GULLIES ON MARS AND CONSTRAINTS IMPOSED BY MARS GLOBAL SURVEYOR DATA. J. L. Heldmann[1] and M. T. Mellon[2], [1]NASA Ames Research Center, Moffett Field, CA, jheldmann@mail.arc.nasa.gov, [2]University of Colorado, Laboratory for Atmospheric and Space Physics, Boulder, CO.

Introduction: The discovery of geologically recent gully features on Mars [1] has spawned a wide variety of proposed theories of their origin including water versus carbon dioxide based erosion and shallow versus deep fluid sources. To test the validity of such gully formation mechanisms, data from the Mars Global Surveyor spacecraft has been analyzed to uncover trends in the dimensional and physical properties of the gullies and their surrounding terrain. Over 100 Mars Orbiter Camera (MOC) images containing clear evidence of gully landforms, distributed in the southern mid and high latitudes, have been analyzed in combination with Mars Orbiter Laser Altimeter (MOLA) and Thermal Emission Spectrometer (TES) data to provide quantitative measurements of numerous gully characteristics. Parameters measured include apparent source depth and distribution, vertical and horizontal dimensions, slopes, compass orientations, and factors controlling present-day climatic conditions.

Proposed Gully Formation Mechanisms: Numerous models have been proposed which invoke various physical processes as well as various agents of erosion to explain the origin of the martian gullies. Mellon and Phillips [2] suggest that a shallow aquifer may be the source of liquid water that ultimately carves the gully features while Gaidos [3] argues for a deep aquifer model. Costard et al. [4] likewise propose that liquid water is the principle agent of erosion, but they suggest that melting ground ice is the source of the water. Gilmore and Phillips [5] also rely on the melting of near-surface ground ice and proposed that meltwater would percolate to an impermeable layer that dips towards an exposed slope wall. Lee et al. [6], Hartmann et al. [7] and Christensen [8] propose that the gullies are formed by liquid water from dissipating snowpacks. Treiman [9] suggested that mass-wasting is also a candidate mechanism of gully formation. In addition, Musselwhite et al. [10] hypothesized that a liquid CO_2 aquifer could form capped by a dry-ice barrier which seasonally breaks out rapidly releasing the liquid CO_2 from the side of the slope.

Methodology: Images from the Mars Orbiter Camera (MOC) have been systematically examined in search of gully features. Malin and Edgett [1] report that the gullies nominally occur poleward of 30°S and extend as far south as the south polar pits. Hence all images from the MOC narrow-angle camera between 30°S to 72°S from mission phases AB1 through M18 (September 1997 through August 2000) were individually examined for the presence of gullies. Quantitative measurements of linear distances were then extracted from the MOC images, elevation data was extracted from the MOLA data, and TES measurements of thermal inertia were used in conjunction with modeled surface temperatures to derive subsurface temperature profiles.

Results: Based on this data, we present numerous trends with respect to the gully systems which must be explained by any viable model of gully formation. We find that the number of gully systems steadily declines as one moves poleward of 30°S, reaches a minimum value between 60°-63°S, and then again rises poleward of 63°S (Figure 1). All gully alcove heads occur within the upper one-third of the slope encompassing the gully and the alcove bases occur within the upper two-thirds of the slope. Also, the gully alcove heads occur typically within the first 200 meters of the overlying ridge with the exception of gullies equatorward of 40°S where some alcove heads reach a maximum depth of 700 meters (Figure 2). Additionally, gullies are found on all slope orientations at all latitudes (Figure 3). Gullies are preferentially found on poleward facing slopes at the extreme high and low latitudes of the studied range but are preferentially found on equatorward facing slopes in the midrange latitudes. Using thermal conductivities derived from TES measurements as well as modeled surface temperatures, we find that ~80% of the gully alcove bases lie at depths where subsurface temperatures are greater than 0°C and ~20% of the alcove bases lie within the solid water regime (Figure 4). Interestingly, none of the gully alcoves lie within the temperature-pressure space of liquid CO_2.

No individual model yet explains all of the observed gully features, but based on this study we can place additional constraints on future models and rule out several proposed hypotheses. Based on a comparison of such measured gully features with predictions of the various models of gully formation, we find that the carbon dioxide, melting ground ice, dry landslide, deep aquifer and snowmelt models are least likely to survive as viable mechanisms to describe the formation of the martian gullies. Although some discrepancies still exist between prediction and observation, the shallow aquifer model remains as the most viable theory

References: [1] Malin M. C. and Edgett K. S. (2000) *Science, 288,* 2330-2335. [2] Mellon M. T. and Phillips R. J. (2001) *JGR, 106,* 23165-23179. [3] Gaidos E. J. (2001) *Icarus, 153,* 218-223. [4] Costard F. et al. (2002) *Science, 295*, 110-113. [5] Gilmore M. S. and Phillips E. L. (2002) *Geology, 30*, 1107-1110. [6] Lee P. et al (2002) LPSC XXXIII, Abstract #2050. [7] Hartmann W. K. (2002) LPSC XXXIII, Abstract #1904. [8] Christensen P. R. (2003) *Nature, 422*, 45-48. [9] Treiman A. H. (2003) *JGR, 108*. [10] Musselwhite D. S. et al. (2001) *GRL, 28*, 1283-1285.

