

COMPARISON OF ELEVATION ON MARTIAN GULLY MORPHOLOGY AT CRATER GULLY SITES.

R. H. Huang¹ and V. C. Gulick^{1,2}, ¹University of Arizona Lunar and Planetary Laboratory (ri-huang@email.arizona.edu), ²SETI Institute/NASA Ames.

Introduction: Today, liquid water is generally unstable on the surface of Mars. However, Mars' surface pressures can vary widely depending on elevation, with atmospheric pressures reaching >10 mb in low-lying features like Lyot Crater (~7000 m; [1,2]) compared to its average surface pressure of 6.1 mb. The effect of these higher pressures may have been recorded in gully system morphology [2].

This study examines two gullied craters at different elevations to investigate the effect of altitude on gully morphology. These sites include Moni Crater (47.01°S 18.77°E; ~1140 m elevation) and a ~13-km unnamed crater in Utopia Planitia ("N Crater", 48.44°N 89.39°E; ~4600 m elevation).

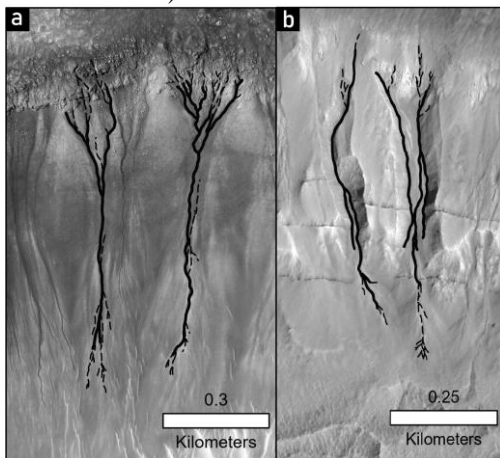


Figure 1. Comparison of high-elevation Moni gullies (a) and low-elevation N Crater gullies (b). Moni imagery from HiRISE image ID ESP_039245_1325, N Crater imagery from HiRISE image ID ESP_037646_2290.

Methods: The study areas selected for detailed morphometric analysis in this project represent craters that are at similar latitudes ($\sim\pm 48$ degrees), with gullies that have a similar orientation, and also have suitable HiRISE DTMs. Following the selection of two study sites, 3 distinct pole-facing gullies and 2 west-facing gullies were selected from each crater, giving a sample set of 5 low-elevation (~4600 m) gullies and 5 high-elevation (~1100m) gullies.

Drainage maps of these 10 gullies were produced in ArcGIS Pro using HiRISE images, the associated DTM, and a hillshade generated from this DTM to determine various morphometric parameters. Additionally, elevation data is used to examine the profile of the center stream line (CSL, the longest and deepest channel) and the slopes of the gully.

Results: The gully systems are on average 0.932 km long for the N crater and 0.956 km for Moni. The N Crater incised the bedrock more deeply, with a maximum depth of ~50 m compared to ~5 m at Moni. The lower-elevation N Crater site also had more sinuous channels with an average sinuosity index of 1.052 and 1.037 for Moni. The sinuosities at both sites are higher for the pole-facing gullies than the west-facing gullies (Moni: 1.044, 1.027; N Crater: 1.054, 1.050; pole-facing and west-facing respectively). Additionally, the N Crater shows a higher stream magnitude than Moni (average Shreve order ~13.4 and ~12.6 respectively), but less overall development with lower Strahler orders (average Strahler order ~2.8 and ~3.2 for N Crater and Moni respectively).

Slope analysis: Several slope parameters were measured within the gully system: the erosional alcove slope, the apex (or transitional channel between erosion and deposition), and the depositional apron. Alcove slopes for N Crater gullies are larger than for Moni (average $\sim 19.2^\circ$ and $\sim 14.1^\circ$ respectively). However, they do not have distinct apex slopes. The N Crater does have an exceptionally high-slope gully, with an alcove slope of 24.9° and an apex slope of 20.0° .

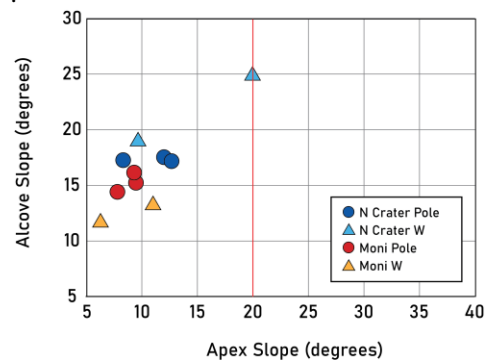


Figure 2. Comparison of alcove and apex slopes of studied gullies. The red line represents the apex angle required to prevent dry flow deposition, $\sim 21^\circ$ [5].

