Investigating the Morphology of a Lunar Sinuous Rille with Remote Sensing and Terrestrial Analogs. O. Ro Hon[1], L. M. Carter[1], and S. S. Sutton[1], [1]University of Arizona, Lunar and Planetary Laboratory, 1629 E University Blvd, Tucson, AZ 85721, USA (ohon@arizona.edu).

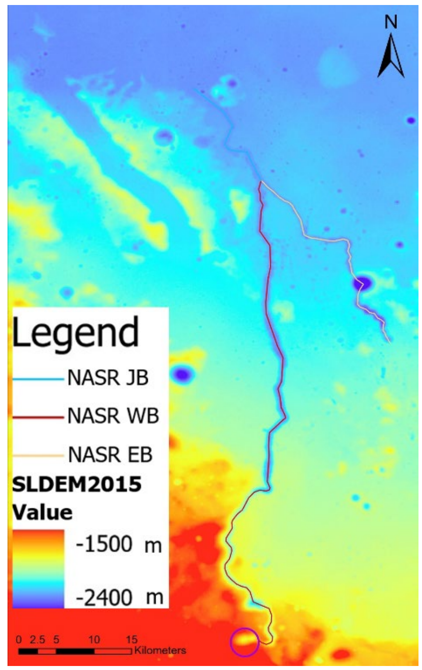
Introduction: Volcanic features on the Moon reveal important information about the evolution of the lunar surface and interior. Lunar sinuous rilles are large winding cuts in the lunar surface, found both in the mare and highlands [1]. These rilles have been proposed to be lava transport systems, similar to, but much larger than, terrestrial lava channels and/or tubes [2]. Further evidence of their volcanic origin is that sinuous rilles can possess features reminiscent of their terrestrial volcanic analogs [2].

The study of rilles and related flows in volcanically complex areas, such as the Aristarchus Plateau, on the Moon are complicated to varying degrees by bombardment, local tectonism, and deposition. The sinuous rilles in the Aristarchus region have been significantly altered since their formation by physical weathering processes. The original morphology has been modified by processes such as impact cratering and the development of wrinkle ridges and fractures. Primary volcanic surfaces have also been obscured by blankets of impact ejecta and thick pyroclastic deposits, which may be related to sinuous rille formation [3 & 4].

This investigation explores the volcanic history of a complex rille system composed of two branches that join toward the rille's northern end, within the northern Aristarchus region. One of the rille's branches crosses steep terrain on the plateau margin and merges into surrounding, relatively flat, mare to the north. The large differences in slope appear to have created several significantly different flow regimes relating to the Northern Aristarchus Sinuous Rille (NASR).

Methodology: A combination of remote sensing datasets was used in ArcGIS to investigate the morphology of the NASR and the surrounding lunar surface. Data within these areas were selected at the highest possible resolution available for each data set. Optical imagery of the rille and surrounding lunar surface was provided by the Lunar Reconnaissance Orbiter Camera (LROC), including the Wide-Angle Camera (WAC) and Narrow-Angle Camera (NAC). These datasets were used to investigate the surface features around the NASR and surrounding mare. The NAC provided the highest resolution imagery of the surface, however, drastically different sun inclinations for the swaths that comprise the rille area make exact feature determination difficult. The topographic data used for the morphology investigation of this work was primarily the high-resolution lunar topography SLDEM2015 [5].

Preliminary Findings: The NASR system is located northeast of the northernmost edge of the Aristarchus Plateau and runs in a roughly north-south direction. The southern portion of the NASR consists of two different branches, the Western Branch (WB) and Eastern Branch (EB). These join and form a single rille, the Joint Branch (JB), towards the NASR's northern end before it merges and disappears into the mare in the basin to the north.



<u>Figure 1</u>: The NASR is displayed on the SLDEM2015 map [5] with lines drawn in ArcGIS indicating its branches. The purple circle indicates the source depression of the EB

The east and west branches of the NASR have some stark differences in their southernmost visible ends. The WB's southernmost point lies on the Aristarchus Plateau at roughly -1500 m, making it the highest elevation of the whole NASR. This end of the WB is notably marked by an elongated (oval-shaped) depression, which would classify it as a source depression [1 & 2]. These factors strongly indicate this is the origin of the NASR's WB, however, its EB does not appear to have such an obvious point of origin.

The visible portion of the EB appears shorter than its western counterpart and it disappears abruptly without any morphological indicators of a source. This could be because its source was covered by later lava flows, or it could continue in a southward direction as a lava tube instead of an exposed channel. Besides its shorter length, the EB is found only on the shallow-sloping lower elevations unlike the WB, which drops precipitously off the Aristarchus Plateau before merging with the EB to form the JB.

Origin of the NASR. The presence of the source depression at the southern end of the WB suggests that this is its point of origin. The placement of this source depression, and a portion of its channel, on the

Aristarchus Plateau further supports this idea because of its high elevation. There is a ~ 600 m elevation change from this point to the maria that contains the rest of the NASR (Fig. 2) and lava flows/channels could not flow upslope to this degree. Further support for a southern origin for the entire NASR comes from its general north-to-south decrease in elevation. The northernmost visible end of the NASR lies at its lowest elevation, and since the Aristarchus Plateau was thought to have been uplifted before the surrounding mare (that most of the NASR lies in) formed, it is unlikely there have been tectonic shifts that would cause the mare containing the NASR to invert its elevation since then [3]. Therefore, the NASR is composed of two rilles that most likely originated from different places and joined together downstream to create the JB until that terminated in the northern mare basin.

