**INTRA-CRATER GLACIAL DEPOSITS AND ICE-MANTLING IN UTOPIA PLANITIA, MARS.** G. Pearce[1], G. R. Osinski[1,2], and R. J. Soare[1,3,4], [1]Dept. of Earth Sciences, University of Western Ontario, London, ON, Canada N6A 5B7 (gpearce5@uwo.ca), [2]Dept. of Physics and Astronomy, University of Western Ontario, London, ON, Canada N6A 5B7, [3]Dept. of Geography, Planning and Environment, Concordia University, Montreal, QC, Canada H3A 1M8, [4]Dept. of Geography, Dawson College, Montreal, QC, Canada H3Z 1A4

**Introduction**: Past workers have described an ice-rich periglacial landscape in Utopia Planitia [e.g., 1,2], a large topographic depression in the northern plains of Mars. There are several features that are widespread within this region and that are consistent with the recent activity of ground-ice and possibly melt-water at the surface, including: thermokarst alases, formed by the melting or sublimation of ice-rich ground; small-sized polygons, formed by thermal contraction and that may be underlain by massive-ice wedges and; crater-rim gullies, which are thought to have been carved by liquid flow [3]. Studies of an ice-rich mantle in a nearby region of the northern plains suggest an atmospheric-deposition origin following obliquity excursions in the late-Amazonian [4]. This scenario is most likely for the mantling unit in our study area; however, questions remain as to the timing and number of mantling events and the importance of periglacial and glacial activity.

Here, we describe a crater in Utopia Planitia that contains gullies around the circumference of the crater wall, small-scale polygons on benches between gullies, and crater-floor features consistent with recent glacial activity – namely lobate ridges that are morphologically similar to end-moraines, which form at the terminus of glaciers in terrestrial environments. Together, these features are consistent with the atmospheric emplacement of ice and the recent flow of liquid water within the crater. The crater is ~100 km south of the closest thermokarst features identifiable from image datasets; however, there is an at least thin mantle around the northern rim of the crater that is identifiable from HiRISE images. Relating this crater with other craters of the region and the nearby periglacial unit, we suggest that there is strong evidence for several episodes of ice-rich mantling in Utopia Planitia during the late-Amazonian, consistent with recent observations at higher latitudes [5] and climate models [6].

**Intra-crater features and processes**: The crater is centered on 39.85° N, 105.41° E, has a diameter of ~11.5 km, and has a double-layer (DLE) ejecta morphology (Fig. 1a). Gullies occur continuously along the inner crater wall and have broad alcoves and aprons, as well as sharply-incised channels. The debris aprons of a few of the gullies were captured by the High Resolution Imaging science Experiment (HiRISE) camera, allowing the identification of sharp cracks that cross-cut channels that emerge from the aprons (Fig. 1b). These cracks have morphologies similar to crevasses, which form at the surface of ice-sheets in Antarctica as tension is released during down-slope movement, typically where a change in slope is encountered (Fig. 2b). These cracks occur in material that appears to originate from the gully apron.

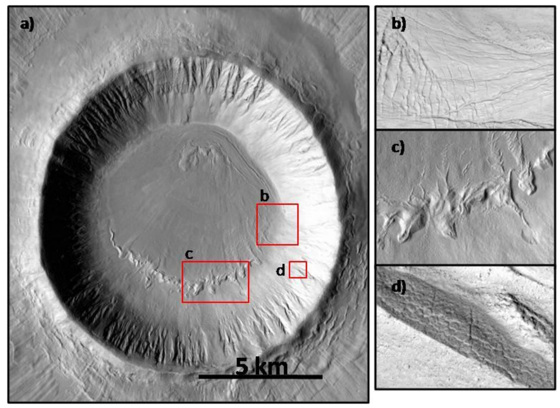


**Figure 1:** This ~ 11.5 km crater contains several features indicative of the recent presence of both water and ice: a) An MRO CTX image showing continuous gullies along the crater wall (CTX-P01_001357_2198_XN); b) Section of a HiRISE image: crevasses across a gully debris apron on the western crater wall (PSP_007001_2200); c) lobate ridges, reminiscent of glacial end moraines, on the southern side of the crater floor (image is from a), and; d) small-scale polygons on benches between gullies (from CTX image).

At high resolution, small-scale polygons < 20 m across can be seen forming within fine-grained benches and terraces between gullies (Figure 1d). Small-sized polygons are common in terrestrial periglacial environments and often contain massive-ice wedges beneath the polygon troughs.

Forming a semi-circle on the southern side of the crater floor are lobate ridges that are raised <30 metres above the floor beneath them (Fig. 1c). The ridges form a continuous, highly sinuous structure that is less than a few tens of metres from the distal reaches of gully debris aprons. The ridges are analogous to end moraines that form at the termini of glaciers during periods of recession in terrestrial settings (Fig. 2a). Supportive of this hypothesis are ridges of positive relief emerging on the northern side of the lobate-ring (Fig. 1c) that are morphologically similar to eskers, which are sub-glacial tubes that form as material is deposited during recessional periods [7]. These two features occur on the southern-side of the crater-floor where insolation levels are lowest and the last-vestiges of glacial features would be most likely found.

