MODE OF EMPLACEMENT OF VALLIS SCHRÖTERI AND THE HUGE PYROCLASTIC CONE SURROUNDING COBRA HEAD, ARISTARCHUS PLATEAU. Lionel Wilson[1,2], James W. Head[2], Erica R. Jawin[3], [1]Lancaster Environment Centre, Lancaster University, Lancaster LA1 4YQ UK; [2]Department of Earth, Environmental, and Planetary Sciences, Brown University, Providence, RI 02912 USA; [3]Smithsonian Institution, Washington D.C. (l.wilson@lancaster.ac.uk)

Introduction: The Aristarchus plateau is the site of sinuous rilles and extensive mantling by fine-grained, low-albedo pyroclastic material [*1-5*], apparently dominated by low-titanium glass beads [*5–7*] forming a deposit ~10-20 m thick [*8*]. The most prominent features on the Aristarchus plateau include several major volcanic features: Cobra Head; the primary sinuous rille (Vallis Schröteri); a smaller, nested inner rille; and a chain of cone-like mounds that extend from Cobra Head south toward Herodotus crater (Figure 1).

Cobra Head is the point of origin of both sinuous rilles, giving the entire feature a serpentine appearance. The rilles are sinuous in nature and extend northwest and then southwest toward Oceanus Procellarum at the western edge of the Aristarchus Plateau [*11*]. Cobra Head itself is an elongate depression on the north flank of a local topographic high, an asymmetric cone-like feature with flank slopes of 1-2° and an irregular, hummocky texture on the scale of tens of meters [*12*]. This mound is ~1600 m high and is one of a chain of at least three such features that extend for ~40 km and are 15-30 km wide (Fig. 1). The cones appear to be genetically related to Cobra Head on the basis of stratigraphy and were likely emplaced contemporaneously with Cobra Head.

Understanding the detailed nature of the formation of both the cone and Cobra Head, as well as the emplacement style and eruptive history of the Aristarchus Plateau as a whole, is crucial to understanding the diversity of lunar volcanism. This work provides a synthesis of the formation of Cobra Head and related features and a context in which the emplacement history of the entire Aristarchus Plateau can be placed [*11*].

Pyroclastics: The Aristarchus plateau is interpreted to contain the largest deposit of glassy, mafic pyroclastic material on the lunar surface, referred to as a dark mantle deposit (DMD) [*7*]. The larger category of DMDs, regional deposits, are generally accepted to be emplaced due to long-duration hawaiian-style fire fountain eruptions, widely dispersing pyroclasts to the surrounding region creating broad, continuous deposits [*13*, *14*]. The crystallinity of the deposit (i.e. the crystalline:glass ratio of the pyroclasts) will depend on the optical density of the eruptive fountain (Fig. 2) [*15*]; higher optical densities (found in the inner region of the fountain) cause longer clast residence times at higher temperatures, leading to a higher degree of crystallinity of the resulting pyroclasts [*5*]. Conversely, in low volume-flux eruptions, the optical density is low throughout the plume, and pyroclasts can quench rapidly. In this way, a deposit can exhibit a range of glassy and crystalline material which is diagnostic of its eruptive environment.

At Aristarchus, however, the emplacement history is less clear. The proximity of mare deposits and sinuous rilles to the pyroclastic materials could imply a shift in eruptive style from explosive to effusive; however, a continuous hawaiian-style fire fountain eruption can also explain the complex morphology of the region.

Cones: The presence of the cone-like features also implies a pyroclastic eruption. Cones have been identified elsewhere on the Moon associated with lunar maria, often interpreted as cinder and spatter cones [*16*]. These features can form in strombolian or hawaiian-style eruptions, where the final cone morphology is dependent on the characteristics of the eruption [*13*]. Cones can therefore form from small, short-lived eruptions, or in longer-duration eruptions, where initially erupted pyroclastic materials can be mantled by accumulated spatter; cones can also form in the waning stages of an eruption – as the effusion rate decreases, spatter is favored to accumulate as the dike closures.

In the case of the Aristarchus cone-like features, the linear nature of the cone chain suggests that several vents opened initially as the dike reached the surface, forming small spatter cones. As the eruption progressed, most small vents closed, and one vent (Cobra Head) persisted for the duration of the eruption. However, the largest dome continued to accumulate spatter throughout the eruption.

Model of the Eruption: We model the eruption and formation of the cones and rilles, using recent theoretical treatments. The axes of the Cobra Head source depression are 11.4 km and 18.4 km. Assuming that the depression is the consequence of thermo-mechanical erosion of the pre-existing surface by the turbulent lava in a pond accumulating from a steady hawaiian eruption producing an optically-dense fire fountain, the implication of the shape is that the vent was a fissure with an active length of ~(18.4 - 11.4 =) 7 km ejecting pyroclasts to a maximum range of (11.4 / 2 =) 5.7 km. This fissure length is of the same order as the lengths of lines of small spatter cones that mark the locations of vents feeding mare lava flows [12]. The analyses of explosive eruptions in [12] imply that, for the simplest case of a monodisperse pyroclast size distribution with no sorting of pyroclast sizes, to eject pyroclasts to a range of 5.7 km the erupting magma's released gas mass fraction would have to be 1425 ppm. From the more detailed analyses in [20], taking account of the sorting due to the polydisperse pyroclast size distribution, the implied magma gas content is 970 ppm.

