Gullies on Mars: Fluvial Processes as Evidence for Liquid Water on Mars

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Abstract

The Mars Reconnaissance Orbiter HiRISE camera has provided unprecedented high-resolution (~25cm/px) views of the surface of Mars. Using HiRISE Digital Terrain Model (DTM) PSP_006261_1410_ESP_014093_1410, we analyzed gully slopes and their geomorphology and morphometry in Corozal Crater. After generating numerous cross-sections across each gully along its profile, we calculated the eroded gully volumes. We also generated longitudinal profiles along each gully and determined that all gully profiles are concave. Average slopes ranged from 14° to 21°. Although gullies form and are modified by various processes, our preliminary findings are consistent with a fluvial origin.

Figure 1. Corozal Crater is located within a much larger crater in Terra Cimmeria at lat. -38.7°, lon. 159.4°E. (HiWeb)

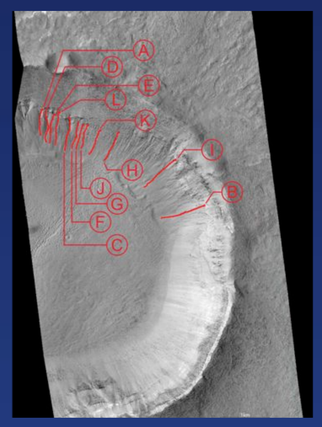

Figure 2. HiRISE image PSP_006261_1410 depicting the eastern portion of Corozal Crater with locations of the 12 gullies studied. The crater has a diameter of 8.33 km.

Morphology

Gullies are landforms that are eroded into the surface and serve as drainage ways for water and sediment. In terrestrial gullies, alcoves are generally formed with a 20° to 25° angled slope; channels are formed with a 10°-20° slope, and the debris fans normally exhibit an angle of less than 10°. Average gully slopes in Corozal crater range between 14° and 21°. Several gullies are eroded into underlying bedrock and exhibit fluvial bedform characteristics as seen in terrestrial gully systems.

Acknowledgements

Thanks to Natalie Glines for generating the perspective view in Figure 3.

Special thanks to the National Science Foundation and CAMPARE for supporting this research, and to my mentor Dr. Virginia Gulick, and the other interns including Carly Narlesky and the rest of the CAMPARE faculty, Dr. Alexander Rudolph and Jennifer Bjerke for all of their support and advice as well as the support from my parents.

This material is supported under the National Science Foundation under Award No. AST-0847170, a PAARE Grant for the California-Arizona Minority Partnership for Astronomy Research and Education (CAMPARE). Any opinions, findings, and conclusions or recommendations expressed in this material are those of the author(s) and do not necessarily reflect the views of the National Science Foundation.

Methodology

Longitudinal profiles of 12 gullies in Corozal Crater were traced using HiRISE stereo images. The center stream line data was then transferred to the HiRISE DTM using the software package ENVI to enable accurate extraction of the elevation and profile of the eroded gully on the crater wall. Perpendicular transect lines (cross-sections) were then created from the starting position at the terminus of the gully and ending at the head of the alcove.

We automated calculation of the eroded volumes of the gully drainages in MATLAB using data gathered from transects spaced at 20m intervals. Transect cross-sectional areas were integrated along the longitudinal profile to determine the total excavated volume. Comparing the volumes of the gully alcove, and channel with the volume of the debris apron can yield an estimate of the likely water volume required to form the gully. The Stream Concavity Index (SCI) is a measure of the concavity along the stream profile and can also be used as an indicator of relative stream power and erosion; the more concave, the more erosion the stream has experienced.