On the northern side of the crater floor are banded cracks and ridges reminiscent of features in concentric fill craters but which do not form complete circles (Fig. 1d). Past workers have suggested that such concentric crater features form by the viscous movement of ice-rich material towards the low-point, or center, of the crater [8]. Whereas concentric crater fill is highly voluminous within the periglacial unit, filling many craters near to their rims, the fill is less substantial in this crater and the features on its floor may be the final remnants of glacial activity within it.

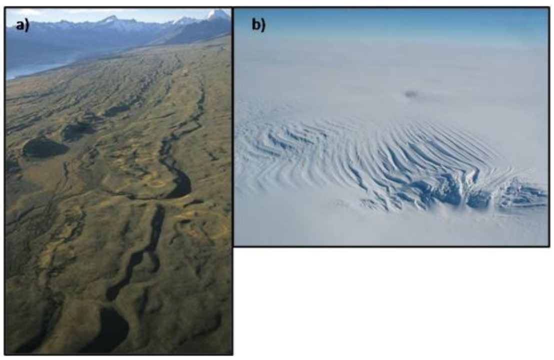


**Figure 2:** Terrestrial features analogous to those within a Utopia crater: a) Glacial end moraines surrounding Lake Pukaki in Southern New Zealand; b) Crevasses at the surface of an ice-sheet in Antarctica

**Icy Mantles in Utopia Planitia:** As part of ongoing research into periglacial processes on Mars and terrestrial analogues, we are completing a survey of landforms in the Utopia/western Elysium Planitia region [9]. As part of our project, we have mapped the distribution of thermokarst, which is shown in Figure 3. The star on the map shows the location of the crater in question, which is ~ 100km south of the nearest thermokarst feature. The high density of thermokarst features north of the crater are part of what appears to be a continuous periglacial landscape that has a broad longitudinal distribution (~40°) and that is narrow in latitude (~15°). As the crater in our study is outside of the thermokarst landscape, it is consistent with either the recent removal of an ice-rich mantle from this area or a separate emplacement event. Preliminary results from our mapping of concentric fill craters and glacial features show that these features occur at considerable distances from the periglacial unit and in all directions. The latter trend is consistent with a basin-wide emplacement process.

**Emplacement events:** Based on the presence of gullies, small-sized polygons, and glacial-like features in a crater in Utopia Planitia, we suggest the recent activity of both ice and liquid water. Placing this crater within the regional context of nearby periglacial activity, there is strong evidence for repeated glacial and periglacial episodes in Utopia Planitia during the late Amazonian. Two episodes, at least, are now obvious: the formation of a broad periglacial unit as evidenced by the distribution of thermokarst features in Figure 3, and; the more recent formation of the Astapus Colles unit, which superposes the former and is identified as a late-Amazonian ice-rich mantle by the most recent USGS mapping survey [10]. We may add a third ice-mantle emplacement event to this sequence if the features discussed in this crater were formed during an event unrelated to the first two. Further surveying and analysis may yield valuable insight into this and other questions concerning climatic and geological events in Utopia Planitia during the late-Amazonian.

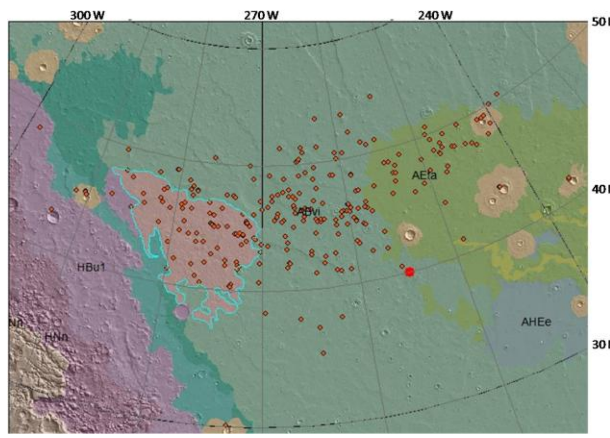


**Figure 3:** Distribution of thermokarst depressions within Utopia Planitia superposed on a MOLA hillshade image (modified from [9]), with geology from [10]. The location of Figure 1 is marked by the bright red point.

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**References:** [1] F.M. Costard, J.S. Kargel (1995) *Icarus, 114*, 93-112. [2] R.J. Soare, D.M. Burr, & J.M. Tseung (2005) *Icarus, 174*, 373-382 [3] R.J. Soare, et al. (2007) *Icarus, 191*, 95-112. [4] J.F. Mustard, C.D. Cooper, and M.K. Rifkin (2001) *Nature, 412*, 411-414 [5] S.J. Kadish, K.W. Head, N.G. Barlow, and D.R. Marchant (2008) *GRL, 35*, 4 pp. [6] F.Forget, J-B. Madelaine, A. Spiga, N. Mangold, and F. Costard (2007) *LPSC XXXVII*, Abstract 8012 [7] H.M. French (2007) *Wiley*, 3rd ed., 458pp. [8] S.W. Squyres (1989) *Icarus,79*, 229-288 [9] R.J. Soare, et al. (2008) *EPSL, 271*, 382-393. [10] K.L. Tanaka, et al., USGS, 2005, 27 pp.