The depression forming the Cobra Head source extends into the larger of the two cones to its south. Measuring far enough to the north to avoid the complications of this, the depth to which the pre-eruption surface was eroded by the lava pond is ~750 m. Estimates of likely erosion rates in rille-forming eruptions are 20 to 30 μm/s [18-19]. Dividing the depth by these rate estimates, the implied durations of erosion are therefore 1.25 to 0.83 years, i.e., 15 to 10 months. Likely magma volume eruption rates during rille-forming eruptions [17] are ~10^4 m^3 s^{-1}. Eruptions lasting 10 to 15 months should therefore discharge ~249 to 375 km^3 of magma.

The largest of the spatter cones located to the south of the Cobra Head depression is approximately circular with a radius of 12.5 km and the next-largest is elongate with long and short semi-axes of 8.5 and 5.5 km, respectively. With heights of ~1600 and ~800 m the corresponding volumes are ~260 and 24 km^3. The larger cone can be explained by a near-point-source vent eruption magma with a gas content of 2100-3100 ppm and the smaller one by a fissure vent ~6 km long erupting magma with a gas content of 930-1370 ppm. The eruptions producing these features must have had a low enough volume flux that the fire fountains were sufficiently translucent that enough heat was radiated from the pyroclasts so that they landed cool enough not to coalesce into a lava pond overflowing to form a lava flow or sinuous rille. Calculations in [17] show that this implies volume fluxes of ~3000 and ~1000 m^3 s^{-1}, respectively.

How then did the nested inner rille form inside Cobra Head (Fig. 1)? Recent work [*17*] suggests that the critical factor in forming sinuous rilles is the duration of flow. In particular, nested rilles require both long-duration eruptions and high effusion rates [*12*]. To form a nested rille, after a primary rille forms the effusion rate eventually decreases and the original lava pool drains. If the eruption continues, a new smaller lava pool will form, from which thermal erosion can carve a depression inside the preexisting rille. In this model for Aristarchus, an inner rille forms due to the evolution of the initial eruption, rather than from a completely separate eruption sourced from a dike that propagated to the same spot in Cobra Head to start a new eruption.

In this interpretation the Aristarchus DMD, cones, Cobra Head, Vallis Schröteri, and the nested rille all formed from a single, continuous eruption.

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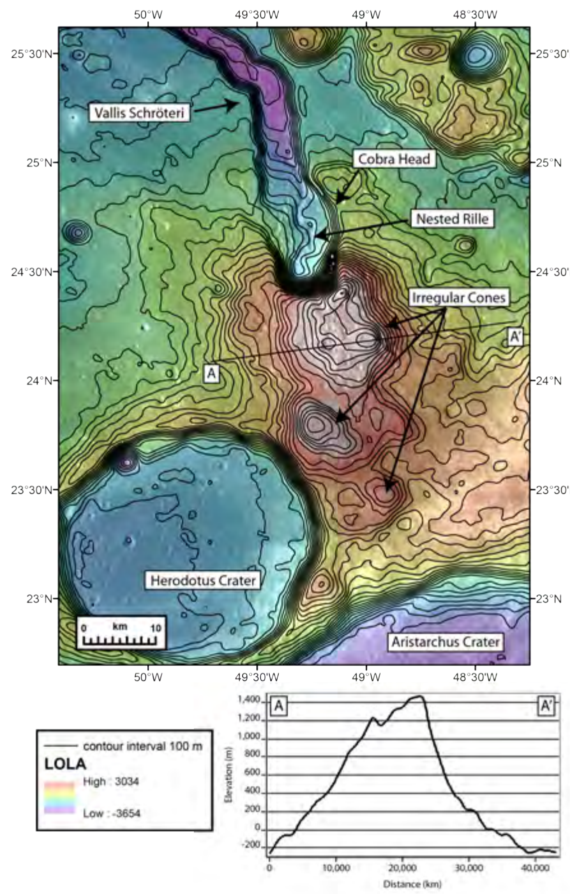

Figure 1. Vallis Schröteri, nested rille, Cobra Head, and adjacent irregular cones. Below: LOLA altimetric profile. Image contours are from a Kaguya DEM; color map is derived from LOLA data; basemap is a WAC mosaic.

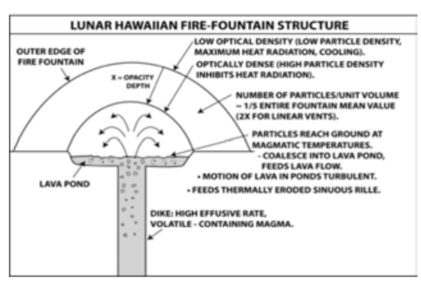

Figure 2. Schematic of fire fountain eruptive plume structure. From [12].