GEOMORPHIC EVIDENCE FOR MARTIAN GROUND ICE AND CLIMATE CHANGE. L. C. Kanner[1], C. C. Allen[2] and M. S. Bell[3], [1]Carleton College (300 North College Street, Northfield, MN 55057, kannerl@carleton.edu), [2]NASA Johnson Space Center, Houston, TX, [3]Lockheed Martin @ Johnson Space Center, Houston, TX.

Introduction: Recent results from gamma-ray and neutron spectrometers on Mars Odyssey indicate the presence of a hydrogen-rich layer tens of centimeters thick in the uppermost meter in high latitudes (>60˚) on Mars [1]. This hydrogen-rich layer correlates to regions of ice stability [2]. Thus, the subsurface hydrogen is thought to be water ice constituting 35+/-15% by weight near the north and south polar regions [1]. We refine the location of subsurface ice deposits at a < km scale by combining existing spectroscopy data with surface features indicative of subsurface ice. A positive correlation between spectroscopy data and geomorphic ice indicators has been previously suggested for high latitudes [3]. Here we expand the comparative study to northern mid latitudes (30˚N-65˚N).

One of the most recognizable terrestrial geomorphic indicators of subsurface ice is an organized network of polygonal fractures. Polygonal terrain is typically found in Arctic and Antarctica permafrost environments and is demarcated by troughs, beneath which grow vertical wedges comprised of ice, sand or combination. Polygonal terrain has also been identified on the Martian surface in high-resolution Viking Orbiter images [4,5] and Viking Lander 2 images [6]. Recent narrow-angle images from the Mars Orbital Camera (MOC) on Mars Global Surveyor reveal the planet's surface features in unprecedented, meter-scale detail. Our study uses these MOC images to locate and map the distribution of small-scale polygons (~10-250 m). It is hypothesized that these polygons form from similar thermal contraction processes as those on Earth [7].

Polygonal terrain on Mars is one of several geomorphic ground ice indicators identified at mid and low latitudes even though water ice is not currently stable equatorward of 60˚ for the present obliquity of 25˚ [8,9]. Climatic variations resulting from dramatic changes in orbital parameters can explain the current spatial distribution of these features [10]. The combination of geomorphic evidence and modeling provides strong indication that ice may have accumulated at mid and low latitudes during periods of high obliquity, 35˚< 45˚ [2,11].

Methods: Using high-resolution, narrow-angle MOC images (1.55-12.39 m/pixel), we mapped polygonal terrain in a latitude band from 30˚N to 65˚N [12]. We used data from August 1997 to February 2003, excluding the September 1999 to February 2000 set. A total of 5,782 images were analyzed. Nearly all images span an area of 3 km in width and 5 to 20 km in length.

Because epithermal neutron flux rates are inversely related to water ice abundance in the uppermost meter, we can map the distribution of ice in the near subsurface. Using corrected epithermal neutron flux rate data in 2 x 2 degree cells, we mapped the relative distribution of hydrogen between 30˚N to 65˚N and used flux rate data in 0.5 x 0.5 degree cells for 30˚N to 65˚N and 300˚W to 240˚W, the Casius Quadrangle. We then compared the surface ice abundance with the surface features in the MOC images.

MOC images showing the presence of polygonal terrain in the Casius Quadrangle were also analyzed to determine polygonal geometry, dominant spatial trends, and indications subsurface water ice.

Observations: Of the total MOC images analyzed, 4.2 % revealed the presence of polygonal terrain, identified in this study as having the following characteristics: diameters of polygons ranging in size from 25 m to 250 m, nearly straight bounding troughs or rims, and angular joins. Frequently, the longest edges of the polygons run parallel and strike north-south.

Polygonal terrain exists at low elevations (<0 km); few polygons were identified south of 35˚N or in the cratered highlands. A particularly high concentration of polygonal ground is present between 288˚W-258˚W and 40˚N-50˚N. In this region, known as Utopia Planitia, 52% of the total 191 images analyzed showed the presence of polygonal terrain. The distribution is similar to that found by Seibert and Kargel (2001) us-

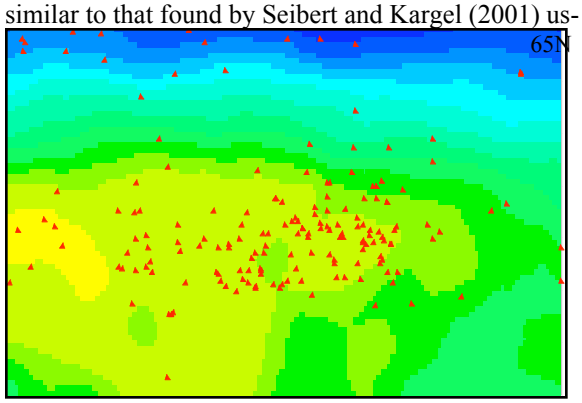

Figure 1: Map of distribution of polygonal terrain (red triangles) with respect to relative water ice in the Casius Quadrangle. Lightly shaded regions are low water ice content and darkly shaded regions are high ice content.

ing fewer MOC images [13].

