Constraining Surface Characteristics that Influence the Morphology of Lunar Sinuous Rilles. D. H. Needham[1], N. E. Petro[2], J. E. Bleacher[2], L. M. Carter[2], [1]Universities Space Research Association/Goddard Space Flight Center (GSFC), 8800 Greenbelt Road, Greenbelt, MD, debra.m.hurwitz@nasa.gov, [2]GSFC.

Introduction: Sinuous rilles represent one of few geologic features that have been studied *in situ* on the lunar surface, yet questions remain regarding how these enigmatic features formed. Topographic signatures of channel margins and layers in the wall of Rima Hadley observed during and after Apollo 15 have been interpreted to support formation either *via* construction and subsequent collapse of a lava tube (e.g., [1]) or *via* incision into the substrate by an insulated, channelized lava flow (e.g., [2-5]). A recent global survey of lunar sinuous rilles [6] quantifies a variety of sinuous rille characteristics, including channel width, depth, length, and sinuosity. Results of this global survey indicate that different classes of sinuous rilles are likely to have formed as the result of different mechanisms, including (1) constructed surface channels with bounding levees (~2% of mapped sinuous rilles, [6]); (2) collapsed lava tubes with aligned pit craters (~3%); and (3) incised surface channels with varied widths, depths, and sinuosity characteristics (~95%).

Within these classes, sinuous rille morphology varies widely. Sinuosity of incised sinuous rilles ranges from 1.03, with minimal sinuosity, to 2.09, where the true length of the channel is twice the straight length of the channel (Fig. 1). Another characteristic of sinuous rille morphology, the meander curvature, ranges from smooth, arcuate curves to sharp, jagged curves. The cause for these observed morphologic variations remains unconstrained. For example, lava that flowed over a poorly consolidated substrate may have produced a channel with a distinct morphology from lava that flowed over a rigid substrate (e.g., [7]).

In this study, we used SELENE/Kaguya Terrain Camera (TC) mosaics and Lunar Reconnaissance Orbiter (LRO) Narrow Angle Camera (NAC) images to measure sinuosity wavelength and amplitude and meander curvature along the lengths of two sinuous rilles, a very sinuous rille north of Rima Seuss in Oceanus Procellarum (Fig. 1b) and Hadley Rille (Fig. 2). Additionally, LRO Miniature Radio Frequency (Mini-RF) radar data and Diviner rock abundance data [8] were used to characterize the near surface cohesion surrounding these sinuous rilles to constrain how surface properties influenced the morphology of lunar sinuous rilles. Constraining the factors that influence channel morphology improves our understanding of how sinuous rilles formed, when they formed relative to the surrounding mare basalts, and what implications their formation have for the intensity and duration of volcanic activity throughout the history of the Moon.

Methodology: To characterize the morphology of two case study lunar sinuous rilles (Fig. 1b, 2), we measured the channel width, depth, sinuosity wavelength, sinuosity amplitude, and meander curvature along the length of each feature using a well defined methodology as described in [6]. We measured channel width by documenting the distance between the crests of sinuous rille walls, and we measured channel depth by taking the difference between the average elevation of opposing wall crests

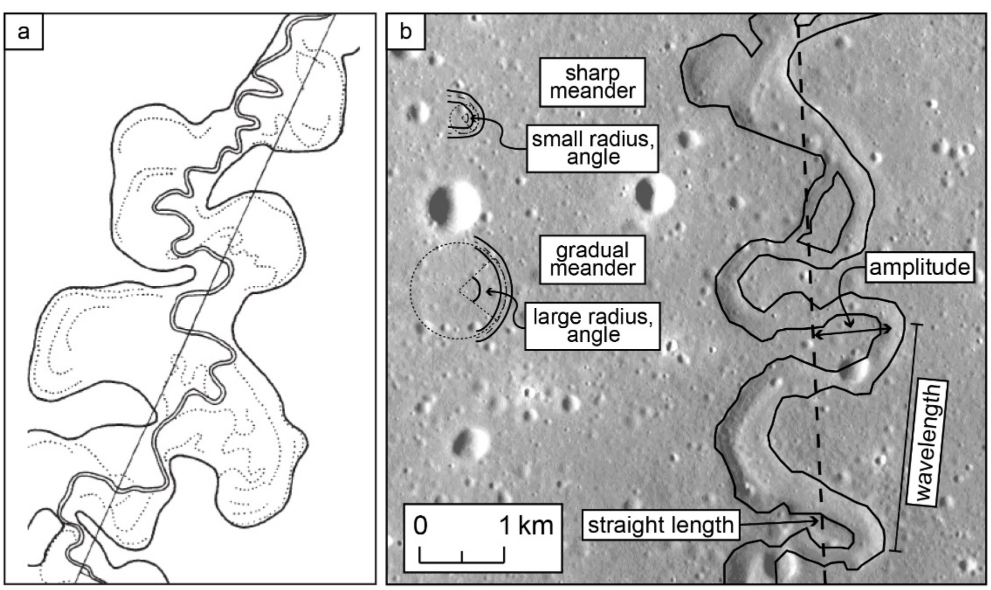

Figure 1: Two key properties of sinuous rille morphology include sinuosity, a ratio of actual channel length to straight channel length (central line), and meander curvature, the angle between points where the channel deviates from an idealized circle of radius *r* (e.g., [9]). For reference, (a) Earth's Murrumbidgee River has a sinuosity of 2.1 (from [10]), and (b) the very sinuous channel north of the Moon's Rima Seuss has an average sinuosity of 1.7.

