Local Variations in Lunar Regolith Thickness: Testing a New Model of Regolith Formation near the Apollo 15 Site

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Introduction

The formation of regolith is a fundamental surface process on airless terrestrial bodies, yet the processes and rates of regolith formation have yet to be fully resolved. A new analytical model developed in [1] describes the growth of regolith by small, simple craters as a function of time, improving on pre-existing Monte Carlo estimates for the regolith. In addition, this model describes the expected variability in regolith thickness on a given geologic unit. An additional factor to consider is regolith transport and its dependence on local slopes.

In this study, we analyze the regolith thickness in the mare units exposed in the walls of Hadley Rille (~26°N, 3.6°E; Panel 1, left) to identify trends in outcrop exposure and local slope characteristics. We compare these observations to those of slopes associated with exposed outcrops in other sinuous rille walls (Panels. 2–4) to determine what slopes outcrops are observed and whether this is consistent between rilles. In addition, we look at the elevation that outcrops occur below the rille margin (defined here as the 5 degree slope contour_, and the distance from this margin to the beginning of the outcrops. Both of these values might be expected to increase with time as the rille's topography degrades [2,3]. Results can have implications both for regolith transport processes as well as for the age of the feature – steeper gradients are expected to have had less elapsed regolith transport, consistent with a younger feature age.

Preliminary results indicate that regolith drapes over mare basalt substrate on the upper part of sinuous rille walls (Fig. 1, below), so direct measurements of outcrop depth beneath crests of sinuous rille walls are not necessarily indicative of regolith thickness.

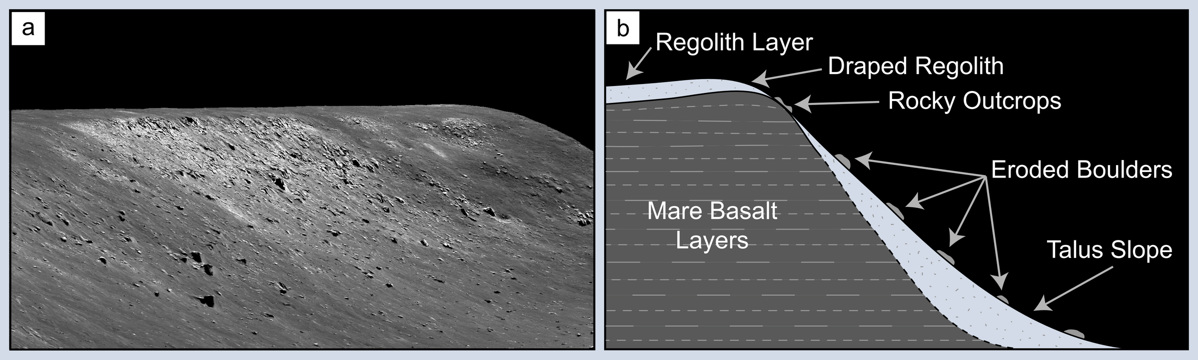


Figure 1. The thickness of layers of regolith exposed in sinuous rille walls are not representive of regolith thicknesses in the mare plains due to regolith draping over rocky outcrops of mare basalts. This lens artificially increases the apparent thickness of the regolith.

Instead, we measure the slope at which outcrops become apparent. We compare observed outcrop-exposing slopes within each sinuous rille as well as between sinuous rilles to identify trends.

Results

Sinuous Rille	Outcrop Slope		Distance from Outcrop to 5°		Elevation Change	
	Median	Standard Deviation	Median	Standard Deviation	Median	Standard Deviation
	Degrees	Degrees	m	m	Degrees	Degrees
Hadley	17.3	5.7	76.0	49.4	13.8	16.3
Schroteri	26.2	6.9	174.1	86.4	53.2	34.7
Beethoven	25.2	5.0	97.7	46.0	28.6	17.1
Marius N	13.7	6.2	33.8	24.5	5.8	6.9
Marius S	20.2	5.4	58.2	43.4	14.1	15.7

Slope

- Outcrop exposures reside at lower slopes than angle of repose (36°, [4]).
- Outcrops observed in the walls of Hadley and the northern Marius Hills rille reside at similar slopes that are less steep than outcrops observed in Vallis Schröteri and Beethoven walls.
- Outcrops in sinuous rille walls can be concealed by internal landslides or by higher rates of regolith transport resulting from the proximity of topographic features outside the sinuous rille.