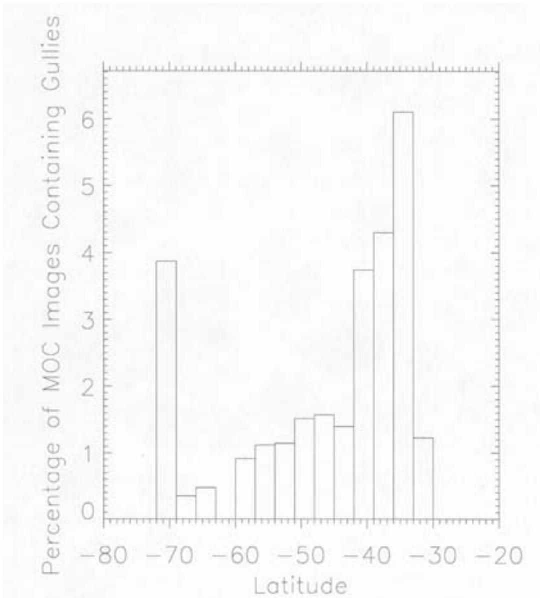

Figure 1. Histogram showing the fraction of MOC images containing clear evidence of gullies compared to all MOC images examined per 3° latitude bin. Images containing clear evidence of gully landforms represent typically 1 to 6% of the MOC narrow angle images. A notable exception occurs between approximately 60º to 70º latitude where few gullies were found.

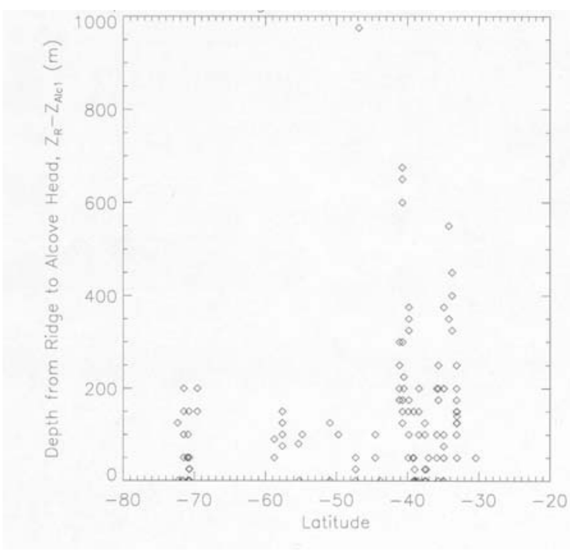

Figure 2. Depth from the overlying ridge to the gully alcove head with respect to latitude.

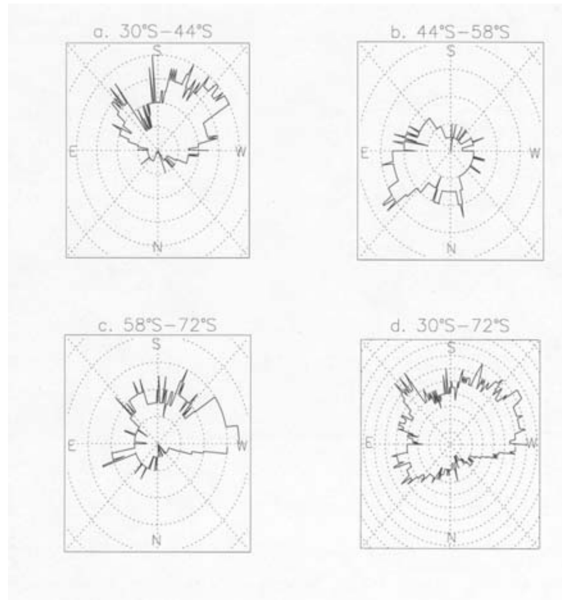

Figure 3. The orientations of the martian gully systems are plotted for three latitude bins (30°S to 44°S, 44°S to 58°S, 58°S to 72°S) as well as for all latitudes examined in this study (30°S to 72°S). The labels "N", "S", "E", and "W" on each orientation plot indicate gullies that are north-facing, south-facing, east-facing, and west-facing, respectively. Contours are in intervals of two gullies within each angle bin of 1º.

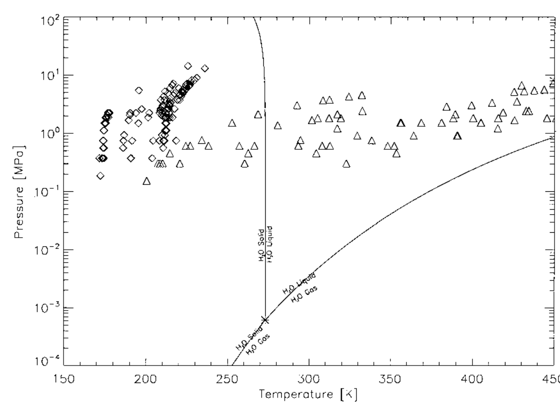

Figure 4. Depth and subsurface temperature of gully alcove bases compared with the H_2O phase diagram. Subsurface temperatures are calculated using TES thermal inertia (I) at each gully site as well as modeled surface temperatures. Triangles represent a dry overburden and the diamonds represent an icy overburden.