HUGE PYROCLASTIC CONES SURROUNDING COBRA HEAD, ARISTARCHUS PLATEAU: RELATION TO VALLIS SCHRÖTERI. Erica R. Jawin[1], James W. Head[1], and Lionel Wilson[2], [1]Department of Earth, Environmental, and Planetary Sciences, Brown University, Providence, RI 02912 USA, [2]Lancaster Environment Centre, Lancaster University, Lancaster LA1 4YQ UK (Erica_Jawin@brown.edu).

Introduction: The Aristarchus plateau is viewed as one of the most complex volcanic regions on the Moon, elevated ~2 km above the surrounding region in Oceanus Procellarum [*1*]. The extensive volcanic activity in this region is evident by the presence of sinuous rilles [*2*], mare basalt flows [*3*], and extensive mantling by fine-grained, low-albedo pyroclastic material [*1*, *3–5*], believed to be dominated by low-titanium glass beads [*5–7*] which are in a deposit ~10-20 m thick [*8*]. The most prominent features on the Aristarchus plateau include Aristarchus crater, Copernican in age [*1*, *9*] and noted for the distinct compositional units in its walls, ejecta, and central peak [*10*]; and Vallis Schröteri, the widest and deepest sinuous rille on the Moon [*2*]. The Aristarchus Plateau is composed of several major volcanological 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 and Aristarchus craters (Figure 1).

Cobra Head is so named because it is the point of origin of both sinuous rilles, giving the entire feature a serpentine appearance. The rilles emanating from Cobra Head are sinuous in nature and extend northwest and then southwest toward Oceanus Procellarum at the western edge of the Aristarchus Plateau: the primary rille is bound at its distal end by an enclosing scarp ~100-200 m high, while the nested rille crosscuts the enclosing scarp of the outer rille and grades into a mare deposit along the plateau margin [*11*]. Cobra Head itself is an elongate depression located on a local topographic maxima that appears to be 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 cone-like features that extend for ~40 km and are 15-30 km wide (Fig. 1). The cone unit appears to be genetically related to Cobra Head on the basis of stratigraphy, and was 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 context in which the emplacement history of the entire Aristarchus Plateau can be placed [*11*].

Pyroclastics: The Aristarchus plateau has been understood 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 (as opposed to smaller, localized deposits), are generally believed 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 glass:crystalline ratio of the pyroclasts) will depend on the optical density of the eruptive plume (Fig. 2) [*15*]; higher optical densities (found in the inner region of the eruptive plume) experience higher temperatures and longer residence times for

