SHAPE ANALYSIS OF MARTIAN GULLIES IN TWO HIGH-NORTHERN LATITUDE CRATERS.

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Introduction: Gullies on Mars are usually defined by an alcove, an incised channel, and a downslope depositional apron [1]. The gully channel is deeper at its source and shallows distally. This holds true for a vast majority of gullies, especially those in southern latitudes. However, several gullies in northern high-latitudes (>50° N) show complex networks with more than one prominent channel. These gullies have not undergone detailed morphologic and morphometric analysis. Morphometric comparison of gully morphologies and their spatially associated landforms can give insight to different gully forming processes and provide clues to past environmental conditions. We studied two gullied craters at latitudes higher than 50° N in an attempt to understand the similarities and differences between the polar drainage environment and more commonly studied areas.

The first crater (63.8°N 292.3°E), located to the northeast of Tantalus Fossae, is about 16.3 km in diameter and contains numerous gullies on its eastern and western interior slopes. Only the east side of the crater has elevation data, so analysis was concentrated on that rim. On this east side, gullies are poorly developed (Fig. 1), with the exception of one gully which is deeply incised. This gully shows a complex drainage network morphology with several deep channels, which incise the entire thin, light-toned apron. At the deepest part of one of the alcoves is an intriguing, 12-m-high eroded, elongated mound, which trends along the slope (Fig. 2).

The second crater (53.6°N 26.3°E) is small, about 4.5 km across, and is located on the northern region of the ejecta blanket of Lyot Crater. It contains gullies on all its slopes, but most of their aprons blend together despite having well-defined alcoves. Only two of the gullies have distinct aprons that could be studied. The first shows several indistinct, broad, shallow discontinuous channel-like forms on its thick, dusty apron. Its alcove is sharply-defined with four branches. The latter illustrates the merging of several gullies with a lobate apron. Pitted features appear on the apron's surface.

Methods: We examined HiRISE stereo images, anaglyphs, and DTMs of both craters to measure and map the gully systems. We also mapped the drainage forms on the crater rim at a lower resolution using CTX images in ArcGIS Pro.

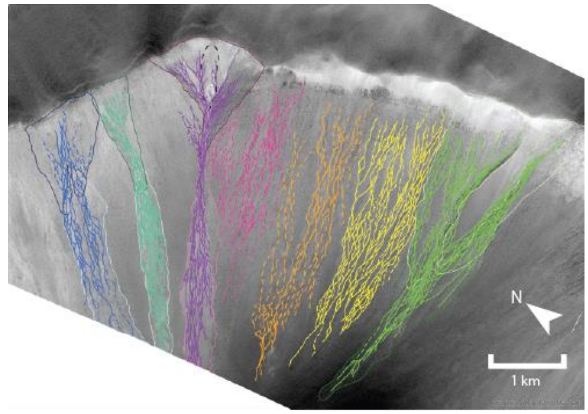

Figure 1: Perspective view of mapped drainage networks of gullies on the northeast rim of the crater at 63.8°N. Each drainage system is represented by a different color. Solid lines delineate the channels, while dashed lines show where channels are less distinct. HiRISE DTM PSP_007429_2440.

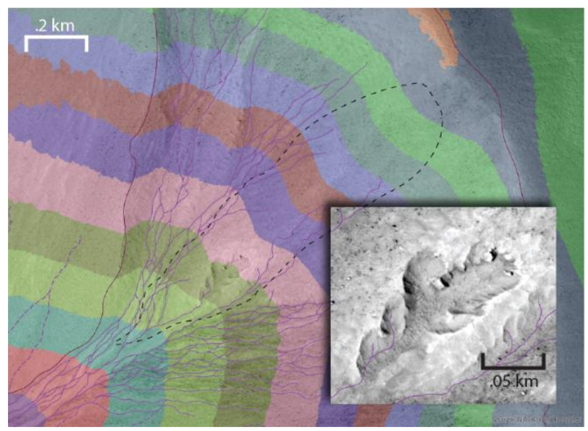

Figure 2: Closeup of the mound in a gully of the crater at 63.8°N. Lain over the original image are topographic contours. An approximate boundary of the mound is traced in black dashes. Inset is the exacvated feature in the mound. In this figure, north is up. HiRISE DTM PSP_007429_2440.

Next, drainage networks were drawn, also using ArcGIS Pro, in more detail using HiRISE imagery (Fig. 1). This includes mapping channels, outlining aprons and alcoves, and delineating individual gully networks. These network drawings can be used to calculate variables that are associated with drainage such as drainage density, sinuosity, and channel length and branching.

In ENVI, transects were drawn across well-defined gullies (Fig. 3). Using elevation data, these transects can generate profiles that show incision into bedrock at the alcove and deposition of material in the apron. These profiles can be used to calculate a variety of quantitative 3D measurements including detailed slopes of the gully systems, gully and apron volumes, volatile loss, and channel incision.

