PROSPECTING FOR MARTIAN ICE FROM ORBIT. L. C. Kanner[1], M. S. Bell[2], and C. C. Allen[3], [1]Carleton College (300 N. College Street, Northfield, MN 55057), [2]Lockheed Martin @ Johnson Space Center (2400 NASA Rd. 1, Mail Code C23, Houston, TX 77058, mary.sue.bell1@jsc.nasa.gov), [3]NASA @ Johnson Space Center (Mail Code ST, Houston, TX 77058)

Introduction: Recent data from the Gamma-Ray Spectrometer (GRS) on Mars Odyssey indicate the presence of a hydrogen-rich layer tens of centimeters thick in high latitudes on Mars [1]. This hydrogen-rich layer correlates to previously determined regions of ice stability. It has been suggested that the subsurface hydrogen is ice and constitutes 35 +/- 15% by weight near the north and south polar regions [2]. This study constrains the location of subsurface ice deposits on the scale of kilometers or smaller by combining GRS data with surface features indicative of subsurface ice.

The most recognizable terrestrial geomorphic indicators of subsurface ice, formed in permafrost and periglacial environments, include thermokarst pits, pingos, pseudocraters and patterned ground. Patterned ground features have geometric forms such as circles, polygons, stripes and nets. This study focuses on the polygonal form of patterned ground, selected for its discernable shape and subsurface implications. Polygonal features are typically demarcated by troughs, beneath which grow vertical ice-wedges. Ice-wedges form in thermal contraction cracks in ice-rich soil and grow with annual freezing and thawing events repeated over tens of years. Ice wedges exist below the depth of seasonal freeze-thaw [3]. Terrestrial ice wedges can be several meters deep and polygons can be tens of meters apart [4, 5, 6], and, on rare occasions, up to 1 km [7]. The crack spacing of terrestrial polygons is typically 3 to 10 times the crack depth [8].

Polygonal terrain is the dominant form of patterned ground seen on Mars [9] and has been recognized in several high resolution Viking Orbiter images [10,11,12,13] and Viking Lander 2 images [14]. High-resolution images from Mars Orbital Camera (MOC) on Mars Global Surveyor reveal Martian surface features in unprecedented detail and meter-sized polygons are more easily discernible and characterized [15]. Martian polygons range in size from 10 m [16] to 10 km [14] or on rare occations up to 20 km [11]. Polygonal terrain is generally grouped based on size and theorized origin into small-scale (~10-250 m) and large-scale (~250 m-20 km) polygons. Small-scale polygons are applicable to this study because it is thought that the origin of small-scale polygons on Mars is the result of permafrost thermal contraction cracking similar to that found on Earth [17,16]. The presence of polygonal ground on the surface generally indicates the presence of ground ice at depths of several meters and can reveal much about the latitudinal distribution of ground ice and ground ice history [17]. Large, multi-kilometer scale polygons likely form by processes unrelated to subsurface ice.

Methods: Using high-resolution narrow-angle MOC images (1.55-12.39 m/pixel), we have noted the presence, absence, and possibility of polygonal terrain around the planet in a latitude band from 30°N to 65°N. Data sets from August 1997-July 2002 were used, less the September 1999-February 2000 set. Polygonal terrain identified in this study can be characterized by the following features: diameter of individual polygons range in size from 25 m - 250 m, polygons are bounded by nearly straight troughs or raised rims and angular joins. Troughs and raised rims frequently show a preferred north-south orientation.

The distribution of polygonal terrain was compared to a mercator projection of GRS relative hydrogen abundance [1,2] as well as a recent geologic map of Mars [18].

Observations: A total of 5,280 images were analyzed and 283 images revealed the presence of polygonal terrain. The distribution of polygonal terrain is scattered throughout the regional band at low elevations (<0m) and nearly all latitudes. The distribution is similar to that found by Seibert and Kargel (2001) [16]. Polygons were identified neither below 35°N nor in the cratered highlands. Particularly high concentrations of polygonal ground are present in the Casius quadrangle between 278°W-258°W and 40°N-50°N. In this region of the Utopia Planitia basin, 74% of the total 132 images analyzed showed the presence of polygonal terrain.

GRS detects hydrogen in high concentrations poleward of 50 +/- 5° [1,2]. The comparision of GRS hydrogen abundance data to the distribution of polygonal terrain shows no correlation (Figure 1). Polygons are present in areas of low concentrations of near subsurface ice as frequently as they are present in areas of high concentrations of near subsurface ice. The high concentration of polygonal ground in western Utopia Planitia correlates to an area of lower concentrations of near subsurface ice.

The majority of polygonal terrain in Utopia Planitia correlates to Hesperian-age units, while there are some occurances to Amazonian-age units [18]. According to Greely and Guest, these units, Hesperian and Amazonian, are of diverse origin – volcanic, tectonic, alluvial, and eolian.

Discussion and Interpretation: What can the anti-correlation between near subsurface ice and presence of polygonal terrain in the Casius quadrangle between 282°W-262°W and 40°N-50°N suggest about the composition of the near and deeper subsurface? One possibility is that the presence of this type of polygonal terrain on Mars is not a response to thermal contraction cracking of ice-rich ground. Ice may be absent at depths of several meters, in turn making the polygonal terrain a response to other contraction processes---desiccation, fracturing of cooling lava, deep-seated horizontal stresses , or stratigraphic control.

On the other hand, ice may exist and do so both as near subsurface ice in the first meter as detected by GRS and as deeper ground ice as seen by the presence of ice-wedging terrain. Data collected in this study suggests the existence of near subsurface and deeper subsurface ice layers which can be explained as a response to climate oscillations. It is likely that hydrogen concentrations in the first meter of the Martian surface are a result of climate conditions at present obliquity. Diurnal termperature occillations affect only the first 2-3 m of the Martian regolith [19]. Ground ice is thought to exist in equatorial regions despite its current instability at the surface [10,20,21]. This conflict can be resolved if deep ground ice is a relic of a colder climate during periods of high obliquity [22]. Theoretical modeling shows that ground ice may have persisted at depths greater than 200 m shortly after the beginning of Mars's geologic history and that ground ice will persist for longer periods of time in regolith of small pore size [23].

If the abundance of Martian small-scale polygons are geomorphically, and structurally similar to terrestrial polygons, their presence should not correlate to hyrdrogen abundance in the first meter for the following reasons: initial propagation of ice wedges occurs below the freeze-thaw layer, or the ice would melt (or sublime), and ice-wedges can extend tens of meters deep. Martian ice-wedge polygons may correlate to thicker layers of ground ice not detected by GRS.

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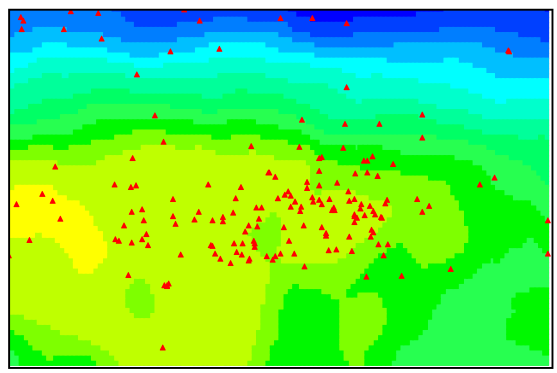

Figure 1. Map of the Casius quadrangle in terms of relative hydrogen abundance (yellow-shaded regions represent areas of low concentrations, blue-shaded regions areas of high) [1,2] and distribution of polygonal terrain marked by the red triangles.