DEPTHS, ORIENTATION AND SLOPES OF MARTIAN HILLSIDE GULLIES IN THE NORTHERN HEMISPHERE. Nina L. Lanza and Martha S. Gilmore, Department of Earth and Environmental Sciences, Wesleyan University, 265 Church St., Middletown, CT 06459 (nlanza@wesleyan.edu).

Introduction: Martian gullies were first identified by Malin and Edgett [1]. Previous work [2] has examined the characteristics of gullies in the southern hemisphere in detail. Less detailed work has been done for the northern hemisphere [3,4]. Gullies are found predominantly in the midlatitudes of both hemispheres between 30°-50° [1,2], which implies a thermal control on their formation. Several workers have suggested that the source material for the gullies is groundwater that flows along or within subsurface rock layers [1,2,3,5]. Other workers have suggested that insolation changes cause near surface ice or snow to melt, thus forming the gullies [6,7].

Here we attempt to better constrain the environment of gully formation by measuring orientation, slope, elevation and depths of gullied and non gullied slopes in the N. hemisphere. This work in an improvement on the methods of [3] and measures a larger set of parameters than [4]. We compare these measurements to published surveys of S. hemisphere gullies [4,5].

Methods: 160 gullies were identified in the northern hemisphere using MOC images, with a focus on the Acidalia and Utopia regions. Digital elevation models (DEMs) were created for the regions containing gullies using the Mars Orbiter Laser Altimeter (MOLA) data. These DEMs were created using the Generic Mapping Tools (GMT) software by a technique developed by Okubo et al. [8]. This interpolation method creates DEMs with an associated error comparable to MOLA measurements.

Next, ISIS was used to create MOC image cubes, which were then converted into geotiffs. The DEM and MOC data were then overlaid in ArcGIS. Once the two data sets were properly aligned, the gullies were digitized. Using Easy Calculate, a set of free ArcGIS tools, the values of depth, slope, and orientation were extracted from the DEM using the regions defined by the digitized gully. This process was repeated for non-gullied slopes. Gully elevation and depth were measured as the top of the gully; elevations of nongullied slopes were measured at the top of the slope. Nongullied slopes were identified primarily in MOC images that also included gullies, and often were measured on the walls of craters that also had gullies.

Results: The gullied slopes appear to have an orientation preference, with low-latitude gullies facing poleward (orientations ~0º and 360º) and high-latitude gullies facing equatorward (orientations ~180º; Fig. 1).

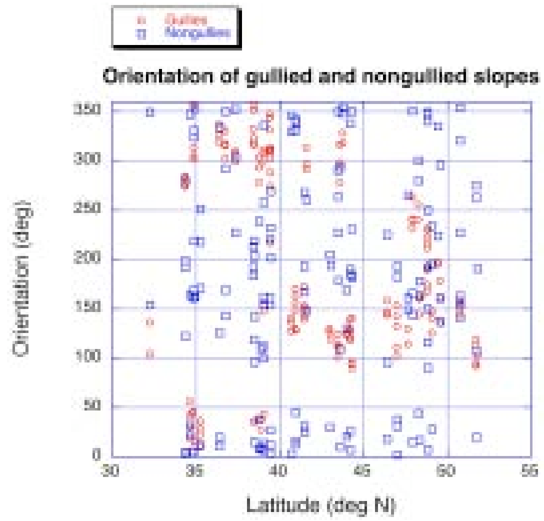

Fig.1. Orientation of gullied and nongullied slopes. North-facing slopes are oriented ~0º and 360º, while south-facing slopes are oriented ~180°.

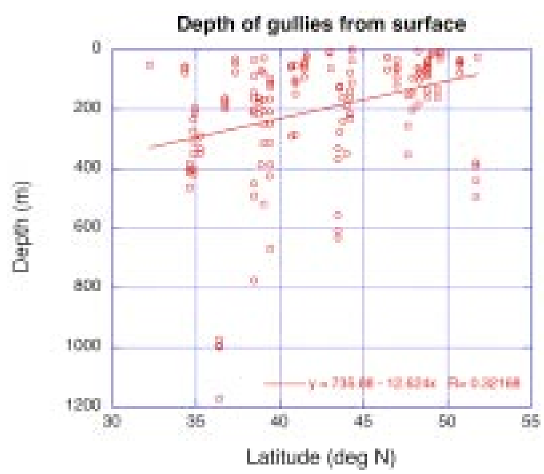

Fig. 2 . Depth of gully tops from surface.

