

AGE-ORIENTATION RELATIONSHIPS OF NORTHERN HEMISPHERE MARTIAN GULLIES AND “PASTED-ON” MANTLING UNIT: IMPLICATIONS FOR NEAR-SURFACE WATER MIGRATION IN MARS’ RECENT HISTORY N.T. Bridges¹ and C.N. Lackner². ¹Jet Propulsion Laboratory, 4800 Oak Grove Dr., Pasadena, CA 91109 (nathan.bridges@jpl.nasa.gov); ²Columbia University, New York, NY 10027 (cnl2007@columbia.edu)

Introduction The finding of abundant, apparently young, Martian gullies with morphologies indicative of formation by flowing fluid [1] was surprising in that volumes of near-surface liquid water in sufficient quantities to modify the surface geology were not thought possible under current conditions [2,3]. Original hypotheses on origin of gullies were mostly centered on groundwater seepage and surface runoff [1] and melting of near-surface ground ice [1,4]. More recently, melting of snow deposited in periods of higher obliquity has been proposed [5-7] as a possible origin of the gullies. Tied to this hypothesis is the supposition that the “pasted-on” mantling unit observed in association with many gullies is composed of remnant snowpack. The mantling unit has distinct rounded edge on its upper boundary and exhibits features suggestive of flow [7,8]. [7] noted that the uppermost part of the mantle marks where gullies begin, suggesting that the source of water for the gullies was within the mantle. The mantle is found preferentially on cold, pole-facing slopes [7] and, where mantled and non-mantled slopes are found together, gullies are observed incised into the latter. In other cases, the mantling material lacks gullies.

Snow formation, pack longevity, and thermal conditions optimum for ice melting are dependent upon thermal insolation, which varies with latitude and orientation [6,9,10]. The amount of insolation and integrated flux onto the surface for a given latitude and orientation vary with Martian orbital elements, especially obliquity. A suitable test for the snowpack model is whether mantle unit and gully characteristics vary as a function of orientation and latitude in a fashion that is easily explainable by recent Martian climate conditions. Toward that end, we have evaluated characteristics of northern hemisphere Martian gullies and compared them to predictions for an origin by snowpack melting. We find that the characteristics are consistent with a snowpack model that is driven by recent obliquity cycling.

Methods: A data base of northern hemisphere gullies compiled by M. Peterson (formerly of Pomona College) was used. This consisted of 260 northern hemisphere gullies from 65 MOC images. Overlapping THEMIS VIS (58 images) and IR (59 images), and VIS images not overlapping with MOC

(24 images), were found by these authors and used to assess regional context and extent of mantle cover. All of the images fall between 30° N and 65°N, and most of them occur in areas of varied topography in the northern hemisphere as opposed to the smoother lowlands. Most of the gullies studied are found along crater walls, although some exist along ridges and other isolated slopes. The alcove length and width and channel length and width of each gully were measured in pixels and then converted to meters using the conversion factor of each individual MOC image. The orientation of each gully, its basic morphology (straight, meandering, etc.) and the presence of mantled terrain near each gully were noted. Preliminary analyses of daily solar insolation for various latitudes, slopes, and obliquities as a function of L_s have also been performed to assess the stability of snowpacks and the potential for melting.

Results: Northern hemisphere gully orientation changes from somewhat random at mid-latitudes to a stronger equatorward trend toward the arctic circle (Figure 1). At mid-latitudes, poleward-facing gullies are generally more distinct, with sharper edges, compared to those facing equatorward (Figure 2). Very smooth material between poleward-facing gullies is interpreted as the same icy mantle proposed by [7] and, given the similarity of tone within and outside of gullies in the mantled areas, gullies here are interpreted as being carved within it. In contrast, the equatorward-facing gullies are commonly filled with bright-toned material that merges with debris aprons down slope. They have an appearance closer to that of dry debris features seen in other areas of Mars compared to the polar-facing gullies. North of about 40-45° latitude, dry debris features are generally lacking at all orientations, pasted-on terrain is found at all orientations, and gullies are more common and better developed on equator-facing slopes. Approaching the arctic circle, gullies appear more distinct, yet are generally shorter than temperate latitude gullies (Figure 3).