Inferred water ice is detected in high concentrations poleward of approximately 60˚ latitude. Our comparison of spectroscopy data and MOC images shows no obvious correlation between the presence of water ice and the existence of polygons. Polygons are present in areas of low concentrations of water ice as frequently as they are present in areas of high concentrations of water ice. The high concentration of polygonal ground in Utopia Planitia is located in an area of low concentration of water ice (Figure 1).

A latitudinal comparison of the geometry and appearance of the polygonal terrain between 240˚W-300˚W and 35˚N-60˚N reveals that polygons at low latitudes (35˚N-60˚N) are demarcated by darkly shaded troughs while bright lineations demarcate polygons at high latitudes (60˚N-65˚N) (Figure 2).

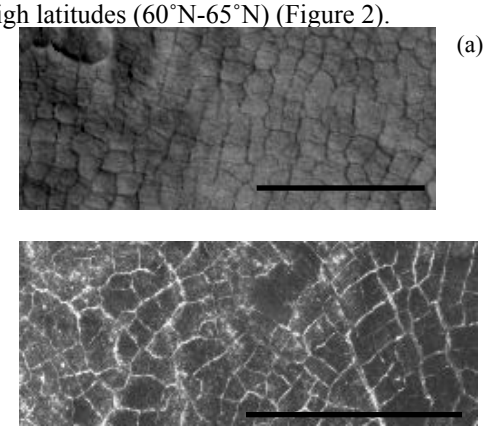

Figure 2: Comparison of polygons at (a) mid latitudes, MOC image MO401631 and (b) high latitudes, MOC image M1900234. Scale bars about equal to 500 m.

Discussion and Interpretation: The presence of polygonal terrain on Mars is indicative of stable water ice at some point, past or present, in Martian climate history. Because neutron and gamma-ray spectrometers record hydrogen abundance in the uppermost meter of the Martian subsurface, spectroscopy data is indicative of stable ice today. Thus, if there is a strong relation between polygonal terrain and hydrogen abundance, then polygons are in equilibrium with current climate. If there is a weak or anti-correlation, then the polygons may reflect a past climate. We believe that our data may reflect, at mid-northern latitudes, a previous Martian climate.

The low correlation between the concentration of polygonal terrain in western Utopia Planitia and water ice in the uppermost meter can offer insight about the composition of the subsurface and past climate. It is possible that while most of the water ice has sublimed from the uppermost meter, the morphology of the polygonal wedges has endured due to a deeper layer of ground ice. As the distribution of polygonal terrain does not obviously correlate to geology, topography, and thermal inertia, it is possible that features of a past climate created an environment conducive to polygon formation [19,20]. More detailed studies of the topography, morphology and dominant trends of the small-scale polygons in this region are anticipated.

Similar indications of climate change can be inferred from the latitudinal variation of polygon morphology. Polygonal terrain characterized by darkly-shaded troughs only exists at latitudes between 35˚N and 60˚N. We suggest this appearance indicates sublimed ice. Polygonal terrain characterized by filling of bright material exists only between 60˚N and 65˚N. We hypothesize that this material is water ice.

Conclusion: Polygonal terrain exists at low elevations (<0 km) and nearly all latitudes between 30˚N and 65˚N, with a unique abundance between 288˚W to 258˚W and 40˚N to 50˚N. Spectroscopy data reveals water ice in high concentrations poleward of about 60˚N. The comparison of MOC images and spectroscopy data yield two main findings: 1) a high concentration of polygons exists where spectroscopy data indicates minimal water ice, and 2) mid-latitude (30˚N-60˚N) polygons look darker than high latitude (60˚N-65˚N) polygons, suggesting sublimation of bright ice. The combination of recent data from MOC and Mars Odyssey indicates that extreme variation in orbital parameters has contributed to significant latitudinal variation of polar processes in Mars history.

Acknowledgements: We thank William C. Feldman, William V. Boynton, and Buck Janes for the neutron and gamma-ray spectrometer data and Sara Mitchell for helpful reviews.

References: [1] Boynton W. V. et al. (2002) *Science, 297,* 81-85. [2] Mellon M. T. and Jakosky B. M. (1993) *JGR, 98,* 3345-3364. [3] Mangold N. *(2003) 3rd Mars Polar Science Conference*, #8043. [4] Carr M. H. and Schaber G. G. (1977) *JGR, 82,* 4039–4054. [5] Morris E. C. and Underwood J. R. (1978) *Rep. Planet. Geol. Prog, NASA TM 79729,* 97-99. [6] Mutch T. A. et al. (1977) *JGR., 82,* 4452-4467. [7] Mellon M. T. (1997) *JGR, 102,* 25,617-25,628. [8] Moughins-Mark P. (1979) *JGR, 84,* 8011-8022. [9] Allen C. C. (1997) *JGR, 84,* 8048-8059. [10] Head J. W. et al. (2003) *Nature, 426*, 797-801. [11] Mischna M. A. et al. (2003) *SICM,* Abstract #3145. [12] Malin M. C. et al. (June, July 2003) *Malin Space Center Systems Mars Orbiter Camera Image Gallery* (http://www.msss.com/moc_gallery/). [13] Seibert N. M. and Kargel J. S. (2001) *GRL, 28,* 899-902. [14] Zuber M. T. et al. (2000) *Science, 287,* 1788-1793. [15] Greeley R. and Guest J. E. (1987) *USGS Misc. Inv. Series Map I-1802-B.*