

## PRESENT-DAY EXPOSURES OF WATER ICE IN THE NORTHERN MID-LATITUDES OF MARS.

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**Introduction:** Water ice is exposed in the martian north polar cap [1], but is rarely exposed beyond the cap boundary. Orbital gamma ray spectrometry data strongly imply the presence of water ice within meters of the surface at latitudes north of approximately 60° [2]. We have examined mid-latitude areas of the northern plains displaying residual ice-rich layers, and report evidence of present-day surface exposures of water ice. These exposures, if confirmed, could constrain the latitudinal and temporal stability of surface ice on Mars.

**Ice-Rich Layer:** Polygonal features with dimensions of 100+/-30 m, bounded by cracks, are commonly observed on the martian northern plains. These features are generally attributed to thermal cracking of ice-rich sediments, in direct analogy to polygons in terrestrial polar regions [3,4]. We mapped polygons in the northern mid-latitudes (30° to 65° N) using all MOC narrow-angle images (resolution ~ 5 m / pixel) from 9/97 through 9/03 [5]. While MOC images show polygons scattered across many areas of the northern plains, 74% of such images showing polygons are centered in western Utopia Planitia (40° to 50°N; 258° to 288°W). This region largely overlaps the Late Amazonian Astapus Colles unit, characterized by polygonal terrain and nested pits “consistent with periglacial and thermokarst origins” [6]. Other authors suggest that this concentration of polygons indicates the presence of a generally continuous ice-rich mantle [3,4]. Ice stability models [7], orbital spectrometry [2], and the occurrence of thermokarst [5] indicate that the ice is concentrated below 1 m in depth and is currently subliming.

We also measured all of the impact craters, with diameters between 100 m and 4 km, occurring on polygonal terrain between 30° and 65° N [8]. The size-frequency distribution of these craters larger than 1 km is concordant with the distribution for larger craters (> 8 km) in western Utopia (N. Barlow, *personal communication*), indicating preservation of a late Hesperian crater population. Of the craters on polygonal terrain, 97% predate the polygonal cracks, indicating Amazonian-age deposition or activation of the ice-rich layer. The size-frequency distribution of craters on polygonal terrain shows a marked deficiency of craters smaller than 1 km, suggestive of mantling. A subset of such craters with diameters between 460 m and 1.12 km are buried to their rims by polygonal terrain, indicating

that the ice-rich layer is locally 30 to 40 m thick [8]. These findings are in accord with recent models of obliquity-driven deposition and sublimation of ice-rich mantles in the northern mid-latitudes of Mars [9].

**Bright and Dark Polygon Cracks:** During our initial survey MOC images, a striking dichotomy of polygon albedo was noted. Many of the polygons, particularly in the northern portion of the study area, are bounded by cracks that are significantly brighter than the polygon centers. Other polygons, particularly farther south, are bounded by dark cracks (Fig. 1).

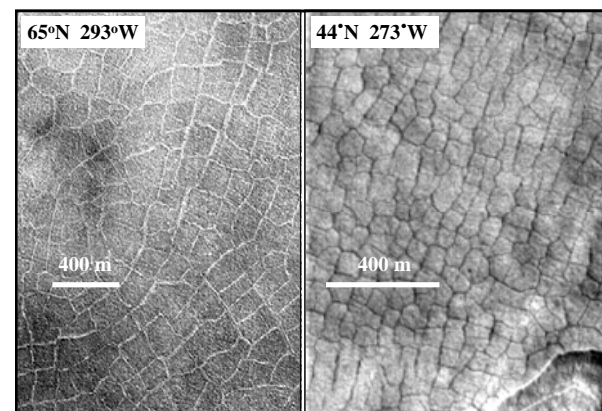


Figure 1. Bright and dark polygon cracks

A survey of the longitude range 240° to 300°W showed that polygons at latitudes between 60° and 65°N are demarcated by bright cracks. Dark cracks bound polygons at latitudes of 35° to 60°N [5].

A complete examination of all MOC images (1997 through 2003) showing polygons in the latitude band 30° to 65°N supported these initial results. At latitudes of 55° to 65°N 45 MOC images show polygons. Of these images 73% show polygons with bright cracks. Between 40° and 55°N a total of 141 images show polygons. Of these images 66% show dark cracks [10].

