

TOPOGRAPHIC CONFORMITY PATTERNS OF LUNAR RILLES. J. W. Conrad¹ and C. I. Fassett², ¹NASA Marshall Space Flight Center, Huntsville, AL 35805. (jack.w.conrad@nasa.gov), ²Johns Hopkins Applied Physics Lab, Laurel, MD 20723.

Introduction: Lunar rilles (LR) are unusual channel features on the Moon's surface which are thought to be formed by lava erosion or drainage and collapse of lava tubes [1]. The observational evidence implies that both mechanical and thermal erosion played a role in LR morphological evolution [2], but have not yet constrained how LR initially form. The relative importance of the two erosional processes, and how they vary with channel size and slope, is still debated [3].

Since LR are similar to a range of volcanic valley-like features on other worlds (e.g., Mars [4], Venus [5], and Mercury [6]), if we can understand how LR formed, it could give us insight into how this type of volcanic process works and how it differs in the no atmosphere environments of the Moon and Mercury. If we can give weight to hypothesizes that tie LR formation to lava tube formation and collapse [1,7], we can use the distribution of LR to determine areas of higher lava tube density in the mare. Additionally, if we can show that LR have been modified from their initial morphology, we can insight into the lunar crustal deformation history.

We are analyzing how LR conform to topography over a range of wavelengths. This analysis can be compared to fluvial features on other worlds. This should help clarify what mechanisms at play can be linked to fluvial processes and which ones differ.

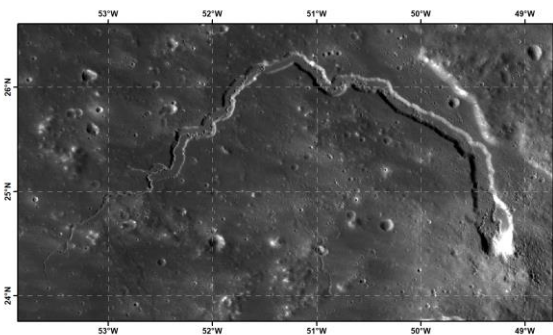


Figure 1: Schröteri Valles. One of the widest (~5 km) and longest (~150 km) LR. The source vent (lower right) points towards a volcanic origin for Schröteri, but its relationship to the surrounding maria is poorly constrained.

Topographic Conformity: To understand how LR act morphologically compared to valleys/ridges on other worlds, we need to calculate metrics that give us that information. [8] used the metrics of percent downhill (%d) and the conformity factor (Λ) to analyze how well

the drainage systems of Earth, Mars, and Titan conform to topography. %d represents the proportion of points along the drainage that are a higher elevation than the next point. Λ is defined as $\Lambda = \text{median}[\cos(\delta)]$, where δ is the angle between the directions of the drainage and the maximum topographic descent.

Black et al. [8] found that at high maximum spherical harmonic degrees (l_{\max}), these metrics trend towards 100% for %d and 1 for Λ . [5], however, found that when enough post-emplacement processes have modified a feature (as happened to Baltis Vallis/BV on Venus [9]), the metrics both trend towards middle values (50%/0). A common element of conformity and percent downhill for valleys on Venus, Earth, and Mars is that these metrics behave similarly. A major increase or decrease in the %d value with increased l_{\max} , is matched with a respective change in Λ . Differences from either of these expected behaviors indicates either the formation or post-formation evolution of LR.

We perform the metric analysis on the set of longest LR. Using [2]'s catalog of LR as a guide, we mapped out the center of each LR longer than 100 km in length in ArcGIS. This gives us a total of 26 LR to use in our analysis. The metric values for each of the 26 LR is calculated individually as we add higher and higher l_{\max} topography [10]. This analysis is done up to $l_{\max}=90$, which corresponds to a minimum wavelength of ~120 km. For metric results of the 26 LR presented in Figure 2, we take a weighted average based on the LR length.

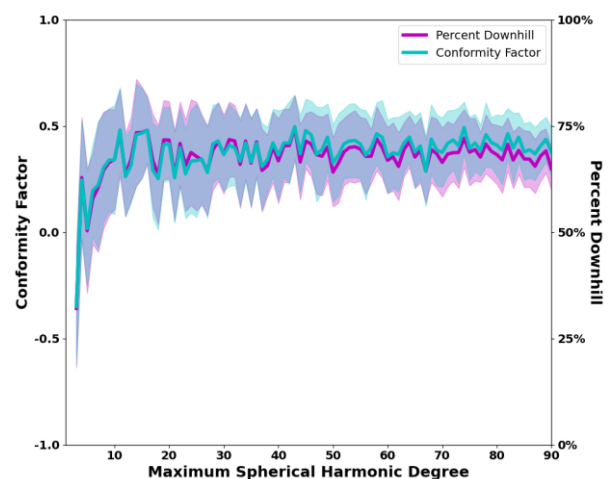


Figure 2: Averaged metric results for the 26 longest LR. Shaded regions represent the standard deviation with metrics weighted by LR length.

Results: When considering the low l_{max} behavior of the metric results, %d and Λ develop in lockstep, with both metrics with both metrics starting at coin flip/orthogonal type behavior (50%/0 respectively). They reach a consistent value at $l_{max} \sim 10$ of %d $\sim 67 \pm 7\%$ and $\Lambda = 0.4 \pm 0.1$, which lasts through $l_{max} \sim 90$.

