GEOMORPHIC ANALYSIS OF MARTIAN GULLIES IN WESTERN ASIMOV CRATER.
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Introduction: The discovery of gullies on Mars in 2000 [1] has produced many questions regarding how and when they formed that still remain to be answered. Multiple hypotheses have been proposed to explain the formation of gullies with different morphologies, including water flows, debris flows, dry flows, downhill sliding of frozen CO_2 blocks and sublimating CO_2 processes.

We have focused on gullies in Asimov Crater, which is an 84 km in diameter impact crater located in the southern hemisphere of Mars in the Noachis quadrangle (47.0° S, 355.05° W). Specifically, our study area includes the west central pit region (WCP) as well as the western crater slope (WS). Our current study reported here, analyzes four gullies in the WCP, two along the WS as well as 6 Recurrent Slope Lineae (RSL) located north of these WS gullies.

Methods: High Resolution Imaging Science Experiment (HiRISE) stereo images and Digital Terrain Model (DTM) data has allowed for a detailed morphologic and morphometric study of these features. Detailed drainage maps using stereo images were produced in ArcMap for each of the gully system (Figure 1, 2).

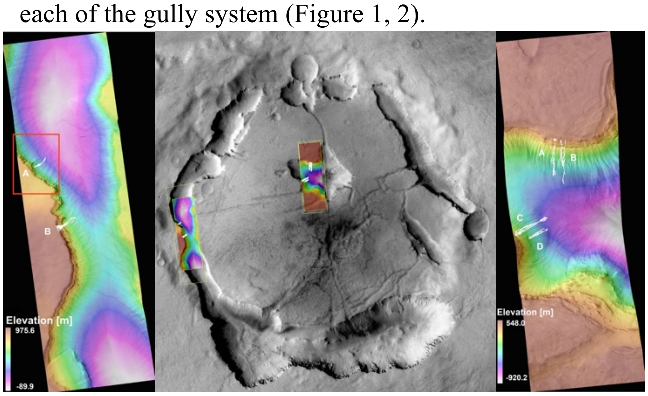

Figure 1: Detailed drainage maps of the 2 gullies along the western slope (left) and the 4 gullies studied in the west central pit region (right). HiRISE DTMs (DTEEC_013268_1330_013123_1330, DTEEC_0136122_1325_013110_1325) are overlain onto drainage maps with gully locations noted. Red box on the left image shows location of RSL.

These maps delineate the extent of the drainage systems and along with the DTM, enable drainage basin areas, widths, lengths, depths, slopes, and other parameters to be accurately measured and characterized. We estimated gully volumes using both the ENVI and ArcMap methods as described in a recent paper characterizing the central peak gullies in Lyot Crater [2].

Results and Discussion:

Max depth ranges from ~9 m for gully A along the WS to ~18 m for gully B in the WCP. The gully lengths range from 1539 m for gully C in the WCP to 534 m for Gully A along the WS. In contrast, the RSL lengths ranged from 96 m to 34 m.

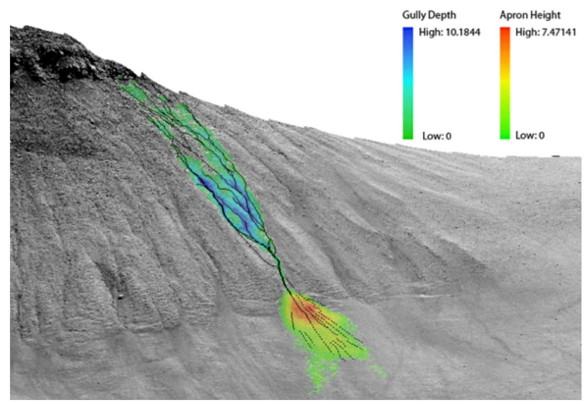

Figure 2: 3D perspective of gully C in the WCP region made using ArcMap. Black lines delineate drainage networks. Colors show depth maps in units of meters relative to a TIN surface either above the gully area or below the apron area.

All gullies had a sinuosity greater than 1, ranging from 1.09 to 1.16 and concave longitudinal profiles, with concavity indices ranging from values of .106 to .209 (Figure 3). RSL profiles were mostly straight ranging from slightly concave to slightly convex (Figure 4).

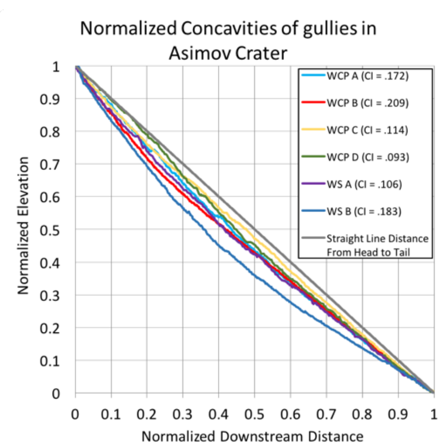

Figure 3. Concavity profiles of gullies in WCP and WS regions of Asimov Crater. The difference between the CSL values and the straight line distance from head to tail can be interpreted and calculated as a concavity index.

