# Interweaving RSL on Mars: Do They Support a Wet Hypothesis?

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**Introduction:** Recurring slope lineae (RSL) are unique features on the Martian surface whose formative mechanisms are still unknown [1]. RSL have been hypothesized to form from fully dry processes such as sediment flows [2], fully aqueous processes including ice melt [3], the deliquescence of salts [4], or the presence of groundwater [5], or from hybrid processes resulting from a combination of both aqueous and dry mechanisms [6].

However, while several aspects of these features (a generally linear trajectory, spatial occurrence in regions of high insolation, etc.) can be attributed to various formation mechanisms, other aspects of RSL expression are more difficult to reconcile, thereby calling the validity of each mechanism into question.

Recurring slope lineae therefore remain enigmatic features, many of whose secrets remain unresolved. This is especially true for the geomorphic expression and variations in that expression observed within certain RSL. While many appear linear in nature, a small subset— notably in Martian craters such as Raga— display an interweaving morphology (**Fig. 1**).

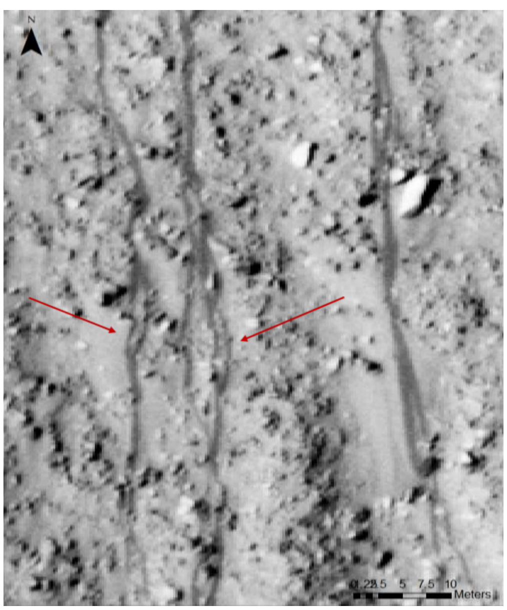


***Figure 1:*** *Example of slope lineae with an interweaving morphology (see arrows) seen in Raga Crater Image ESP_014011_1315. Flow direction is oriented towards the top of the image.*

This morphology has not been discussed at length in the literature and raises several broad and important questions about the nature of recurring slope lineae, and specifically about the geomorphic expression of interweaving RSL (**Fig. 1**). We seek to determine whether interweaving slope lineae can provide insight into the formative nature of RSL, and postulate that the interweaving exhibited by recurring slope lineae does help to further constrain the formative mechanism for these interweaving features.

**Methods:** For this study, we utilized two map-projected JP2 image files of Raga Crater sourced from the University of Arizona's HiRISE imagery website— ESP_014011_1315 ("Image A") and ESP_031773_1315 ("Image B"). Both files were downloaded and imported into ArcGIS Desktop 10.7.1.

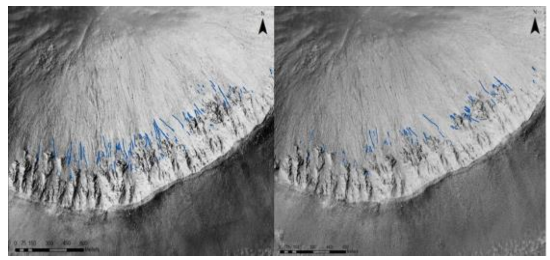

***Figure 2:*** *The 143 RSL in Image A (left) and 85 RSL in Image B (right), highlighted in blue.*

We manually mapped 143 RSL in Image A and 85 RSL in Image B (**Fig. 2**). Bifurcating, anabranching, and interweaving channels were all counted as part of a singular slope lineae if they initiated from the same point. Slope, aspect, and elevation data for the region— as well as straight-line "valley length" distances from the initiation to termination points of each RSL— were also accounted for using both their respective raster datasets and the built-in Measure tool within ArcMap 10.7.1.

Within each image, the channel length of both interweaving and single-channel RSL's (excluding short tributary and distributary links) was calculated to quantify sinuosity by using each RSL's respective channel length divided by its valley length. The resulting shapefile contained 267 channel-valley pairs.

The sinuosity of each channel— straight (channel-to-valley ratio less than 1.1), sinuous (channel-to-valley ratio between 1.1 and 1.5), or meandering (channel-to-valley ratio greater than 1.5) was also derived and recorded.

**Results:** We observed 143 distinct RSL composed of 173 individual channels in Image A, and 85 distinct RSL composed of 94 individual channels in Image B (**Fig. 2**). In both images, RSL occurred only on the southern to southeastern slopes of Raga Crater and on nearly identical slopes in terms of angle and orientation. Approximately 87% (198 of 228) of RSL were found to contain just a single channel. Approximately 10% (23 of 228) had two channels, ~2% (5 of 228) had three channels, and less than 1% (2 of 228) had four channels (**Fig. 3**).