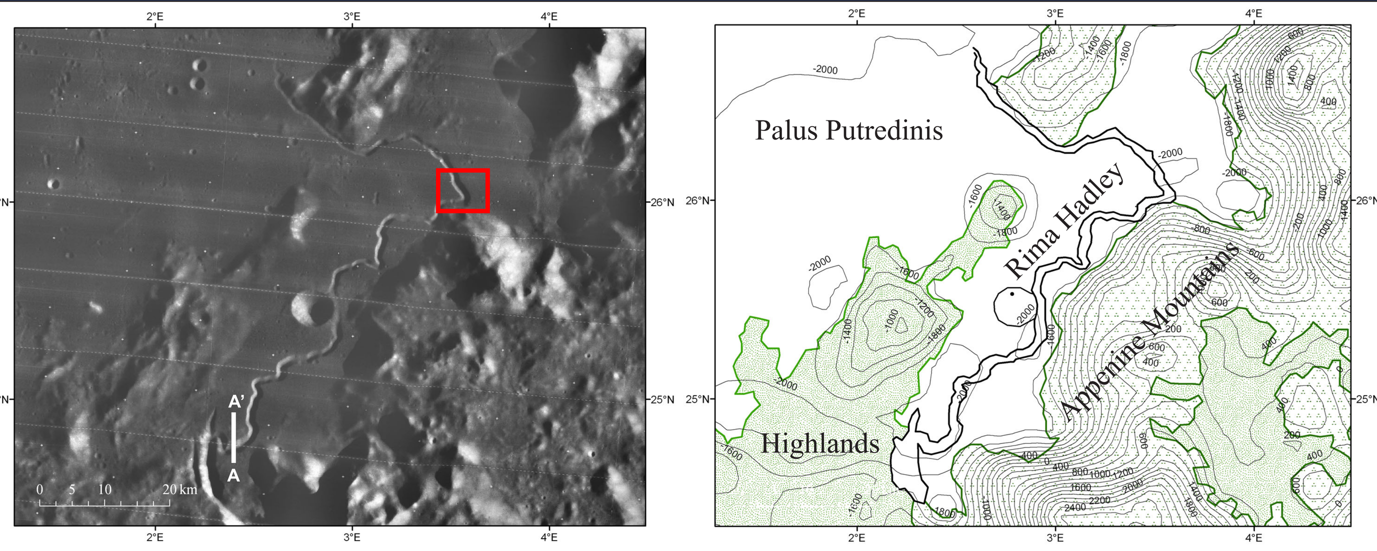
Distance and Elevation Change from Outcrop to 5° Slope Contour

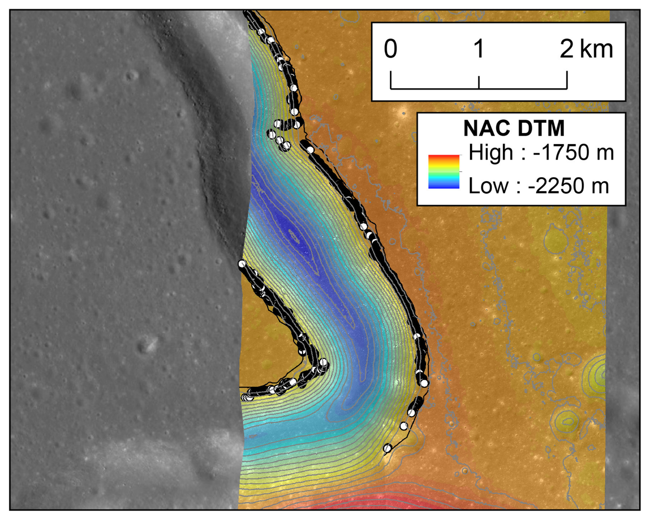
- This distance is expected to increase with feature age because as regolith is transported, the terrain is rounded, resulting in the retreat of the sinuous rille wall and an increase in distance between wall exposures and slope threshold [2,3].
- The median distance between outcrops and the slope threshold varies widely for each analyzed sinuous rille, suggesting the ages of the analyzed features also varies.
- Vallis Schröteri has the largest distance and elevation changes between outcrops and slope threshold, which could indicate this is among the older features analyzed.
- The northern Marius Hills sinuous rille has the smallest distance and elevation changes, and could be among the younger features analyzed.