**Bright and Dark Spots:** Many of the highest resolution MOC frames showing polygons in the northern plains also show small numbers of bright spots and larger numbers of dark spots scattered across the terrain (Fig. 2). The spots are particularly noticeable in western Utopia Planitia, the area with the highest concentration of polygons. No systematic mapping of these spots has yet been conducted, so the latitudinal variation of spot albedo is currently unknown.

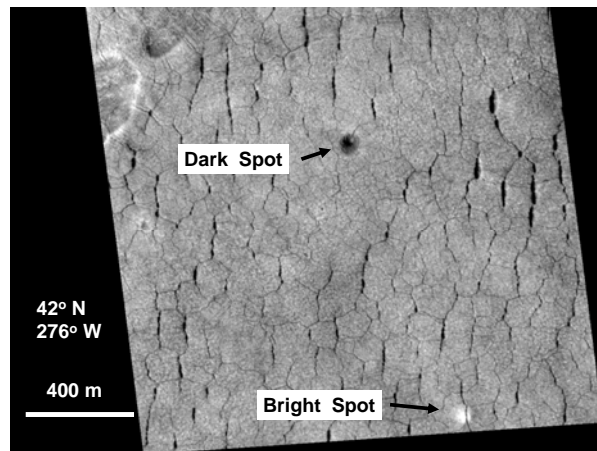


Figure 2. Dark and bright spots on polygons

The spots range from tens of meters to approximately 100 meters in diameter. Many of the bright spots are centered on the cracks bounding the polygons. Some, but not all, of the dark spots are also centered on cracks. The spots are uniformly bright or dark at MOC resolution. Neither type shows evidence of raised rims nor ejecta blankets. The spot morphologies are distinctly simpler than those of the freshest small impact craters imaged by MOC [11].

**Discussion:** Sublimation polygons have been formed and preserved in the upper reaches of the Antarctic Dry Valleys [12]. These polygons form under strongly sub-freezing conditions, without involvement of liquid water. Exposed ice in these features may be preserved, particularly in the bounding cracks. However, in some cases exposed ice is removed by sublimation, owing to the low humidity and katabatic winds. The polygon morphology is characteristically preserved even when no ice is visible at the surface. Ice remains at the cores of these polygons, where the ice is shielded from sublimation by overlying sediments.

The martian polygons formed at latitudes of  $55^{\circ}$  to  $65^{\circ}$ N characteristically have bright bounding cracks, which we interpret as exposed water ice. Thermal models and orbital spectrometry both indicate that the stability line for near-surface water ice is currently at latitudes north of  $60^{\circ}$ .

The majority of polygons in our survey located between  $40^{\circ}$  and  $55^{\circ}$ N show dark bounding cracks. These are interpreted as polygons from which the exposed ice has been removed by sublimation. This interpretation indicates that the long-term stability limit for exposed ice, even in deep cracks, lies near  $55^{\circ}$ N.

The bright spots are also interpreted as exposed ice, due to their prevalence on terrain mapped as ice-rich. One possible origin is formation by small meteorite impacts. Analogous bright craters dot the sur-

faces of the icy satellites of Jupiter, where impacts excavate ice-rich material from beneath dark surfaces [13]. Another possibility is that ice rose to the surface along bounding cracks. Such “ice diapirs” have been proposed for features on Mars, Europa, and Enceladus [14,15,16].

Bright spots are rare relative to dark spots. If they have the same origin, this observation suggests that the bright material darkens with time. If the bright spots are indeed composed of water ice this is a reasonable interpretation, since these spots are prevalent at latitudes around  $40^{\circ}$  N, well south of the ice stability line.

**Future Observations and Implications:** The ground-penetrating radars currently in orbit on Mars Express and MRO should be able to confirm the presence and measure the depth of the ice-rich layer forming the Astapus Colles unit. If this layer is confirmed it will strengthen the interpretation of bright polygon bounding cracks and bright spots as exposed ice.

One of the first images released from the HiRISE camera on MRO shows details of polygons and a possible bright spot in Utopia Planitia, and additional images should augment and improve upon MOC coverage. The CRISM spectrometer on MRO, with 59 spectral bands and a spatial resolution around 20 m, should allow identification of the material exposed in the polygon bounding cracks and in the bright spots.

If the bright material is indeed exposed ice, its presence in the martian mid-latitudes will serve as an additional test of ice stability models and the sensitivity of orbital spectrometry. The bright spots can provide an indication of near-surface ice independent of polygonal and thermokarst terrain. Recent ice diapirs, if confirmed, will provide another demonstration that Mars is an active planet with a complex water cycle.

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