A REASSESSMENT OF THE SPATIAL ORIENTATION OF GULLIES IN THE MARTIAN MID-LATITUDES. R. M. E. Williams[1], [1]Planetary Science Institute, 1700 E. Fort Lowell, Suite 106, Tucson, AZ 85719, williams@psi.edu.

Overview: The purpose of this study is to assess the orientation of Martain gullies in middle-latitude craters with complete or near-complete image coverage at decameter-scale resolution. Examination of THEMIS VIS images of gully sites shows that pole-facing orientations are observed only in a specific latitude band (30-50° S); outside of this region, there is no observed preference to gully orientation.

Background: Small-scale features resembling terrestrial water-carved gullies observed in Mars Orbiter Camera (MOC) narrow-angle images at middle and high latitudes are comprised of an alcove, channel and apron, all attributes consistent with fluid-mobilized mass movement processes. Malin and Edgett [1] proposed groundwater seepage of liquid, likely water, from an acquifer resulted in surface runoff that carved the channel and transported sediment to the apron deposit.

Gullies are located where the current atmospheric and temperature conditions is below the triple point of water yearround [2]. Researchers have attempted to address this apparent inconsistency in the seepage-fed surface runoff model by modifying the fluid source region: a shallow acquifer that is either insulated by the overlying soil layer [3] or experiences localized geothermal heating [4], a deep acquifer [5], or melt-generated runoff from an ice-rich mantle [6,7] or snowpack [8-11]. Alternatives to fluvial models have also been proposed including carbon-dioxide gas supported flow [12,13] and dry landslide [14] processes in the generation of gullies.

Controversy persists regarding the exact formation mechanism for Martian gullies. No model explains all of the observations. There are variations in gully type (e.g. occupied gullies, those apparently associated with stratigraphic layers, gullies that occur on dunes, etc.); therefore, it is possible that Martian gullies as a landform class are polygenetic and that sub-classes formed by alternate or complimentary processes [15]. A comprehensive evaluation of these models based on observations of the physical and dimensional properties of Martian gullies found inconsistencies with models that include exogenic processes (e.g. snowfall, wind) or flow materials without liquid (e.g. carbon dioxide, dry granular flows); Heldmann and Mellon [16] concluded that models that include a subsurface water reservoir feeding surface runoff are the most plausible theories to explain the origin of most Martian gullies. In addition, numerical models to simulate the flow of liquid water on Mars shas demonstrated that formation of short gullies (~500 m) is presently feasible on Mars outside the pressure-temperature stability regime of liquid water [17]. Furthermore, two gully sites have brightened in the last five years, evidence that gullies are active today and these bright deposits have attributes consistent with emplacement by flowing liquid water [18]. The synthesis of observations and model results has led most researchers to conclude that liquid water was involved in the formation of gullies.

A key observation from the original report fundamental to some formation models (notably snowmelt models) is gully azimuth orientation, initially reported to be preferentially pole-facing within craters [1]. Several studies have re-examined this claim. Global and hemispherical studies have shown gullies occur in all orientations [15,16,19]. However, there may be a latitude dependence to gully orientation [e.g. 6]. Within the Newton Basin, the majority of the gullies have pole-facing orientations in latitudes between -30º and -44º S, while at latitudes above -45º S, equator-facing orientations are more prevalent [11]. All of these studies rely on MOC data which has a small footprint (maximum width of 3 km, variable down-track length) relative to the size of the impact crater. Without images covering the entire crater, there is an inherent bias in these investigations.

Observations: Four-hundred sixty-four middle-latitude (30-65° latitude) craters known to have gullies [19] in them were examined for existing THEMIS VIS sum 1 (18 m/pix) image coverage. Although there are fewer gully crater sites in the northern hemisphere (54 locations), over half of them had greater than 75% THEMIS VIS image coverage. In the southern middle latitudes, only one-fifth of the candidate sites met the image coverage criteria (90 locations). In both hemispheres, the spatial distribution of sites with adequate image coverage is representative of the total population of gully crater locations. Illumination issues (saturation) impeded the number of valid observations for eastern (DN=255) and northwestern/western (DN=0) crater walls.

Preliminary observations show differences in gully orientation as a function of latitude. In the northern hemisphere, the occurrence of gullies was observed at approximately the same frequency for all cardinal orientations with the exception of the poorly sampled east and west crater walls (fig. 1A). No pole-facing preference was observed. Gullies on northern and southern crater walls occurred in equal numbers. In contrast, there appears to be a pole-facing prefer-

ence for gullies located in southern middle latitude craters (fig. 1B). Gullies were observed three times more often on northern crater walls (pole-facing) than on their southern, equator-facing counterparts.