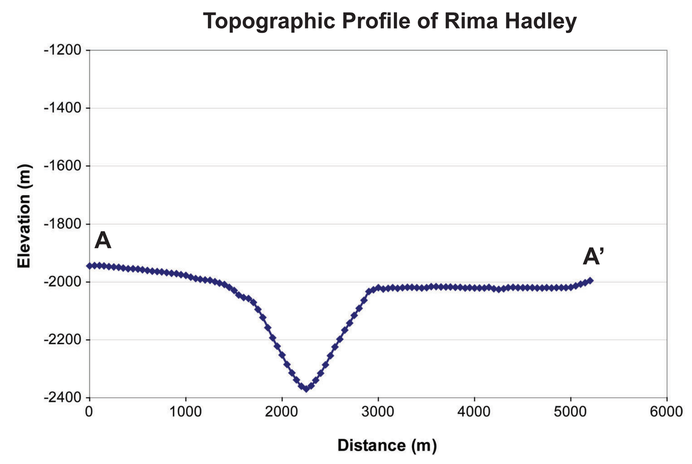
Key Points

- Our method comparing the slopes and elevations at which outcrops appear on sinuous rille walls shows promise for understanding (1) Regolith Transport and (2) Sinuous Rille Profile Modification with Age.
- Future work will include an additional comparison with mare basalt unit ages, more detailed assessment of geologic factors influencing results, and analysis of more rilles.