The non-gullied population shows no apparent orientation preference. MOC images may exclude many E-W slopes due to the N-S trending MOC footprints that are often centered on craters. However, the nongullied population is fairly evenly distributed across all orientations, which implies that the orientation preference of the gullied slopes is not an artifact of the dataset.

Figure 2 shows the relative depths of the gullies below the surface. The average depth of the gully tops is 202 m below the surface, but ranges from ~top of a slope to over 1 km below the surface. This is consistent with Heldmann and Mellon's results for the southern hemisphere [2,5], as well as previous results for the northern hemisphere [3], although with a larger range. As the latitude decreases, the gully depth generally increases. The tops of the gullies follow the local topography of the northern hemisphere with an average depth of -4173 m.

The average slope for gullied slopes is ~17.4º (Fig. 3). Gullied slopes appear to become steeper as the latitude decreases, with the steepest slopes below 40º.

Discussion: The preferred orientation of gullies with latitude is seen in both hemispheres [2,9] which underscores a role for insolation in gully formation. At the time of gully formation, low latitude, equator-facing slopes are too warm for gully formation, while the high latitude, pole-facing slopes are too cold.

The model of Costard et al. [10] shows that at high obliquities, poleward facing slopes having the highest insolation, while Hecht's [11] model shows that at the current obliquity, equator facing slopes have the highest insolation. Since both slope orientations are represented, it may indicate either that there are two generations of gullies, or that maximum insolation is not the primary control for gully formation.

The gullies' measured starting depths from the surface are consistent with those in the S. hemisphere [2] and with N. hemisphere measurements in [4] and [5]. At lower latitudes, gullies appear to form deeper from the surface. The results inply that surface temperatures are controlling the depth of melting of subsurface ice in aquifers [2] or over aquicludes [5]. It is more difficult to explain why snowmelt models would initiate gully formation lower on the slope face at lower latitudes, since snow is a near-surface phenomenon.

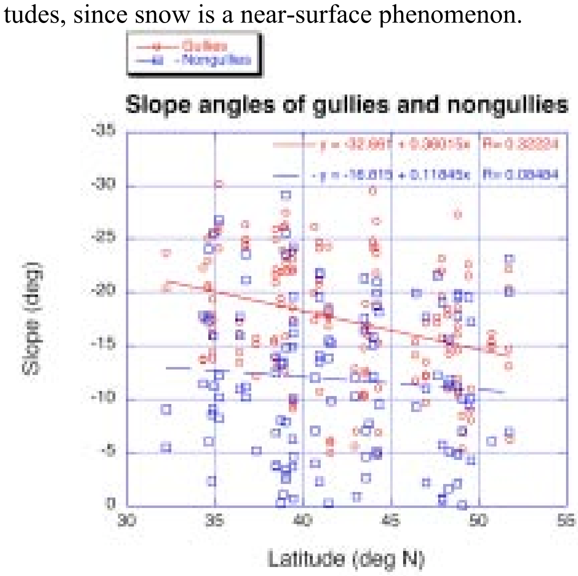

Fig.3. Slope angles of gullied and nongullied slopes.

The average slopes of gullies in the N. hemisphere is identical to the S. hemisphere average of ~18º [9]. Many of these slopes are well below the angle of repose, which Heldmann and Mellon [2] point out obviates mass wasting processes as the sole mechanism of the gully formation. As latitude decreases, the gullied slope angles increase slightly. Hecht [11] finds that for maximum insolation, an equator facing slope between 25º-65º latitude must satisfy the relationship s > L – I, where s is slope, L is latitude, and I is the inclination, which is currently ~25º. Thus, slopes must be shallower at lower latitudes for maximum insolation. Our results show that gully-bearing slopes are steeper at lower latitudes. This supports the idea that maximum insolation at current obliquity may not be desirable for gully formation, and that a specific temperature range is required.

Conclusion: Orientation, depths and slopes of N. hemisphere gullies mimic those of their southern hemisphere counterparts. We find strong evidence for insolation is a control on gully formation. We propose that gullies form where there is an idea combination or orientation, slope and depth that creates a specific temperature-pressure environment that allows for subsurface water or ice to be released on the surface, thus forming the gullies.

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