The data was subdivided into latitude bins to further explore the relationship between latitude and gully orientation. For the northern middle latitudes with a smaller sample size, the data was parceled into the lower (30-45° N) and higher (45-65° N) middle latitudes. In both cases, gullies were observed in all orientations and no preference for pole-facing slopes was observed. A narrower range of latitudes was adopted for the southern middle latitudes: lower (30-40° S), central (40-50° S) and higher (50-65° S) mid-latitudes. Gully orientation varied in these latitude bins. In the lower mid-latitudes, pole-facing slope orientation is dominant. The center latitude bin shows a similar effect, but to a lesser degree. However, at the high mid-latitudes, the occurrence of gullies on the northern and southern crater walls occurs with the same frequency and no preference in orientation is observed.

Gully Albedo Changes. Malin et al. [18] report changes in gully brightness within the last five years at two gully sites which indicate that gully formation is occurring at present. Although this discovery was announced late in the data collection portion of this study, two additional sites with light-toned gully deposits were noted in the examination of data for this investigation. No time constraints can be placed on the emplacement age of these lighter deposits, but this observation highlights the need for high resolution repeat monitoring of gully locations, which is particularly critical with the apparent loss of the Mars Global Surveyor (MGS) spacecraft.

Discussion: This study shows that the relationship between latitude and gully orientation is complex. Preferential orientation of gullies on pole-facing slopes is evident only in a select latitude band (30-50° S), the location of the majority of Martian gully sites. In the northern middle-latitudes and at high southern mid-latitudes, gullies are found with all orientations.

These observations suggest that the formation of gullies is dependent on a number of factors and these factors may vary by location. For example, solar insolation, dust content in snow, and attributes of the geologic setting (i.e. rock permeability, acquifer geometery, etc.) are all variables that can influence gully orientation. There is also the possibility that gullies are polygenetic [15] and that the variation in gully orientation reflects different formation processes in different locations, a hypothesis that is testable by cataloging gully types. Furthermore, several proposed formation models are optimized under past conditions (e.g. high obliquity [6]), suggesting that certain gully types formed during distinct time periods.

Future work will involve collecting additional data. Williams has submitted region of interest (ROI) requests for 153 additional sites where acquisition of a THEMIS VIS image would provide complete or total coverage of the crater. In addition, correlations with age, geology and elevation will be evaluated.

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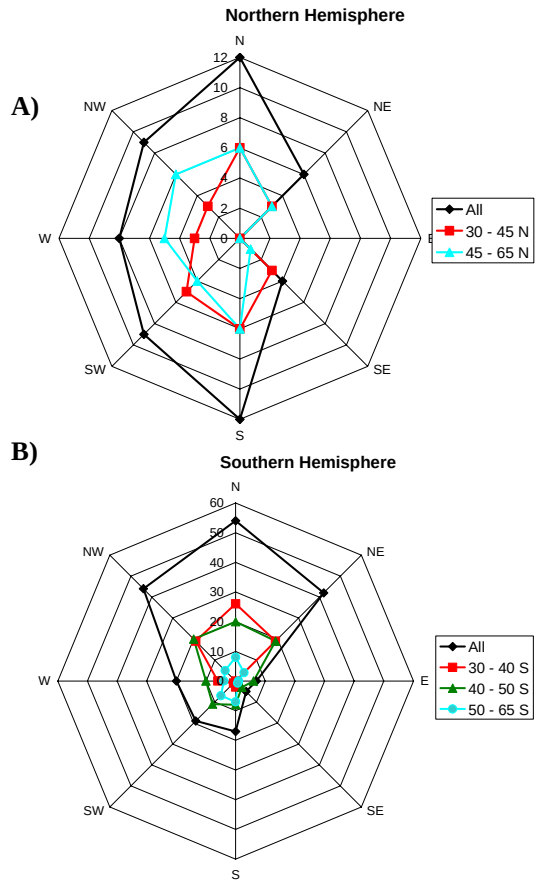

Figure 1: Orientation of gullies in middle latitude craters. Number of observations for each case is denoted in parentheses. **A)** Northern hemisphere craters. All (32), 30 – 45° N (20), 45 – 65° N (12). **B)** Southern hemisphere craters. All (90), 30 – 40° S (33), 40 – 50° S (42), 50 - 65° S (15).