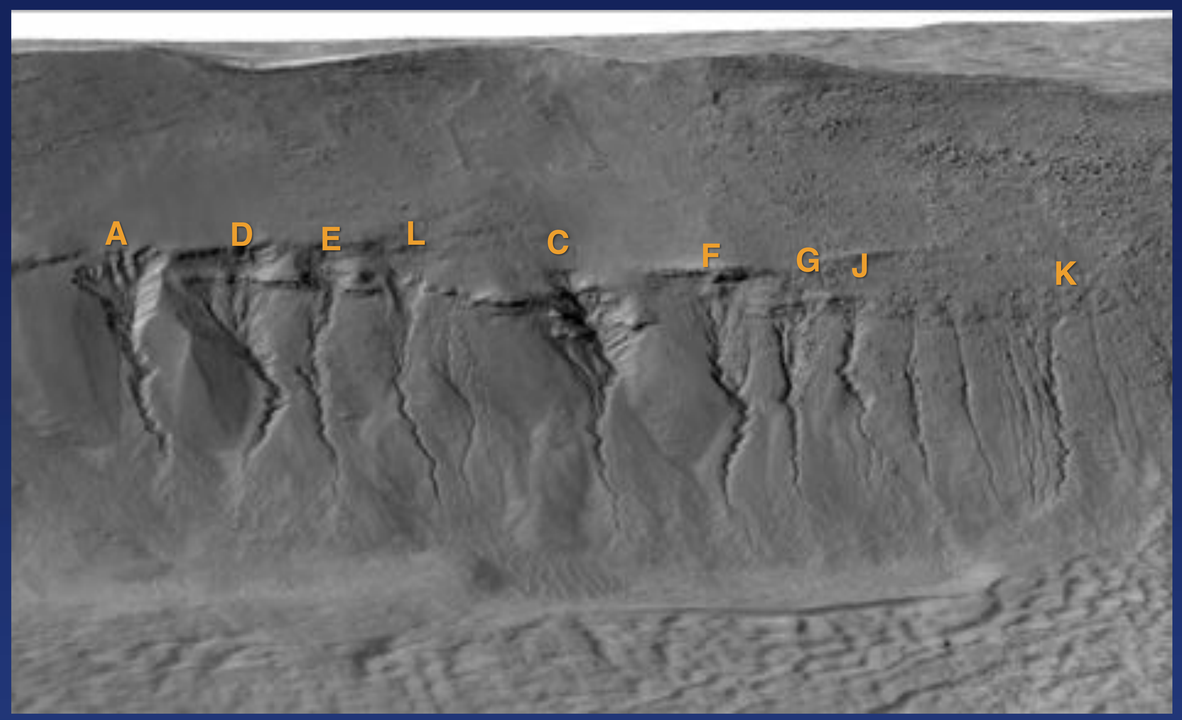

Figure 3. Perspective view of Corozal Crater towards the North. Nine of twelve gullies studied are shown here. The other three gullies are located to the East.

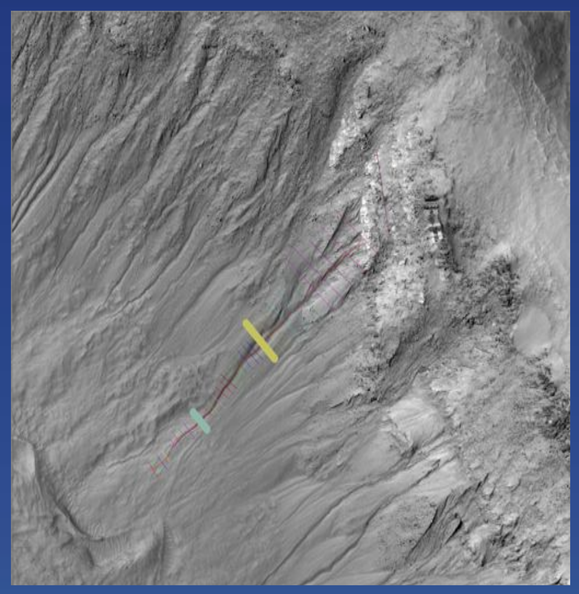

Figure 4. Example of perpendicular cross-sectional lines down center stream line of a gully.

