MULTIPLE GENERATIONS OF GULLY ACTIVITY IN WESTERN UTOPIA PLANITIA, MARS. T. N. Harrison[1†], G. R. Osinski[1,2], L. L. Tornabene[1], and C. M. Stuurman[3] [1]Centre for Planetary Science and Exploration/Department of Earth Sciences, University of Western Ontario, London, ON, Canada. [2]Department of Physics and Astronomy, University of Western Ontario, London, ON, Canada. [3]University of Texas at Austin Institute for Geophysics, Austin, TX, USA. [†]Current affiliation: NewSpace Initiative, Arizona State University, Tempe, AZ, USA (tanya.harrison@asu.edu).

Introduction: Here we investigate gully formation in Western Utopia Planitia based on stratigraphic relationships between gullies, scalloped depression bearing terrain (SDBT) (terrain denoted as ABp by Kerrigan et al. [1], determined to be ~50–85% water ice by volume based on Mars Reconnaissance Orbiter (MRO) Shallow Radar (SHARAD) data by Stuurman et al. [2]), and concentric crater fill (CCF) [3]. This will help to inform on the relative timing of the geologic processes in the region in the Late Amazonian, and how Western Utopia is evolving under present-day conditions.

Methods: Mapping and image analysis were completed using MRO Context Camera (CTX) and High Resolution Imaging Science Experiment (HiRISE) images in the Java Mission-planning and Analysis for Remote Sensing (JMARS) software package [4] spanning 30–60°N and 70–150°E. Gullies were analyzed from the global database of Harrison et al. [5].

Results: In Western Utopia, gullies predominantly occur south of ~43°N (Fig. 1). Within the SDBT, gullies are relatively sparse, only occurring in craters hosting heavily eroded scalloped depressions, while non-gullied craters host no scallops (Figs. 2A–B). Some gully aprons are observed that superpose scalloped depressions, while other aprons are truncated by scalloped depression growth (Fig. 2C–D). In craters where both CCF and gullies are observed in contact with each other, the gullies always superpose the CCF. Where the CCF exhibits extensional fracturing along the margins, gully fans are observed that both cover the CCF fractures and are cut by them up to ~60°N. These two relationships are sometimes observed within a single gully system, and other times the relationship differs across multiple gullies along a single slope. This implies that gully formation in western Utopia post-dates the emplacement of CCF in the region, and has occurred coincident with CCF retreat/removal.

Features characterized as "sinuous downslope ridges" found in association with southern hemisphere gullies by Dickson et al. [6] are observed in association with some gullies in Utopia (Fig. 2D) from 37–50°N, consistent with the latitude range where highly dissected latitude dependent mantle (LDM) occurs [e.g., 7]. These ridges are sometimes observed with associated degraded debris aprons and are sometimes thinly mantled by polygonally fractured material (not present on younger fan lobes on the same slope). We agree with the interpretation of Dickson et al. [6] that these ridges represent inverted gully channels from older periods of gully activity that are now being exhumed from within degrading ice-rich pasted-on deposits. This requires that tens of meters of this pasted-on material have been removed from crater walls in Western Utopia.

We interpret the mantled gully aprons to be representative of older periods of gully activity that pre-date the most recent episode of SDBT deposition. Younger gully aprons terminate farther upslope than the relict aprons, possibly reflecting a reduction in gully activity over time. This would be consistent with a meltwater source (from either pasted-on material [8] or near-surface ground ice [9]) where the source is/was undergoing desiccation.

From ~30–40°N, 47 craters containing "gully-like" features are observed. Analysis of these during the creation of our global gully database [5] found these features to be highly localized to Utopia Planitia. These features consistent of alcoves and aprons with predominantly linear, poorly defined channels or mass movement chutes. In some cases, wide, eroded channels are observed that start mid-slope with no clearly associated alcoves and/or aprons preserved. In other cases, mantled alcoves are observed without any visible evidence of associated preserved channels and/or aprons. The gully-like features typically superpose extensional fractures suggestive of CCF removal; however, older disconnected fans are crosscut by fractures associated with CCF retreat. These older fans show evidence of eroded levees flows and channel segments, and are much broader than the stratigraphically younger lobes upslope. Based on the morphology and stratigraphy, we interpret the discontinuous fan segments to represent periods of gully activity where the pasted-on mantle upslope has either partially or entirely (depending on the crater) eroded away, with the gully-like features representing more youthful periods of mass movement activity involving little to no water.

Implications: Gully formation and activity has occurred repeatedly across a range of obliquity and climate conditions in Western Utopia, after the cessation of the CCF-forming glacial conditions (if gully activity occurred here before CCF emplacement, the evidence has been destroyed). The stratigraphic relationships between gullies and scalloped depressions/CCF clearly show that gullies have been active coincident with the formation and growth of scalloped depressions, as well as the retreat of CCF. The observation of inverted gullies within pasted-on deposits on crater walls supports the hypothesis of Christensen [8] that gully formation—in at least some locales—is intimately linked to melting of ice within the pasted-on material. Gully activity persists in an extremely limited capacity in Utopia today, documented thus far in only one location which appears to be consistent with a frost-related process [10]. However, we suggest that this may not be the same process by which gullies originally formed.