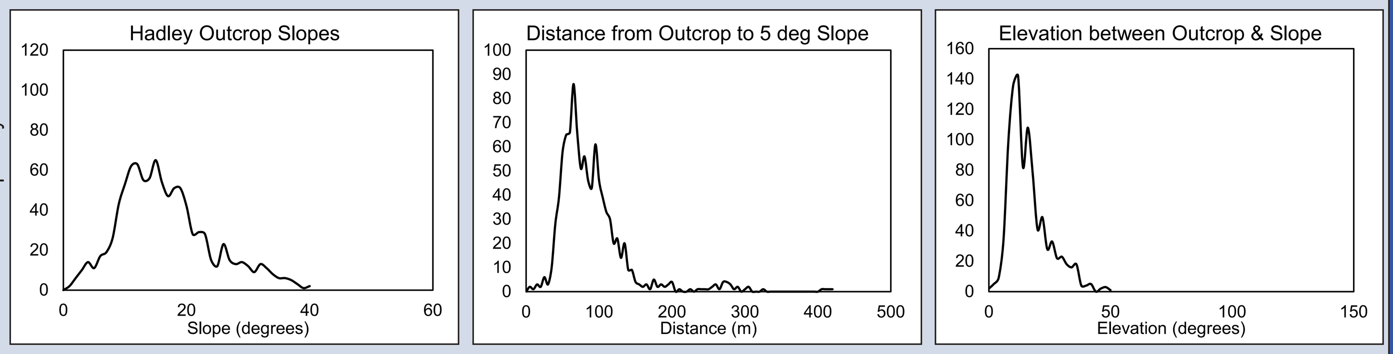
Rima Hadley





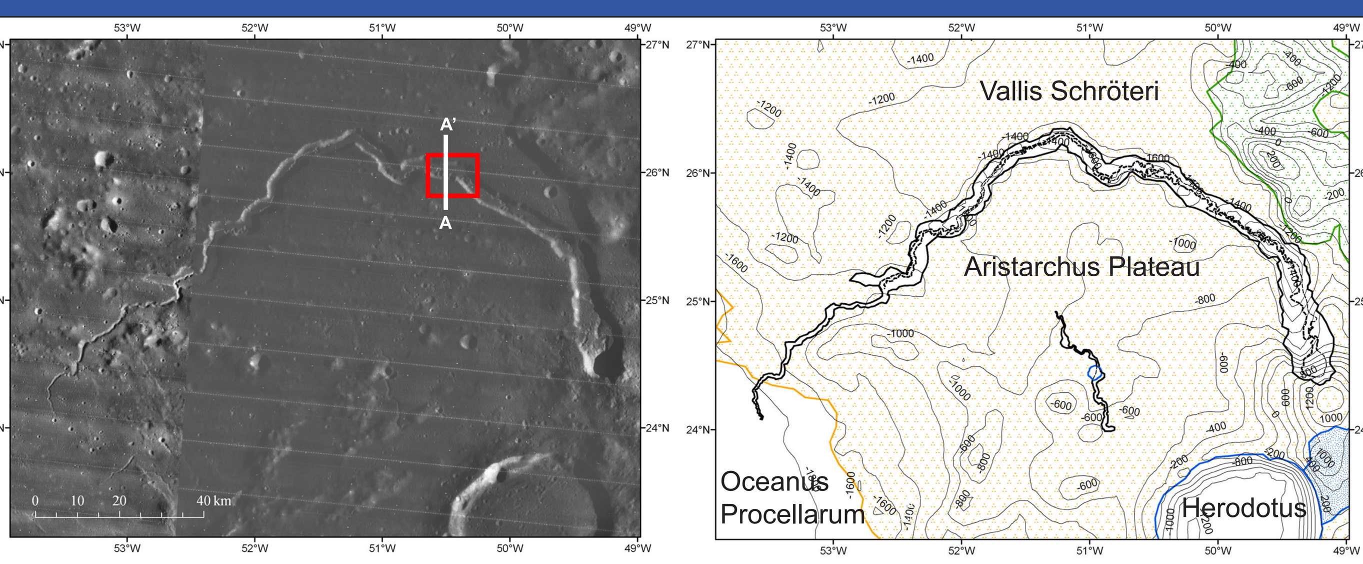


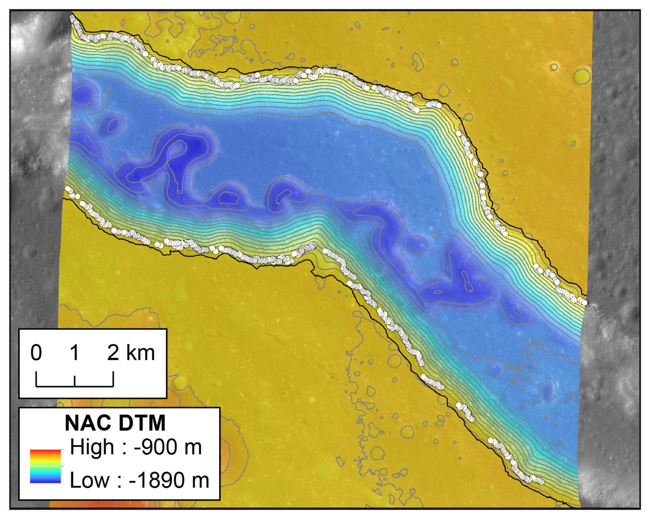
In each panel, Lunar Orbiter and Kaguya Terrain Camera images were used for context and sketch maps, contoured LROC NAC stereo imagery and DTM data were used to observe outcrops in sinuous rille walls, and LOLA tracks were used to create rille topographic profiles.