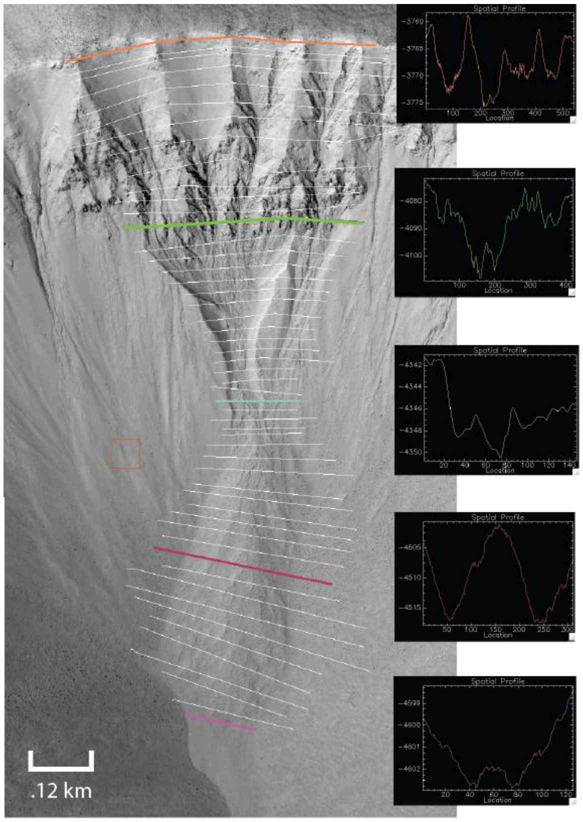

Figure 3: Image of the northern gully in the crater at 53.6°N. Drawn across it are the transects. Transect color correlates with the color of the profile to the right of it. Notice the incision through resistant layers at the top of the gully and deposition at its base. HiRISE stereoimage ESP_019438_2340

Results: There are several interesting features in both selected craters. Both had unique gullies with morphologies that are uncommon in lower latitudes.

Crater Northeast of Tantalus Fossae: In a gully of the crater at 63.8°N, we see a complex network of channels, especially in the apron. The morphology of these apron channels resembles terrestrial braided streams, where episodic water flows transports large volumes of unconsolidated material to the apron. The crater material appears largely is unconsolidated and the apparent brightness of the apron may be due to an icy composition. In addition, we observed an anastomosing center stream line (deepest and most continuous channel), which suggests several episodes of erosion and deposition.

At the gully alcove, the elongate mound appears particularly bright compared to its surroundings. This brightness in addition to its being located in the deepest, likely most shaded part of the alcove, lends resemblance to a dust-covered snowpack, which is being excavated by relatively recent volatile action.

Crater in Lyot Ejecta: In the second crater at 53.6°N, the two studied gullies appear very different despite originating in the same crater. The first has a well-defined, thick apron, which makes the gully particularly well-suited for the transect method of volume calculation. It has scallop-shaped escarpments on its western side which are superimposed on the original alcove boundary. This suggests that episodic flows have reshaped the alcove.

A distinctive feature in the second gully in this crater is the appearance of relatively shallow depressions on the apron. Transects of these pits show they are on average about 50 meters in diameter and about 1.4 meters in depth. The depressions are morphologically consistent with sublimation pits, which would indicate high volatile subsurface volumes in the crater.

Conclusions: Complex networks in gully aprons appear morphologically similar to braided stream networks. This could be due to unconsolidated sediment composing the crater slopes. The extreme channeling morphology is more reminiscent of surface water flows than crudely channeled debris flows. Escarpments and erosional networks suggest multiple episodes of transient surface reworking in one spot. This is more common with ephemeral water features than mass movement. Pitted surface features, especially on the gully apron, suggest the sublimation of subsurface volatiles, which may be remainders of liquid volatiles that originally shaped the feature. These volatiles would be less abundant in a dry flow model.

Future Work: The initial conclusions drawn in this project can be further tested using a variety of methods that show whether surface conditions in the recent past could have accommodated liquid flow as opposed to mass wasting. This has been done in a previous 3D geomorphic study [2] that considered surface pressure and temperature (TES, THEMIS) in Lyot crater in addition to topography, aspect, landform associations and detailed gully slope and volume measurements. Quantitative and qualitative comparisons with terrestrial gullied landforms and other martian gullies would also be informative. Thus, further calculation and analysis of measurements made using these gullies would prove useful.

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References: [1] Malin and Edgett (2000) *Science* 288, 5475, 2330-2335. [2] Gulick et al. (2018) *Geological Society, London, Special Publications* 467, 233-265.