NORTHERN HEMISPHERE GULLIES ON MARS: ANALYSIS OF SPACECRAFT DATA AND IMPLICATIONS FOR FORMATION MECHANISMS. J. L. Heldmann[1], H. Johansson[2], E. Carlsson[2], and M. T. Mellon[3], [1]NASA Ames Research Center, Moffett Field, CA, jheldmann@mail.arc.nasa.gov, [2]Lulea University of Technology, Swedish Institute of Space Physics, Kiruna, Sweden, [3]University of Colorado, Laboratory for Atmospheric and Space Physics, Boulder, CO.

Introduction: The origin of geologically recent gullies on Mars has remained controversial since the discovery of these features by Malin and Edgett in 2000 [1]. 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. Hypotheses to explain the formation of the gullies invoke shallow liquid water aquifers [2], deep liquid water aquifers [3], melting ground ice [4, 5], snowmelt [6, 7, 8], dry landslides [9], and carbon dioxide aquifers [10]. We test the validity of such gully formation mechanisms by analyzing data from the Mars Global Surveyor and Mars Odyssey spacecrafts to uncover trends in the dimensional and physical properties of the gullies and their surrounding terrain.

A similar study has previously been completed for gullies located in the southern hemisphere of Mars [11]. The work presented here focuses exclusively on gullies in the northern hemisphere based on the identification of 136 Mars Orbiter Camera (MOC) images containing clear evidence of gully landforms, distributed in the northern mid and high latitudes. These sites have been analyzed in combination with Mars Orbiter Laser Altimeter (MOLA), Thermal Emission Spectrometer (TES), and Gamma Ray Spectrometer (GRS) data to provide quantitative measurements of numerous gully characteristics. Parameters measured include apparent source depth and distribution, vertical and horizontal dimensions, slopes, compass orientations, near-surface ice content, and factors controlling present-day climatic conditions.

Methodology: Images from the Mars Orbiter Camera (MOC) have been systematically examined in search of gully features. Edgett et al. [12] report that the gullies nominally occur poleward of 30° in both the northern and southern hemispheres. Hence all images from the MOC narrow-angle camera between 30°N to 90°N from mission phases AB1 through R15 (September 1997 through March 2004) 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. Gully locations were also compared with GRS data to investigate whether gully occurrence is correlated with the presence of near surface ground ice.

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. Findings reported here generally support earlier results discussed by Heldmann and Mellon [11].

We find that the number of gully systems is greatest between 30°N-45°N and tapers towards more poleward latitudes (Figure 1). Gullies form in a variety of terrain types as 84% form in craters, 4% in knobby terrain, 3% in valleys, 7% in other terrain types, and 2% in unknown terrain (no wide angle MOC context image). The geographic distribution of gullies is shown in Figure 2. Northern hemisphere gullies are most concentrated in Utopia Planitia, Acidalia Planitia, Tempe Terra, and Arcadia Planitia. Additionally, gullies are found on all slope orientations at all latitudes but overall are preferentially found on equatorward facing slopes in the northern hemisphere (Figure 3).

We also examine subsurface temperature and pressure fields to assess the possibility of liquid aquifers to feed the gullies. Using thermal conductivities derived from TES measurements as well as modeled surface temperatures, we calculate the depth to the 273K isotherm (liquid water melting point) for all 136 locations of gully occurrence. We find the depth to the 273K isotherm is less than 200 meters for 90% of the gully systems (Figure 4). Most gully alcove bases are below this required depth since based on measurements of 42 alcoves, the average depth to the alcove base is 350 m. Using thermal conductivities derived from TES measurements as well as modeled surface temperatures, we find that ~93% of these gully alcove bases lie at depths where subsurface temperatures are greater than 273K and ~7% of these alcove bases lie within the solid water regime. Interestingly, none of the gully alcoves lie within the temperature-pressure space of liquid CO_2. Additionally, gullies generally are found in areas of low water content based on the GRS data (Figure 5). Although GRS is only sensitive to the upper meter of soil, this finding is consistent with the relatively low thermal conductivities as derived from TES data and the implication of a dry overburden layer which results in the relatively low (<200 m) depths to the 273K isotherm in these regions (Figure 4).