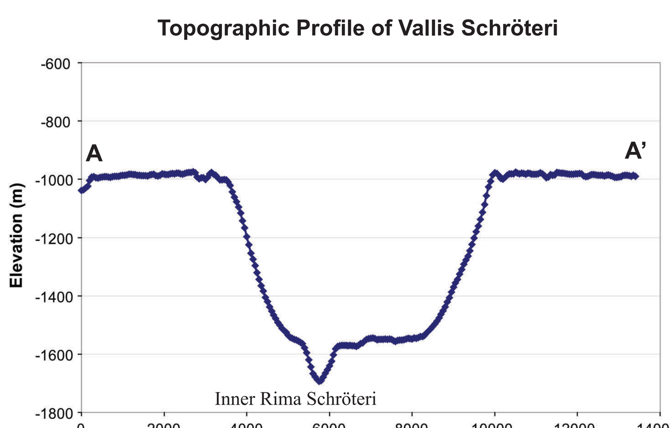


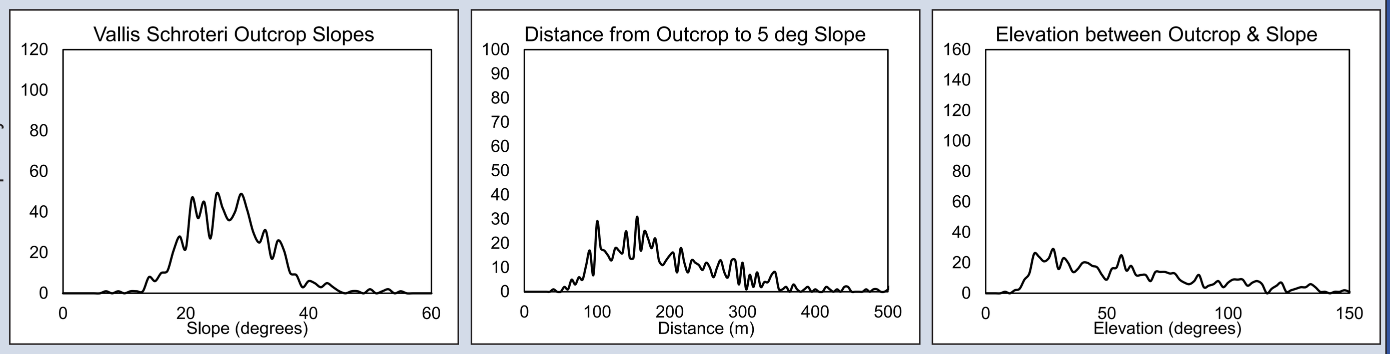
Hadley outcrops are fairly consistently located ~76 m from the slope threshold at slopes of ~17°. Outliers in distance are mainly due to a slump block artificially lowering outcrops on the rille wall.