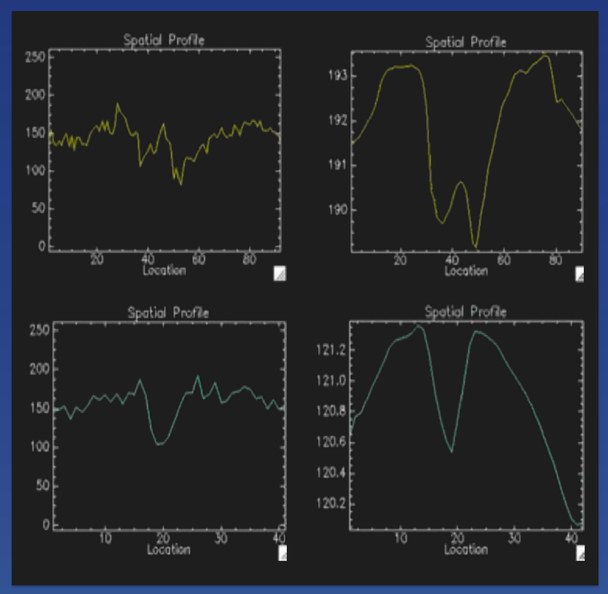

Figure 5. ENVI Pixel versus Transect Length (m) graph (left) and Elevation versus Transect Length (m).

Results

Plotting slope against gully location (clockwise from due North in Corozal Crater) revealed no significant correlation, as shown in Figure 6A. Slopes in the twelve gullies averaged 19°, with a minimum of 14° and maximum of 21°. Low slope values suggest that fluvial processes may have dominated sediment transport through the system, rather than pure dry gravitational flows. Figure 6C shows the longitudinal profiles of the twelve gullies and plots the elevation of the channel thalweg with distance along each gully from source region to terminus. Peaks in total gully volume coincide with high SCI values (Figure 6B and D). This may suggest a correlation between the volume eroded and the impact of stream power as reflected in the stream concavity index.

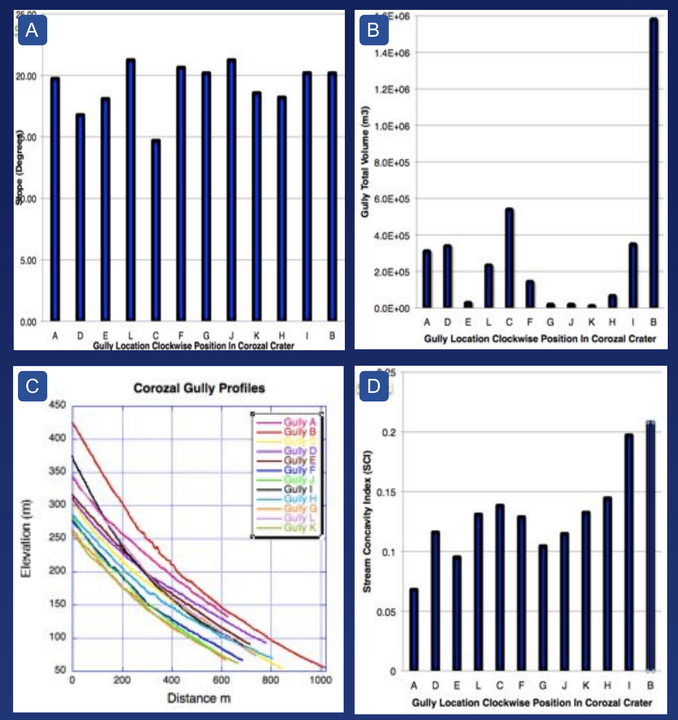

Figure 6. Some geomorphometric results for Corozal Crater gullies.

Future Work

Further work involving Corozal Crater would include gathering additional gully geomorphometric data from DTMs. Comparison of volume calculations for both the gully systems and their debris aprons can provide information on likely water or volatile volumes. Sediment transport rate estimations can provide information on the minimum duration of likely flows. Such information can be used for comparisons with data from crater gullies located in other areas and terrestrial analogs.

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"HiRISE," High Resolution Imaging Science Experiment. University of Arizona, http://hirise.lpl.arizona.edu.

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