Another characteristic analyzed was the apex slope of each gully, which is the point along the gully profile where sediment starts to deposit at the top of the apron. For dry flow processes the apex slope of a gully is typically greater than 21°, while lower slopes are thought to involve water processes [3]. Apex slope measurements of the gullies ranged from 12° in gully B to 18° in Gully C in the WCP , and from 12°-14° on the WR.

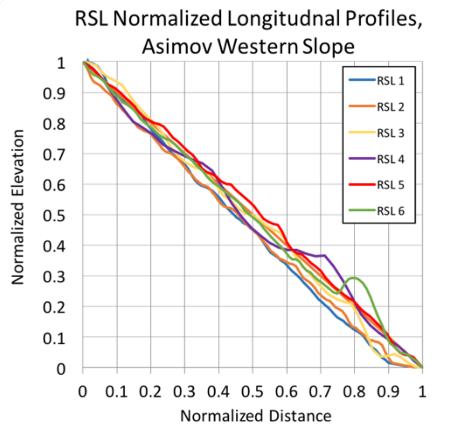

Figure 4. Longitudinal profiles of RSL in the WS region of Asimov Crater.

The gullies analyzed here all have an apex slope well below 21°, suggesting that a fluid (likely water) was needed to emplace these flows during gully formation. RSL had average slopes ranging from 29° to 32° with terminal slopes ranging from ~7° -37°. These slopes are much steeper, showing that different processes (likely dry) were involved for most of the RSL.

Using the methods described in [2], when we compared the gully volumes to their apron volumes, both methods showed a missing volume difference between the amount of sediment removed from the gully versus the amount of sediment deposited in the apron (Figure 5). This is consistent with our previous gully studies [2, 5] and suggests that gully formation probably involved a large volatile (water and/or CO_2) content. This missing volume may have been excess water and/or ice that was in a slurry with the sediment which eroded the gully.

Comparison with Previous Work: A previous study of Asimov Crater focused on the eastern central pit and on the SW crater slope (outer trough) [4]. Three of the five gullies analyzed in this region showed missing volume differences of nearly 100%. The other two gullies, D and E, showed missing percentages of 99.65% and 93.84% respectively, found by averaging the ENVI and ArcGIS method percentages.

The WCP and the WS gullies showed more variability in missing volume differences. The missing volume differences ranged from 94.37% to 8.16%. Overall, there appears to be less volume missing from gully aprons along the western side of the crater versus the eastern side of the central pit and SW side of the crater rim.

Discovery of RSL in the Study Area: During our analysis of the gullies, RSL were identified north of the gullies studied along the western slope of Asimov Crater (Figure 1). The two images used in the analysis were taken on May 14, 2009 and June 22, 2009, during the Southern Spring (Ls 265.4°), and the Southern Summer (Ls 289.7°), respectively. The RSL increased in length from the Spring to Summer image. RSL may indicate the presence of volatiles in this area.

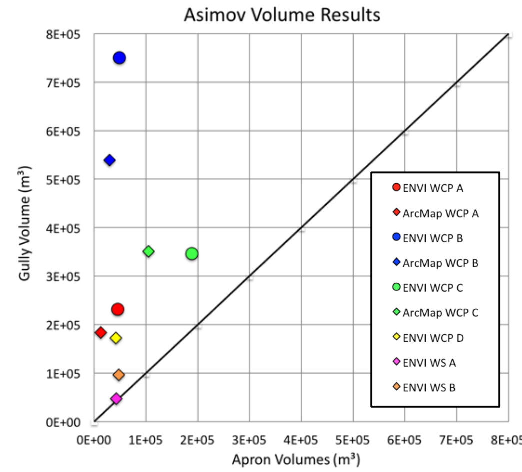

Figure 5: Gully volumes plotted against their apron volumes in gullies studied.

Conclusions: Evidence strongly supports the presence of a volatile component in the formation of these gullies. These gullies cannot have formed by dry processes, but rather a fluid most likely water must have been a factor in their formation. The results are similar to previous studies in which there is a large difference in gully and apron volumes [2, 5]. There appears to be more variability in the missing volume differences found along the western slope and western central pit versus the eastern central pit and SW crater slope [4].

In addition, concave longitudinal profiles also offer evidence consistent with fluvial formation. Gully apex slope measurements less than 21 degrees provide additional evidence against formation solely by dry flow processes. While the terminal slopes of most of the RSL were well above 21° and therefore consistent with dry flows, the presence of two RSL with terminal slopes between 7° and 9° may imply involvement of a volatile component in their formation.

References: [1] Malin M. C. & K. S. Edgett, 2000, Science, 288.5475, 2330-5; [2] Gulick, V. C., Glines, N., Hart, S., & Freeman, P., 2018. Geological Society, London, Special Publications, 467. [3] Kolb, K. J., McEwen, A. S. , Pelletier J. D., 2010. Icarus, 208(1), 132–142. [4] Paladino, T., Gulick, V.C., Glines, N., 2017. LPSC, #2889. [5] Gulick et al. 2017.LPSC #1970.

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