EMPLACEMENT SCENARIOS FOR VALLIS SCHRÖTERI, ARISTARCHUS PLATEAU, THE MOON.

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Introduction: Vallis Schröteri, the largest rille on the Moon [1], displays a complex morphology and superposition relationships that cannot be explained by a single emplacement process. Understanding the formation of Vallis Schröteri is important to understanding the volcanic evolution of Aristarchus Plateau. Using data from past missions to the Moon, including Lunar Orbiter (LO), Apollo, and Clementine, we present emplacement scenarios based on terrestrial analogues to account for the morphologic relationships observed between the primary rille, inner-rille, and cobra-head. Future missions, such as Lunar Reconnaissance Orbiter (LRO), will provide detailed, comprehensive data sets that can be used to address questions about the formation of Vallis Schröteri.

Background and Previous Work: Aristarchus Plateau is a topographic high on the nearside of the Moon, west of Mare Imbrium [Fig. 1a]. The plateau rises ~2 km above the surrounding maria and slopes to the west [2]. A dense concentration of rilles and impact craters are embayed by lavas from Oceanus Procellarum [Fig. 1b]. The complex stratigraphy is comprised of volcanic and impact related deposits [2-5]. Highland material, exposed at the head of Vallis Schröteri and in Crater Aristarchus, is overlain by basaltic material cropping out in the upper walls of the craters and rilles on the plateau, and both units are mantled by iron-rich pyroclastics [4,6]. Vallis Schröteri originates towards the central part of the plateau and forms an arched channel flowing west towards Oceanus Procellarum [Fig. 1b].

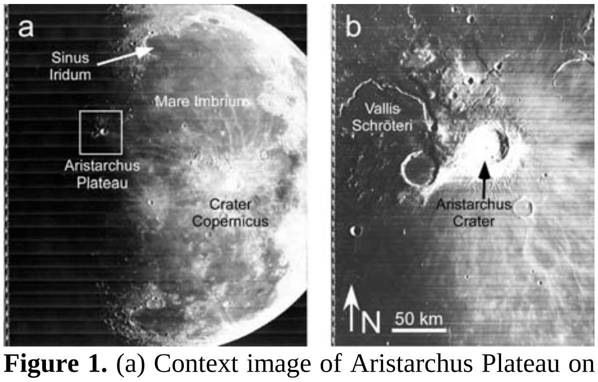

Figure 1. (a) Context image of Aristarchus Plateau on the lunar nearside. White box outlines the field of view in Fig. 1b. Lunar Orbiter image IV-138-M. (b) Vallis Schröteri, ~125 km long, begins at the central part of Aristarchus Plateau and extends to the west towards Oceanus Procellarum. Lunar Orbiter image IV-150-H3.

Rille Morphology: Vallis Schröteri has three main features: the primary rille, a sinuous inner-rille, and a mound of material surrounding the source vent (referred to hereafter as the cobra-head) [Fig. 2].

Primary Rille. The primary rille is 125-km long and up to 4.5 km wide and 400 m deep [7]. Morphologic observations of the rille include: 1) a broad, flat floor [Fig. 2c], 2) outcrops exposed in the upper section of rille walls [Fig. 2c] [7], and 3) an enclosing scarp at the distal end [Fig. 2d].

Inner-rille. The inner-rille originates at the cobra-head [Fig. 2b], is ~170-km-long, and has an average width of 640 m and depth of 95 m [8]. The inner-rille has very sinuous, gooseneck meanders [Fig. 2c]. Additionally, the inner-rille cross-cuts the distal wall of the primary rille and extends for another 40 km [Fig. 2d].

Cobra-head. A topographic mound, ~1000 m in relief above the margin of the primary rille [9], surrounds the circular source vent of the rille [Fig. 2b]. The basal dimension of the mound is ~ 35 x 55 km [9]. The cobra-head might be contaminated by ejecta from Aristarchus crater.

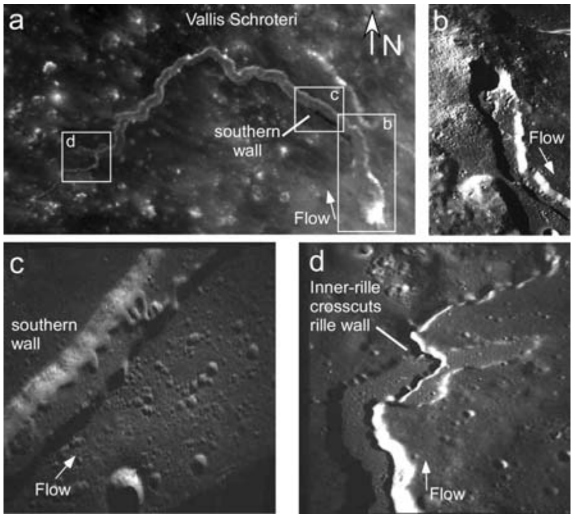

Figure 2. (a) Clementine albedo image of Vallis Schröteri. White boxes outline Figs. 2b, 2c, and 2d. (b) The 'cobra head'. AS15-0332. (c) Outcrops exposed in the upper portion of the southern wall. The primary rille has a flat floor with a sinuous inner-rille. AS15-95-12968. (d) Inner-rille crosscuts the wall of the primary rille. AS15-92-12509.