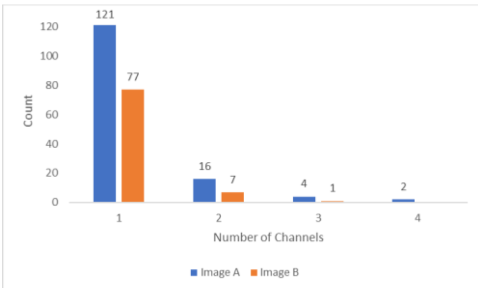


***Figure 3:*** *Measured channel counts for all channels in both Image A and Image B.*

*Sinuosity:* Conversely, 4% of channels (10 of 267) were determined to be sinuous; the highest sinuosity ratio found was 1.204. None were classified as meandering (**Fig. 4**).

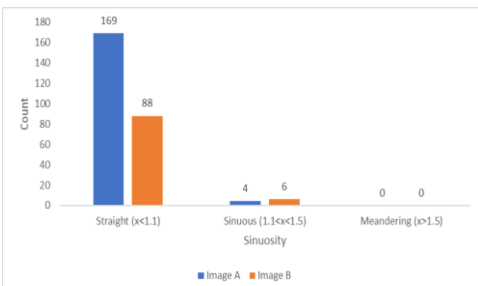


***Figure 4:*** *Measured degree of sinuosity for all channels in both Image A and Image B.*

Most of the channels cataloged as sinuous— six of ten— were found to be part of multi-channel RSL systems. However, only four anabranching RSL contained sinuous channels. Six sinuous channels were part of the four multi-channel lineae, whereas four sinuous channels were part of single-channel lineae.

*Channel Bifurcation and Confluence:* Of the seventy-seven channel bifurcations, approximately 51% (39 of 77) were found on slopes that became shallower in the few meters either immediately before or immediately after the bifurcation took place. By contrast, only around 25% (19 of 77) of the channel confluence points were on slopes that became shallower around where the channels reconvened.

**Discussion:** In addition to the interweaving RSL (**Fig. 1**) found at Raga Crater, slope lineae that exhibit similar morphologies have been found at other locations on Mars, such as at Lohse, Tivat, and Rauna Craters. Interweaving— and to an extent, more sinuous— slope lineae, therefore, are not a phenomenon solely relegated to Raga Crater. It is likely that hundreds to thousands of interweaving slope lineae are present on the surface of Mars.

*Channel and RSL Count:* The difference in total RSL abundance (**Figs. 2 and 3**) may be due to a variety of factors, including the spatial resolution of the imagery making it more difficult to discern RSL, or differing climactic conditions causing either fewer or smaller slope lineae to appear, thereby decreasing the overall count. Atmospheric conditions, the prevalence of local dust cover, or local variations in temperature and humidity may also play a role.

*Sinuosity:* Minimal channel sinuosity (**Fig. 4**) may be the result of the relatively short nature of all channels catalogued or may instead be the result of flow dynamics— with sinuous channels potentially indicating a change in energy available for flow. However, as six of the ten channels found to be sinuous are also a member of an RSL that consists of multiple channels, there is a possible link between multi-channel systems and higher values for sinuosity measurements. While it may simply be a result of a small sample size leading to skewed results, this correlation should nonetheless be explored further to either confirm or rule out the potential for a causal effect.

*Channel Bifurcation and Confluence:* Slope angle plays an integral role in channel bifurcation; as the slope shallows out dramatically, more channels tend to appear. This would support an aqueous formation mechanism, as dry flows— upon progressing downslope— tend to simply stop progressing (as opposed to begin bifurcating) when the slope becomes too shallow [7]. This is consistent with the research done here, as both single- and multi-channel RSL tend to continue progressing downslope, even if the slope is quite shallow at certain locations along the transect.

**Conclusions:** We propose that the RSL seen in Raga Crater and elsewhere on Mars are formed from an aqueous process due to the presence of both interweaving and higher sinuosity channels, in contrast to what would be expected from a downslope directed gravity flow of dry sediment. Our research suggests that changes in slope angle near the bifurcation point of slope lineae are associated with the interweaving patterns seen in RSL, and that higher sinuosity in those channels may also influence the interweaving nature of these features.

**References:** [1] Stillman, D. E. et al. (2020) *Icarus*, *335* (August 2019), 113420. [2] Schmidt, F. et al. (2017) *Nature Geoscience*, *10*(4), 270–273. [3] Möhlmann, D. T. F. (2010) *Icarus*, *207*(1), 140–148. [4] Gough, R. V. et al. (2016) *Planetary and Space Science*, *131*, 79–87. [5] Abotalib, A. Z., & Heggy, E. (2019) *Nature Geoscience*, *12*(4), 235–241. [6] Raack, J. et al. (2017) *Nature Communications*, *8*(1). [7] Tebolt, M. et al. (2020) *Icarus, 338*, 113536.