]. Gully depths hover around the average in the majority of geologic units except for gullies in unit Hvm, the mottled member of the Vastitas Borealis Formation in Acidalia Planitia. Gullies in exposures of unit Hvm lie ~130 m below the local surface (Fig. 2). We assume that these craters are exposing materials of the surrounding mapped material units.

Discussion. Our hypothesis is that three components are necessary to produce gullies: 1) near-surface ground ice, 2) a melting mechanism, and 3) a rock layer within reach of the groundwater that serves as its conduit or facilitates melting.

Ground ice is observed at the majority of gully locations in the N. hemisphere (not so for low latitude gullies S. hemisphere), and gully locations correspond to geochemical evidence of ground ice [15]. We agree with other workers that the relationship between the ice flows and gullies appears to be genetic [5,9]. However, the detailed relationship between ground ice and gullies is variable: gullies are seen to be associated with occupied alcoves, flowing ice and toe lobes in the N. hemisphere craters and S. high latitudes (Dao Vallis) whereas there is no evidence for ice at the S. low latitude gullies (Nirgal Vallis, Gorgonum Chaos). We have also noted a system above that seems to emanate directly from mantled [10] materials. We agree strongly with [11] that not all gullies are necessarily formed by the same mechanism. Gully formation as the result of melting beneath surface ice [7], may be plausible for gully systems that are independent of individual rock layers, do not postdate the icy lobes and seem to emanate directly from mantled materials. Gullies and lobes commencing at rock layers may be produced by the same groundwater system, where slope temperature controls the presence or absence of ice (see also [5]).

Temperature. In the N. hemisphere, the fact that gullies occur on slopes of various orientations and that gullies and toes of viscous material occur within the same crater support the theory that microclimates are controlling melting at a given location [16]. Detailed measurements underway seek to constrain the local thermal environment of gullied slopes, but temperature cannot be the sole control on gully formation in the presence of ground ice if gullies do not occur on every similar slope in an area. This is suggested by the fact that gullies are regionally clustered.

Conclusion: Geology. As seen with S. hemisphere gullies, the heads of the majority of N. hemisphere gullies correspond to exposed layers that appear to be competent material (cliff-formers). This suggests a genetic relationship between the rock layer and the gullies; where there are no layers gullies will not form. Furthermore, the depths of N. hemisphere gullies correspond generally to geologic unit. This supports the correspondence of the gullies to the competent rock layers in the material unit and suggests that this unit has properties that allow it to serve as a conduit for groundwater or a facilitator of melt generation. Finally, the commencement of gullies in the uppermost 700 m (typically upper 300 m) must be addressed by models for gully formation. It has been suggested this is the depth of the 273K isotherm [3], and/or melt waters are flowing along the uppermost regional impermeable layer [2] or within a permeable layer [17]. Snowmelt models [7, 8] are difficult to reconcile with this observation.

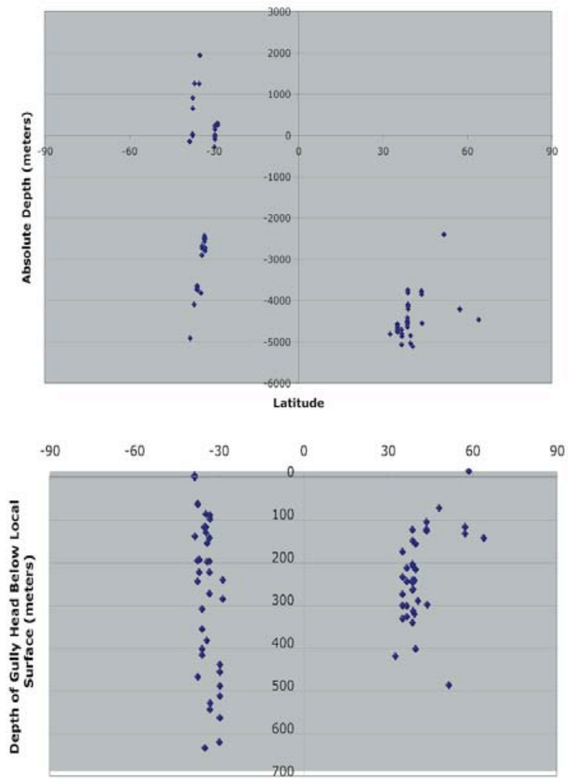

Fig. 1 (a, top) Absolute elevation and (b, bottom) depth below local surface for all gullies measured.

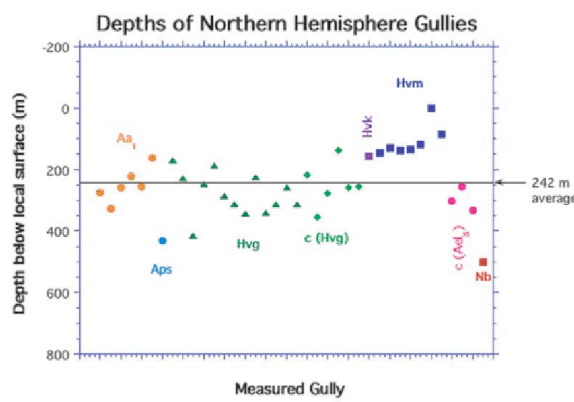

Fig. 2. Depths of N. hemisphere gullies correlated to specific geologic unit. See text for unit description. Error bars omitted for clarity but ≤20 m.

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