Discussion: The complex relationship between the morphologic elements of Vallis Schröteri can be explained through a combination of emplacement processes. The difficulty lies in arranging these processes into a viable sequence of events that result in the final observed morphology. Here, we discuss emplacement processes that could explain key observations about the primary rille, inner-rille, and cobra-head morphologies.

How was the primary rille established? Establishment of the primary rille might have resulted from 1) a preferred pathway formed within a sheet flow on the surface of the plateau or 2) lava confined to fractures or valleys in pre-existing topography [7]. Furthermore, emplacement of lava over a loosely consolidated regolith could have facilitated the formation of a channel [8].

How did the primary rille achieve the observed depth? Lava within an established channel could have thermally and mechanically eroded through the substrate material [8,10]. The depth might have been achieved from constructional processes, including lava overflowing the top of the rille [6,10], combined with thermal and mechanical erosion processes. Outcrops in the rille walls could be the result of overflow from the rille or relatively older lava flows that have been eroded through. The true depth of the primary rille might be obscured by material solidified within the channel.

Why does the primary rille have a flat floor? Some lunar rilles display a U- or V-shaped profile. Here, a flat floor is observed. We interpret the flat floor to have formed by a late-stage lava flow solidifying within the primary rille or a flow reoccupied the rille. This could be the natural shape of the floor.

Why is the distal margin an enclosing scarp? Curiously, the distal end of the primary rille does not grade out evenly into the plateau or Oceanus Procellarum. Instead, a scarp defines the terminus of the rille [Fig. 2d]. We suggest the flow had established a channel for at least 125 km of the flow length, but then had a non-channeled, dispersed zone of lava that extended beyond the channel. This is similar to morphologic observations of the 1907 and 1984 flows on Mauna Loa volcano, Hawaii [11, 12]. If lava from the primary rille is diverted towards Oceanus Procellarum via the inner-rille, then as lava drains from the channel and not the dispersed zone, a scarp could form.

Was the primary rille a lava tube or a channel? A lava tube scenario would require a significantly strong roof to connect sides of the rilles, quantitative parameters which we do not calculate or present here. Insulation of the lava is necessary for the flow to retain heat if thermal and mechanical erosion of the substrate did occur. The width of the rille suggests it was most-likely a channel with a significant amount of surface crust covering and insulating the flow, but no single piece connecting across the rille to form a roof.

What is the origin of the inner-rille? The flow in which the inner-rille is located was either: 1) the last remnants of the lava flows that formed the primary rille or 2) a flow that reoccupied the primary rille after a hiatus or pause in the eruption and solidified forming a flat floor and obscuring the original primary rille floor.

How did the sinuous gooseneck morphology form? The morphology of the inner-rille resembles fluvial river channels [7]. The tight bends would be difficult to form without: 1) a low viscosity lava [13], 2) establishment of a preferred path, but with easily modified margins, and 3) mechanical and thermal erosion. Lunar flows are typically 1 to 15 m thick [14]. Based on the depth of the inner-rille, this suggests a channel formed within a flow that was thickened due to confinement by the primary rille walls or a thin lava flow eroded the underlying material [8].

How did the inner-rille cross-cut the primary rille? A point of weakness in the primary rille was exploited by the inner-rille flow. The cross-cut could have formed by: 1) overflow and branching of lava at the distal end of the primary rille that lead to thermal and mechanical erosion of the wall, 2) a lava tube or channel branching from the primary rille, or 3) diversion of lava through a fault or fracture in the wall. Exactly which scenario is most plausible will require higher resolution data from LRO.

How did the cobra-head mound originate? A volcanic deposit from a fire fountain event of volatile-rich magma as it reached the lunar surface is a likely explanation for the formation of the cobra-head. We envision this process to be analogous to events and morphologies observed at Pu'u O'o and Pu'u Pua'i on Kilauea volcano, Hawai'i [15]. Mounds with similar morphologies and associated rille-like channels are observed on the Galapagos volcanoes [16, 17].

Summary: Various emplacement processes for terrestrial volcanic features are used to explain morphologic relationships observed at Vallis Schröteri. LRO will provide comprehensive data sets that can be used to test scenarios we have discussed here.

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