Vallis Schröteri



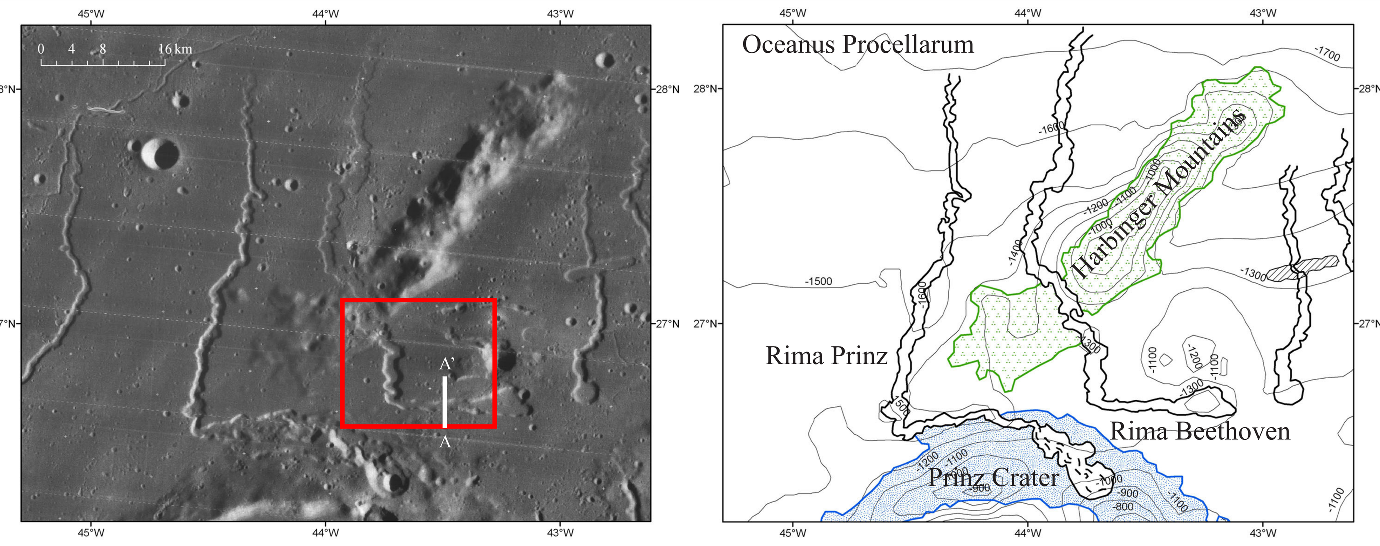


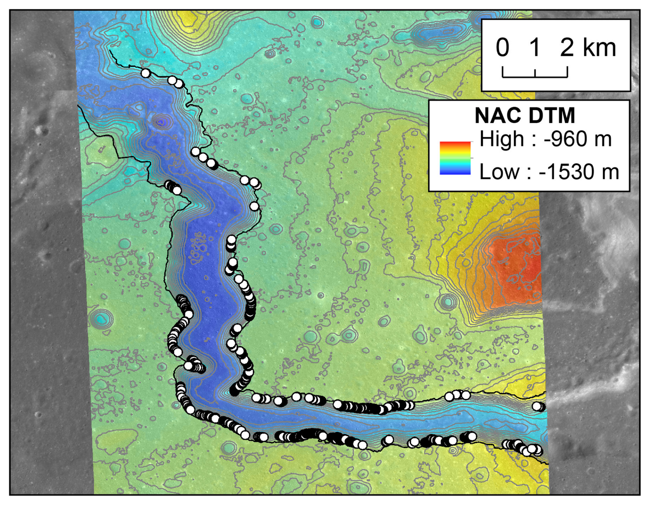


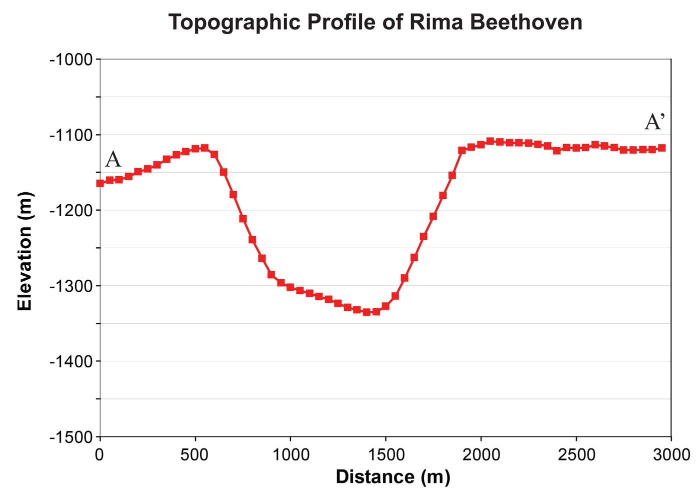


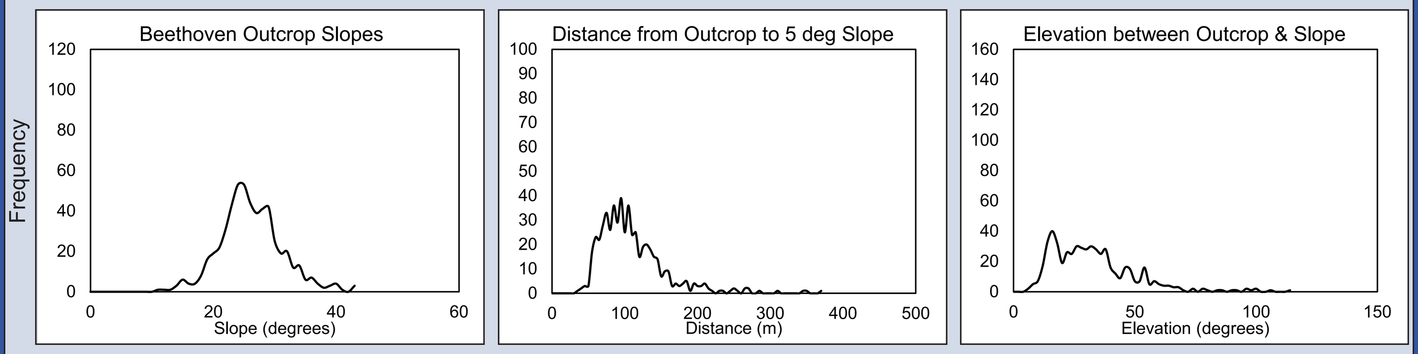
Vallis Schröteri has a typical clustering of outcrop slopes, but distance and elevation change between outcrops and slope threshold vary widely, possibly due to local slumping or substrate inhomogeneity.