Interpretation: These observations are consistent with a gully origin via melting from two or more snowpacks of differing ages. We propose that north-facing temperate latitude snowpacks are remnants from the most recent period of high obliquity, in which snow was placed ubiquitously on

the surface before being removed via sublimation and gully formation on equator-facing slopes. Gullies on equator-facing slopes at mid-latitudes are the last in a sequence that carved into the substrate, whereas those on pole-facing slopes are frozen in time from enhanced melting in the last obliquity cycle or are being produced at a slow rate today. In contrast, snow formation in polar latitudes has covered over any packs or gullies from the past obliquity cycle, such that the observed gullies there are younger and therefore at a lower state of maturity (shorter) than more temperate latitude gullies. Based on published work [11] similar trends are not apparent for southern hemisphere gullies. Gullies there likely date mostly or entirely from the past obliquity cycle, given the dryer south polar cap and regolith water sources and higher solar insolation capable of removing snow compared to the north.

Despite these compelling observations, we recognize that gullies, snow processes, and the effects of climate are poorly understood and that multiple processes may be responsible for the suite of features classified as “gullies.” What we have proposed here is a hypothesis that should be tested with further observations and modeling. Furthermore, only preliminary studies focusing on northern hemisphere gullies have been reported [12] and further work is needed to compare and contrast these with gullies in the south.

Acknowledgement: We are indebted to M. Peterson (Pomona College) for compiling a list of northern hemisphere MOC images containing gullies.

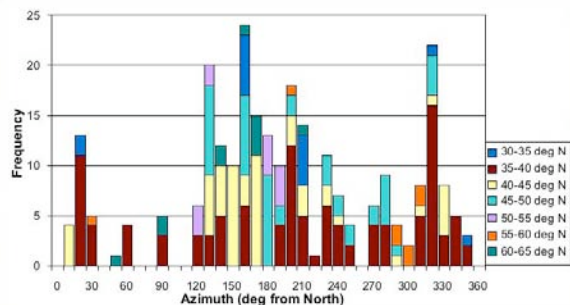


Figure 1: Gully azimuth vs. orientation as a function of 5° latitude bin.

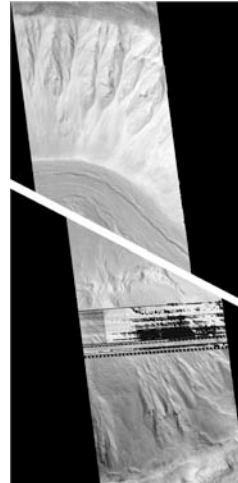


Figure 2: MOC image showing contrasting gully characteristics on poleward- (bottom) and equatorward-facing (top) slopes. This image of a crater has been cropped in the middle and contrast enhanced to aid visibility. The latitude is 40°N. The equatorward-facing slopes appear to have been cut directly into the rock, whereas the poleward-facing slopes are embedded in mantled terrain. MOC image M19-01410 (Credit: Malin Space Science Systems).

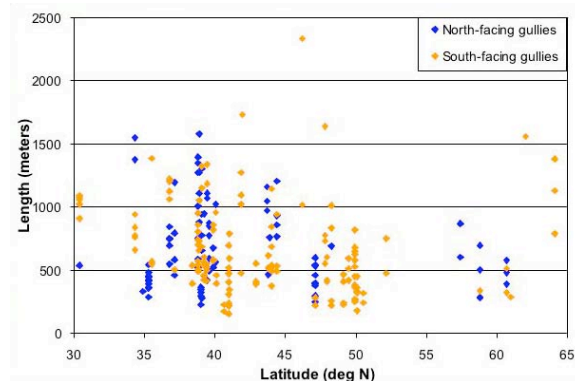


Figure 3: Gully length vs. latitude. Note the general decrease in the range of lengths from temperate to more northern latitudes.

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