References: [1] Kerrigan M. C. et al. (2012) *LPSC 43,* abstract 2716, [2] Stuurman C. M. et al. (2016) *GRL, 43*, 9484–9491. [3] Squyres S. W. (1979) *JGR, 84*, 8087–8096. [4] Christensen P. R. et al. (2009) *AGU Fall Mtg,* abstract IN22A-06. [5] Harrison T. N. et al. (2015) *Icarus*, *252*, 236–254. [6] Dickson J. L. et al. (2015) *Icarus, 252*, 83–94. [7] Mustard J. F. et al. (2001) *Nature, 412*, 411–414. [8] Christensen P.R. (2003) *Nature, 422,* 45–48. [9] Costard F. F. et al. (2002) *Science, 295*, 110–113. [10] Dundas C. M. et al. (2015) *Icarus, 251*, 244–263.

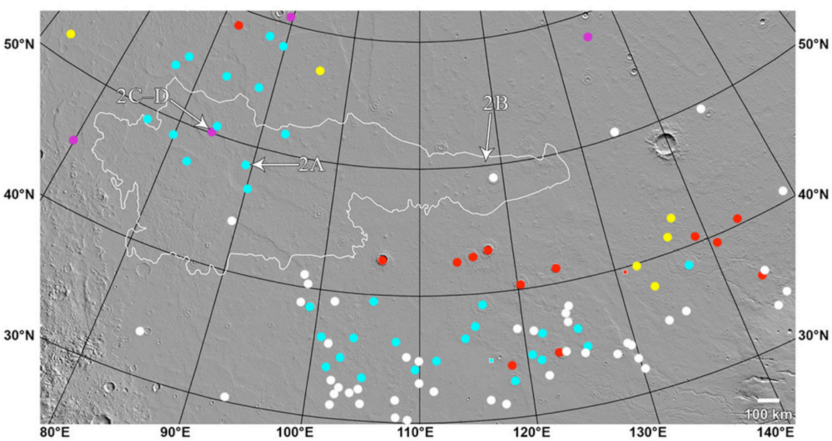

Figure 1. Gullies (colored dots) and gully-like features (white dots). For gullies, teal = pole-facing preference, red = equator-facing, yellow = east/west, and purple = no preference. White outline denotes the scalloped depression bearing terrain (SDBT) ("ABp" unit as mapped by Kerrigan [1]). Locations of frames in Figure 2 marked with white arrows.

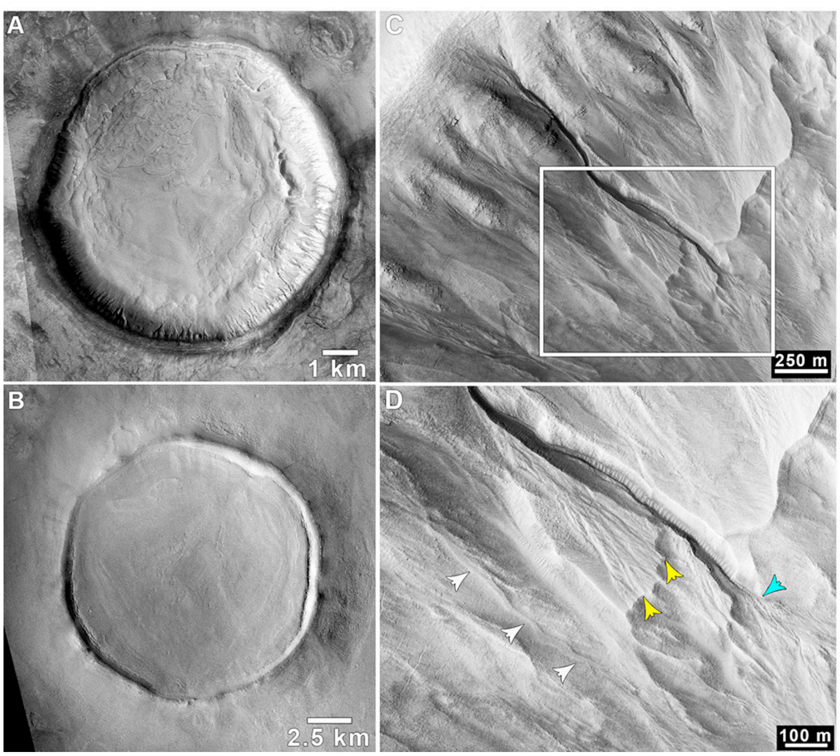

Figure 2. (A) Example of a gullied crater in the SDBT. Subframe of CTX F05_037646_2275 and F02_036446_2267. (B) Example of a non-gullied crater in the SDBT. Subframe of CTX B18_016837_2289. (C) Multiple generations of gullies on mantled crater walls. White box denotes the location of D. Subframe of HiRISE ESP_022561_2305. (D) A sinuous downslope ridge—interpreted to be an inverted gully channel (white arrows)—adjacent to an older gully fan truncated by a scalloped depression (yellow arrows) and a gully that post-dates the most recent episode of scallop development (teal arrow). Subframe of HiRISE ESP_022561_2305.