We can compare the lunar results to metrics of rivers and valleys on other worlds (Figure 3). This analysis has been completed for rivers on Earth [8], valley networks on Mars [8], and BV on Venus [9]. Both LR metric results line up well with [8]’s results of Earth river networks. They lie below the relatively undeformed Martian valley networks and far above the tectonic deformation dominated signal of BV.

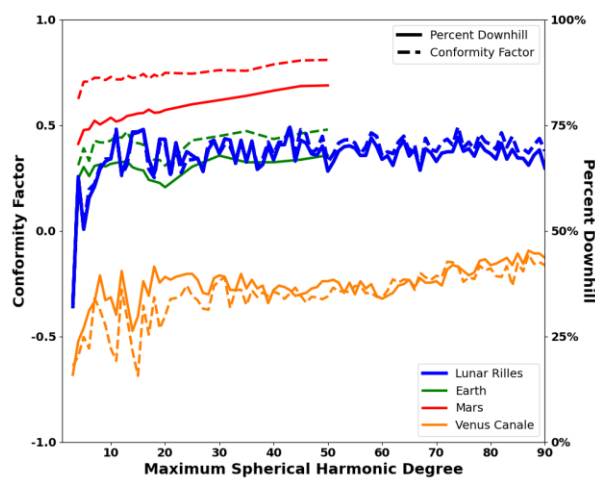


Figure 3: Comparison of LR metric results (blue) to other worlds (Earth/green, Mars/red, Venus/orange).

Discussion: Our results are somewhat surprising based on [8]’s interpretation of the difference in metric values between Earth and Mars. Earth’s metric values are suggested to be lowered due to the interplay of active tectonics and fluvial system adaptation. On Mars, the topography at long wavelengths was set before valley network formation, letting the metric values reach higher topographic conformity at longer wavelengths. The full effects of a wide wavelength range of tectonics occurring after formation on metrics can be seen with the Venus canale results [9] below 50%/0.

On the Moon, however, LR’s individually formed rapidly (~ 1 s to 10s of years [3]) and in the absence of prominent long wavelength (>1000 km/ $l_{max} \sim 10$) active tectonic deformation. As such, we are not invoking an Earth-like story to explain why the LR topographic conformity we observe is so similar to Earth’s. We are currently investigating lunar crustal loading history to explain our observations. We are also investigating formation mechanism, particularly if the formation of LR initially as “lava tube”-like structures within mare

lava sheets [1,7] can produce the signal that we observe at long wavelengths. At short wavelengths (higher l_{max}) we also observe an interesting divergence from fluvial systems (Figure 4).

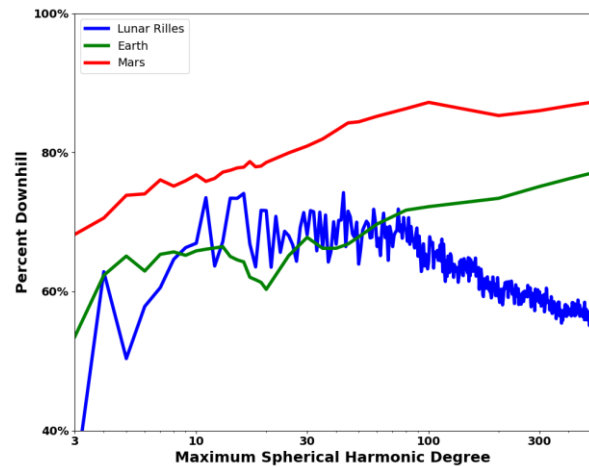


Figure 4: Percent downhill results extended to shorter wavelengths (min. wavelength ~ 22 km). LR diverges from Earth rivers at $l_{max} \sim 80$ to 100 (~ 140 to 110 km).

For fluvial channel forming processes that are perfectly delineated and have not experienced deformation after formation, we expect %d to reach 100% as topography and valley orientation are perfectly resolved. LR instead trends away from 100% and towards $\sim 50\%$ at shorter wavelengths. It is unknown if the poor topographic conformity at short wavelengths is due to the formation process or post-formation deformation. The hypothesis that we are currently investigating is the non-conformity signal being driven by fluid pressure, which allowed the lava to effectively ignore short wavelength surface topography.

Acknowledgments: We thank Debra Needham for providing us their LSR GIS files to ease our mapping comparison. JWC’s research is supported by an appointment to the NPP at MSFC, administered by ORAU under contract with NASA.

References: [1] Hulme G. (1982) *Geophys. Surveys*, 5, 245–279. [2] Hurwitz D. M. et al. (2013) *PSS*, 79-80, 1-38. [3] Hurwitz D. M. et al. (2012) *JGR: Planets*, 117, E12. [4] Carr M. H. (1974) *Icarus*, 22, 1-23. [5] Baker, V.R. et al. (1992) *JGR: Planets*, 97(E8), pp.13421-13444. [6] Hurwitz D. M. et al. (2013) *JGR: Planets*, 118, 471–486. [7] Roberts C.E. and Gregg T.K.P. (2019) *Icarus*, 317, 682-688. [8] Black B. et al. (2017) *Sci.*, 356, 727-731. [9] Conrad J. W. and Nimmo F. (2021) *LPSC*, 52, #1636. [10] Wiczorek et al. (2015) *Tre. on Geophys.*, 10, 153-193.