and the elevation of the lowest point in the rille at that location, as detected by Lunar Orbiter Laser Altimeter (LOLA). To note variations in sinuosity, we measured the wavelength and amplitude of each meander, and we characterized the curvature of meanders (Fig. 1). To document wavelength, we measured the distance between meander apices on one side of the channel, and to document amplitude, we measured the distance between the meander apex and the straight-length line (e.g., Fig. 1). We defined meander curvature as the angle between the points where the channel deviates from an idealized circle of radius *r* fit to the meander (Fig. 1, e.g., [9]). A large *r* and angle notes a gradual meander, whereas a small *r* and angle notes a sharp meander (Fig. 1). These parameters were measured at several points along the length of each sinuous rille to characterize any variations in channel morphology.

In addition to channel morphology, we also characterized the surrounding substrate to identify whether surface properties affected the formation and final morphology of sinuous rilles. In particular, we mapped topographic obstructions and substrate structures, and we characterized the cohesion of ejecta surrounding young craters to determine how rigid or friable the surrounding substrate was at the time of sinuous rille formation. Rocky ejecta is interpreted to be indicative of a rigid substrate (e.g., basalt), whereas friable ejecta is interpreted to be indicative of a poorly consolidated substrate (e.g., regolith). Observed channel morphologies were then correlated with observed substrate properties to identify trends between channel morphology and substrate characteristics.

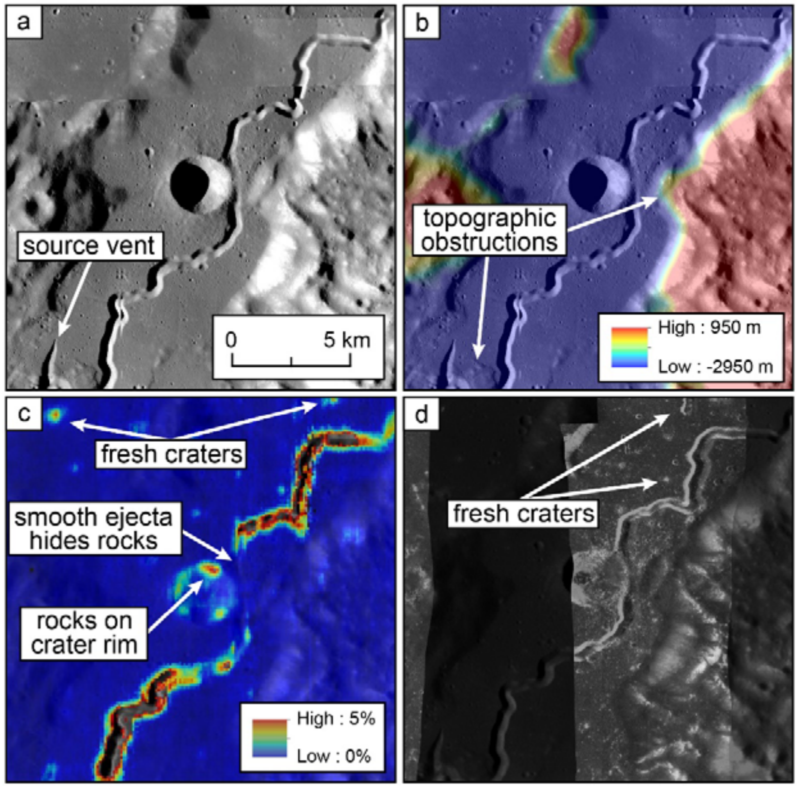

Figure 2: Hadley Rille shown with (a) Kaguya TC image data, (b) LOLA topography data, (c) Diviner rock abundance data, and (d) Mini-RF 12.6 cm radar data. These datasets are used to characterize surface and substrate properties that may have influenced the formation of this sinuous rille. Topographic obstructions affected lava flow direction, as expected, and further analyses of Diviner and Mini-RF data will determine if surface cohesion influenced channel formation.

Initial Results and Conclusions: Observations of the sinuous rille north of Rima Seuss (Fig. 1b) indicate a feature with unique morphology on the Moon, with significant sinuosity and looping meanders that produced oxbow cutoffs. Downstream, after an abrupt change in orientation from north to east, this rille maintains a significant, though less substantial sinuosity, and channel width and depth decrease with distance from the source. In contrast, Hadley Rille (Fig. 2) has a constant sinuosity more typical of lunar sinuous rilles, and a constant width and decreasing depth as distance from the source increases. Fresh craters near Hadley Rille indicate higher concentrations of rocks, suggesting a rigid basaltic substrate was present during channel formation. This is consistent with rille formation during or just after the emplacement of the surrounding mare. Further analyses will determine whether a similar scenario occurred with the formation of the rille north of Rima Seuss or if, alternatively, time elapsed between mare emplacement and rille formation, allowing a more sinuous channel to form in a more developed, poorly consolidated regolith.

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