Rima Beethoven



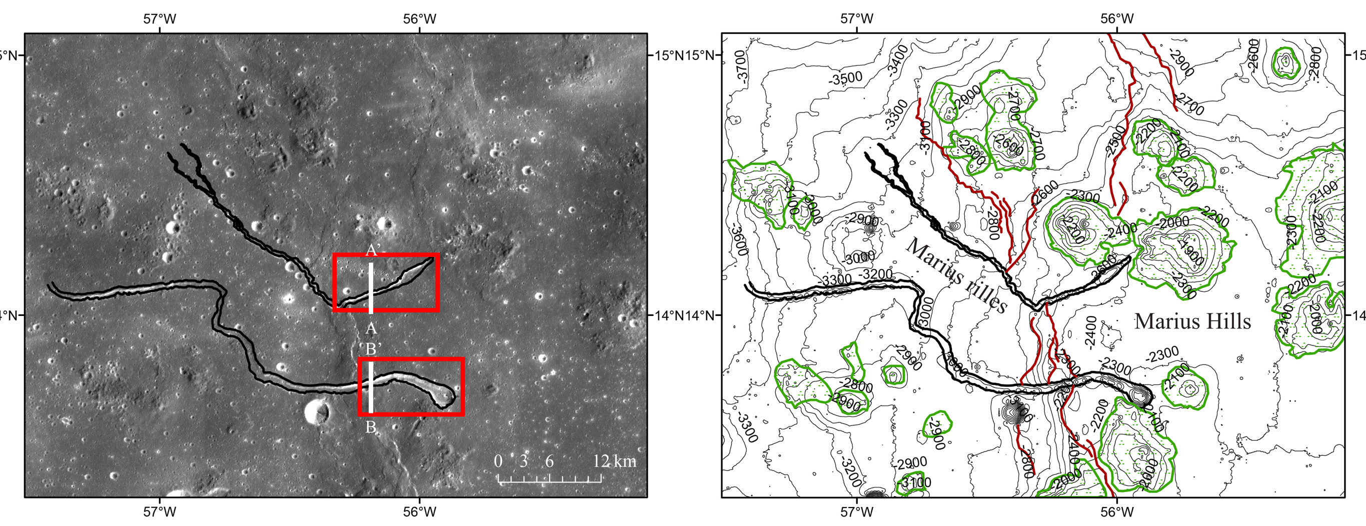


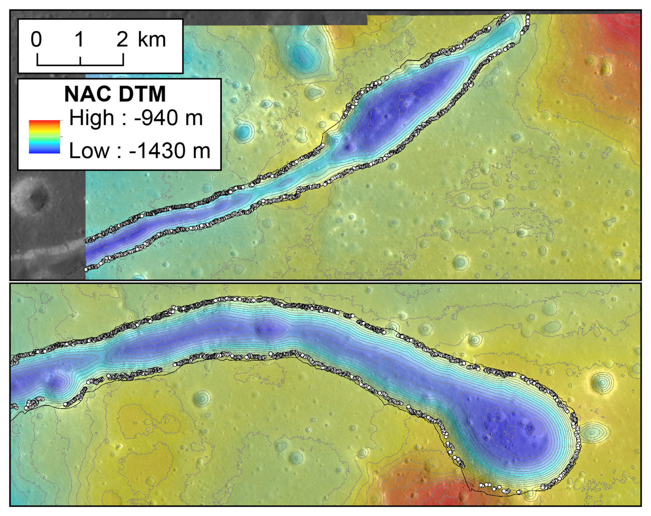


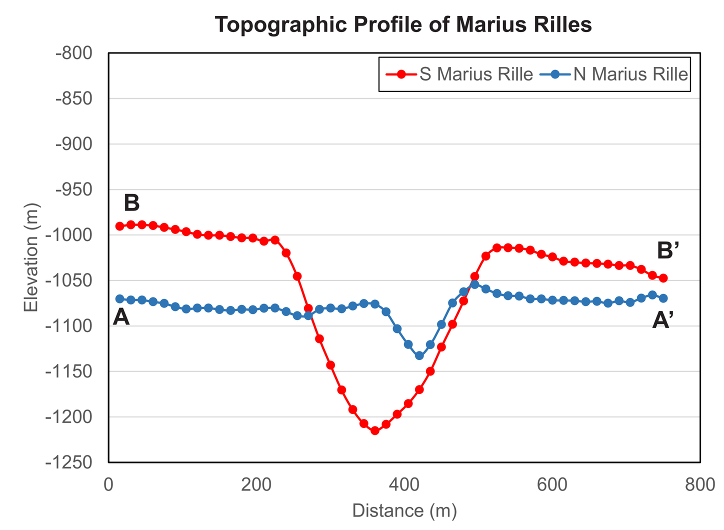


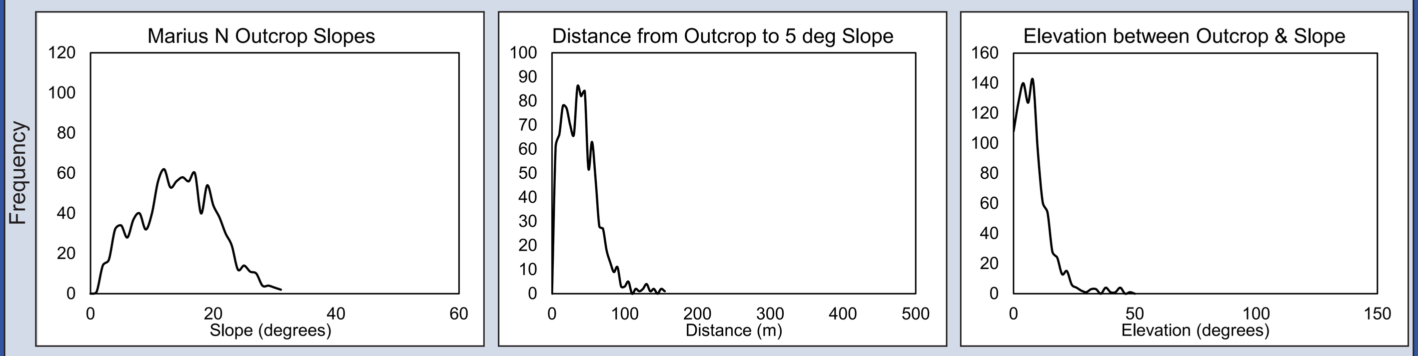
Beethoven has a similar high slope of 25° for outcrop exposures as Vallis Schröteri, but a much shorter distance and smaller elevation change, potentially consistent with a younger age for Beethoven.

Marius Hills Sinuous Rilles

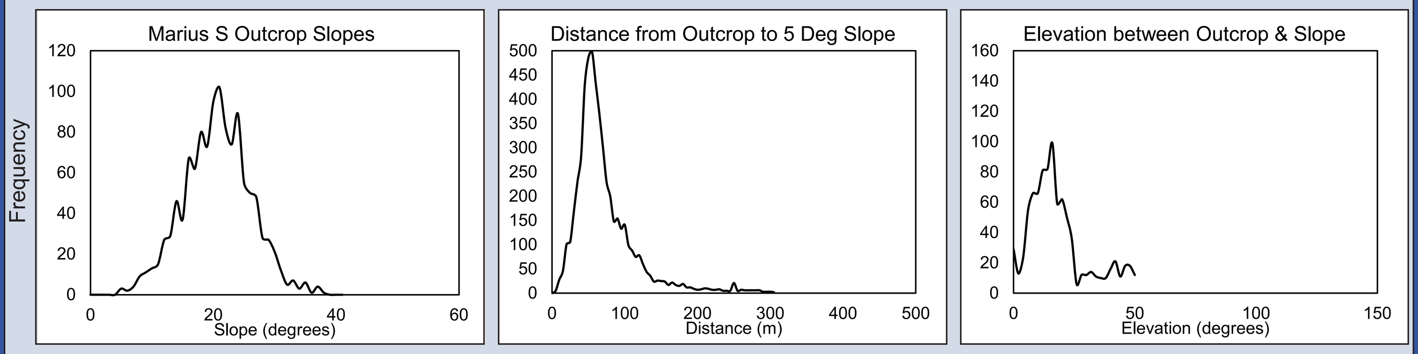








The northern Marius Hills rille has lower outcrop slopes than the southern rille but similar distances and elevation changes between outcrops and slope threshold.



The slopes may indicate a younger age for the northern rille. Alternatively, the different outcrop slopes may indicate variations in local topography and substrate influences on sinuous rille wall exposures.

References

[1] Hirabayashi, M., et al. (2018), accepted to JGR.; [2] Fassett, C. I. and Thomson, B. J. (2014), J. Geophys. Res. - Planets, 119(10), 2255-2271; [3] Fassett, C. I. and Thomson, B. J. (2015), 46th LPSC, abstract 1120; [4] Wagner, R. V., et al. (2013), 44th LPSC, abstract 2924.

Acknowledgements

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