Future/Continuing Work: Cross-sectional topographic profiles will be extracted along the length of the rille. Changes in rille morphology along its length can be used to investigate possible changes in flow regimes. This increased detail will provide data that can be used in geologic interpretation and comparisons to terrestrial analogs.

Analog work. The exact mechanisms of sinuous rille formation are not well constrained and terrestrial analogs provide a way to understand how rille features may be related to specific volcanic processes acting during formation. Lava channels and a lava tube generated by Hawaiian volcanism were chosen as the terrestrial analogs for the NASR because of general and specific similarities to features observed along the NASR and because of the depth of knowledge known about their formation.

Kazumura Lava Tube. A profile of the WB shows that, as it travels down the side of the Aristarchus Plateau, there are a series of sharp drops each with a depression at its base that then slopes uphill until the next drop. These features bear resemblance to the cascades and plunge pools observed in Kazumura Lava Tube (located on Kīlauea volcano, HI) [6]. The formation of these features in this lava tube setting could be informative about the temperature and other properties of the lava that formed the rille. With the topographic profiles of the sinuous rille, it may be possible to identify further similar features and explore the formation mechanisms associated with those and how they could be applied to the lunar environment.

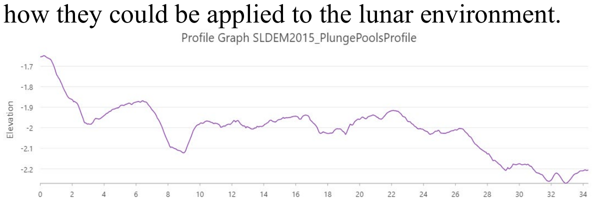


Figure 2: profile (in km) along the WB of the NASR from its source depression (at 0 km) and off the Aristarchus Plateau shows possible Cascades and Plunge Pools. The second possible plunge pool evens out at ~10 km from the source depression where the WB has crossed the steepest portion of the Aristarchus Plateau. From ~10 km onward the rille is on/ following the edge of the plateau and decreases more gradually until it is totally off the plateau (at ~32 km).

2018 Kīlauea eruption- Fissure 8 channel. The fissure 8 lava flows and channel created by the 2018 Kīlauea eruption is a good example of the formation of a large terrestrial lava channel that has been well documented. The same profile technique will be used on a DEM of this lava channel [7] to compare the changes in the structure, size, and shape to those observed to occur throughout the NASR.

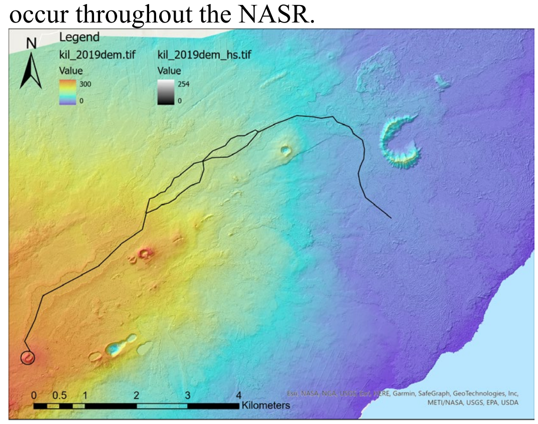


Figure 3: The DEM and Hillshade [7] of the fissure 8 lava flow show its vent (circled), along its channel (the black line), to its end as the lava flows have spread along the coast.

The end of this channel (Fig.3) also bears resemblance to the northern distal end of the NASR where it merges and disappears into the mare lava flows (Fig.1). The Kīlauea channel ends where lava spread across the flat coastal plain, causing the channel to shallow and disappear into an inflated sheet flow. The northern end of the NASR system originating from the Aristarchus Plateau also appears to shallow and merge in a similar fashion with mare basalts in the basin suggesting a similar process.

Flow regimes responsible for the features seem to change from turbulent and erosive on the steep descent from the plateau, to laminar and meandering on the lower flanks, and finally to broad shallow channels that may merge into inflationary sheets at the edge of the basin.

Acknowledgments: The topographic profile code being used in continuing work was created and provided by Dr. Sarah Sutton.

References: [1] Hurwitz D. M. et al. (2013) *Planetary & Space Sci.*, *79-80*, 1-38. [2] Hurwitz D. M. et al. (2012) *JGR, 117,* E00H14. [3] Campbell B. A. et al. (2008) *Geology, 36(2),* 135-138. [4] Trang D. et al. (2017) *Icarus, 283,* 232-253. [5] Barker M. K. et al. (2015) *Icarus, 273*, 346-355. [6] Allred K. & Allred C. (1997) *Journal of Cave and Karst Studies, 59(2),* 67-80. [7] Mosbrucker A. R. et al. (2020) *USGS.*