Long profile analysis: The topographic long profile is a measure of the elevation change with downstream distance. These measurements show a large variance in CSL profile concavity among the measured gullies. Generally, there is poor separation between gullies at each site, though the west-facing gullies in both craters show a straighter profile. The gullies at the high-elevation site are steeper in their upper section than

shallow downstream. One notable stream line is found on the west wall of the low-elevation site; its profile shows a shallow linear upper slope, then a highly concave downstream section.

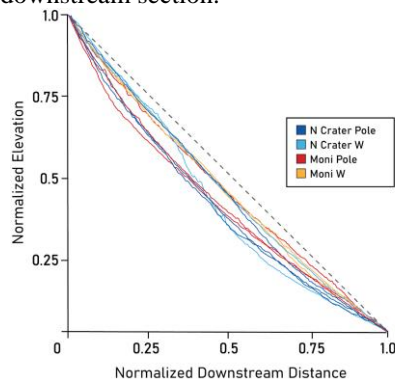


Figure 3. Normalized long profile concavity plot for studied gullies. The dashed line indicates a flat profile.

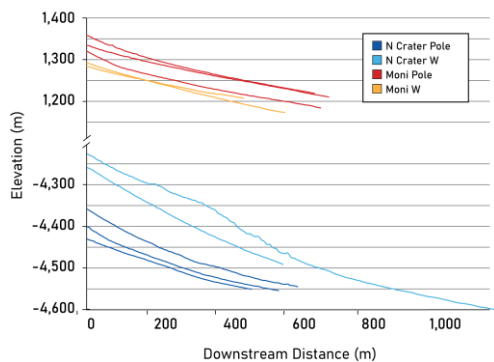


Figure 4. Long profile elevation plot for studied gullies. This style of chart highlights the gully lengths and changes with elevation.

Conclusions: *N Crater:* The low-elevation site in the Northern hemisphere has extensive evidence for the presence of past subsurface water ice, such as scalloped sublimation features, polygonal terrain [3], and a lobate ejecta blanket, which could have provided a water source during the formation of these gullies. Profiles across the channels are V-shaped with flat floors, suggesting initial fluvial erosion and subsequent infilling of the channel. Gully aprons show distributary channels all across their surface, while the overall gully system has concave long profiles and tributaries have moderate stream orders, supporting a fluvial origin. These gullies deposit at low angles, far below the angle of repose for dry materials ($\sim 35^\circ$, [4]) and the angle for kinetic friction ($>21^\circ$, [5]) with the exception of one gully. Different alcove textures and superimposed fans suggest post-emplacement debris flows or mass-wasting, which may explain why some gullies have high slopes incongruous with other gullies of the same orientation.

Moni: Our measurements correspond to conclusions made by Glines et al [6], which suggests that the gullies in Moni were formed by liquid water flows. Similar to [6], we observed concave channels on low slopes, branched development, and volatile loss.

Summary: The intention of this study was to investigate the effect of elevation on gully morphology due to the increased stability of water at higher atmospheric pressures. As both sites indicate the presence of liquid water during the gully emplacement process, it is unlikely that elevation solely contributed to the formation of the gullies and their morphology.

There appears to be more variation within the gully sites themselves than between them. Morphologically, we see different complexities and networking of channels between the pole-facing and west-facing slopes, which implies that insolation and heating angles has a larger effect on these gullies than elevation alone.

However, the stronger overall development of channels in the N Crater, evidenced by high concavities and stream orders as well as increased bedrock incision, suggest that liquid water flow played a larger role at this site compared to Moni. At its lower elevation, liquid water could have been stable for longer at the N Crater site, affecting these morphologic parameters.

Future work: Sample sites with extreme elevation differences were chosen to best capture how this difference affects gully morphology. This means that craters in dramatically different geologic environments were used, which may control the gully morphology more strongly than elevation alone. One interesting site, Nqutu Crater (38.04° S, 169.55° E; [7]), contains gullies at different altitudes within the same crater. This may provide an interesting study site as these gullies formed under the same geologic and climatic conditions.

Additionally, only a very small sampling of 10 gullies among thousands on Mars were chosen. A larger sampling would reduce unintentional sampling biases as well as diminish the effect of regional geology on morphologic comparisons.

Future work should expand these methods and examine other morphometrics such as gully volume differences, alcove and apex slopes, as well as surface temperature and pressure conditions through TES and surface temperatures using THEMIS.

References. [1] Haberle R.M. et al. (2001) *JGR: Planets*. [2] Gulick et al. (2019) *GSL*, <http://dx.doi.org/10.1144/SP467.17>. [3] Levy J.S. et al (2009), *Earth and Planet. Sci. letters*. [4] Conway S.J. et al. (2011). [5] Kolb K.J. et al. (2010). [6] Glines et al. (2016) *LPSC XLVII*, Abstract #2464. [7] Harrell et al. (2022) *LPSC LIII*, Abstract #TBD.