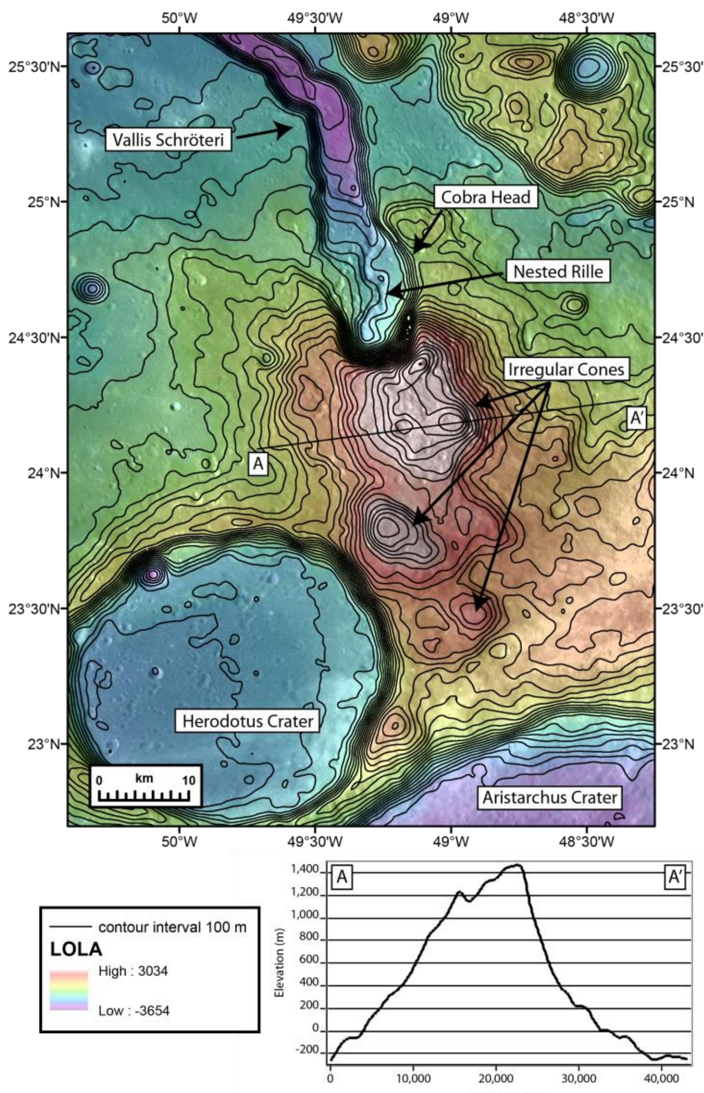

Figure 1. Vallis Schröteri, nested rille, Cobra Head, and irregular cones adjacent to Cobra Head. Below: LOLA altimetric profile. Image contours are from a Kaguya DEM; color map is derived from LOLA data; and the basemap is a WAC mosaic.

pyroclasts, leading to a higher degree of crystallinity (and a lower glass:crystalline ratio) of the resulting pyroclast [*5*]. Conversely, in smaller 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.

In Aristarchus, however, the emplacement history is less clear; the proximity of mare deposits and sinuous rilles to the pyroclastic materials could implicate 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 implicates 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 dike closure initiates.

In the case of the Aristarchus cone-like features, the linear nature of the chain of cones could suggest that as the dike propagated towards the surface, several vents formed in the initial stages of the eruption, forming small spatter cones. As the eruption progressed, the smaller vents closed and a single, central vent (Cobra Head) persisted for the duration of the eruption. The largest dome continued to accumulate spatter through the remaining duration of the eruption.

Proposed Emplacement: The optical density is variable within the eruptive plume during a pyroclastic eruption (Fig. 2); the inner, optically thick portion of the plume inhibits radiative cooling. The particles present in this portion of the plume will be erupted and land while maintaining magmatic temperatures, and can coalesce into a lava pond [*12*, *13*]. It has been shown that thermal erosion of the substrate may occur due to long-duration eruptions with high effusion rates [*13*, *17*]. Turbulent flow within this lava pond and in the lava flowing out of the pond will thermally erode a broad depression into the substrate. In the case of Aristarchus, this process acted to form Cobra Head, as well as a sinuous rille originating from the lava pond, creating Vallis Schröteri.

In the outer parts of an eruptive plume, lower optical densities lead to rapid radiative cooling and inhibited crystallization (Fig. 2) [*5*]. In the Aristarchus eruption, this quenched glassy material would have been dispersed across the plateau, creating the DMD identified in visible and spectral data [*3–5*].

In the intermediate region of the eruptive plume (between the optically dense and optically thin regions) (Fig. 2), cooler pyroclasts will form clots of material, but remain molten in their interior, as seen in terrestrial cinder cones [*12*, *15*]. In terrestrial cinder cones, clots of material can accumulate to form spatter and local vertical constructs, which form rough, irregular features. The proximity of the cone-like feature at Cobra Head suggests that it could have formed in an analogous process, through an accumulation of partially molten pyroclast clots in the transition zone of the eruptive plume [*12*].

How then did the nested inner rille form inside Cobra Head (Fig. 1)? Recent work by Wilson and Head (2015) [*17*] suggests that the critical factor in forming sinuous rilles is the duration of flow. In particular, nested rilles require both long-duration eruptions as well as high effusion rates [*12*]. To form a nested rille, after a primary rille forms the effusion rate eventually decreases and the original lava pool will drain. As the eruption continues, a new smaller lava pool will form, in 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 flow, rather than 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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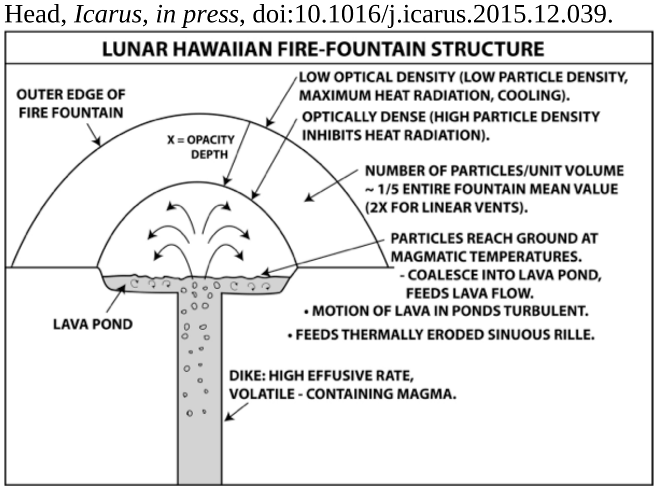

Figure 2. Schematic of fire fountain eruptive plume structure. From [12].