No individual model yet explains all of the observed gully features, but based on this study and the similar analysis completed for the southern hemisphere [11] 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 the least likely mechanisms to describe the formation of the Martian gullies. Although some discrepancies still exist between prediction and observation, the shallow aquifer model still 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. [11] Heldmann, J. L. and Mellon M. T. (2004) *Icarus, 168,* 285-304. [12] Edgett, K. S. et al. (2003) LPSC XXXIV, Abstract #1038.

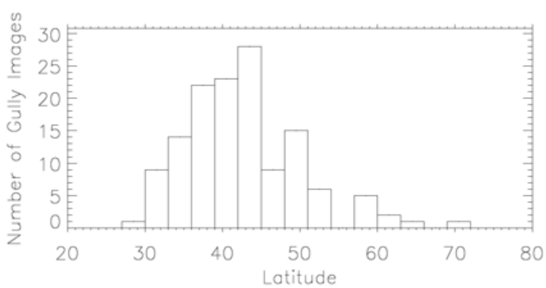

Figure 1. Histogram showing the number of MOC images containing clear evidence of gullies per 3° latitude bin in the northern hemisphere.

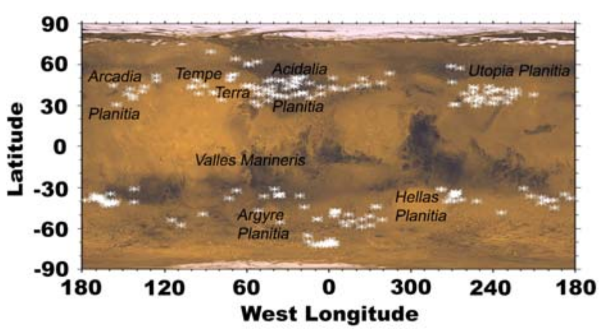

Figure 2. Geographic distribution of Martian gullies. Southern hemisphere gully locations are derived from Heldmann and Mellon (2004).

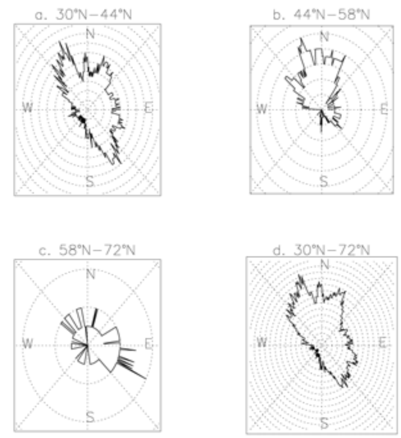

Figure 3. The orientations of the Martian gully systems are plotted for three latitude bins as well as for 30°N-72°N. The labels N, S, E, W refer to the direction from which the gullies flow. Gullies plotted above the X axis flow from the north towards the equator. Gullies plotted below the X-axis flow from the south towards the pole. Contours are in intervals of two gullies within each angle bin of 1º.

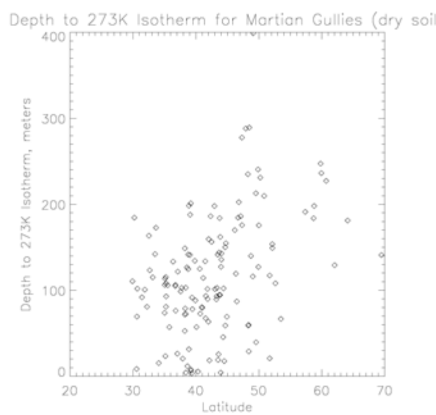

Figure 4. Calculated depth to 273K isotherm for northern hemisphere gully locations based on TES surface temperatures and thermal conductivities.

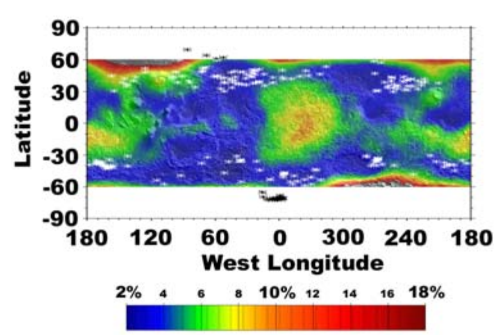

Figure 5. Location of Martian gullies with respect to water content based on GRS data; percentages refer to water ice content. Southern hemisphere gully locations are derived from Heldmann and Mellon (2004).