EROSIONAL HISTORY OF THE NORTHEASTERN FLANK OF APOLLINARIS MONS, MARS: INSIGHTS FROM HIGH-RESOLUTION MORPHOLOGY, TOPOGRAPHY AND CRATER POPULATIONS. F. C. Chuang, D. A. Crown, and D. C. Berman, Planetary Science Institute, 1700 E. Ft. Lowell Road, Suite 106, Tucson, AZ 85719 USA (chuang@psi.edu).

Introduction: Mars has an abundance of volcanic landforms that have been observed and studied during more than four decades of exploration of the Martian surface [1-4]. Comparisons within and between Martian volcanic centers have provided general constraints on the spatial variability and history of volcanism on the planet. As surface images and other datasets have improved in coverage and resolution, more details about Martian volcanism are emerging, including constraints on lava rheology, eruption conditions, and eruptive styles and magnitudes [5-10].

Apollinaris Mons (formerly Apollinaris Patera) is a ~5.4 km high and ~190 km wide volcanic edifice with a 85 km wide summit caldera complex [11]. Much of the volcano's northeast flanks appear heavily eroded with smooth deposits that slope away from the caldera. Within these smooth deposits are high-standing plateaus that likely represent remnants of the original upper or near-upper surface of the volcano. This region of Apollinaris Mons presents an opportunity to study the history of flank erosion using high-resolution datasets and to assess the styles and magnitudes of erosion, as well as implications for eruptive processes.

Background: Apollinaris Mons (center: 9.2°S, 174.8°E) is located south of the Elysium volcanic province, bordered to the north by the Medusa Fossae Formation. The southeastern flank of the volcano is comprised of a large, gently sloping apron extending 140 km from the caldera margin. The heavily eroded northern flanks show an erosional morphology grossly similar to the flanks of Tyrrhenus and Hadriacus Montes, whose radial valley systems are attributed to fluvial erosion of layered, relatively unconsolidated pyroclastic deposits [12-14].

Recent studies of Apollinaris Mons have identified it as a source of fine-grained friable deposits in nearby equatorial regions of Mars [15], a potential source for lava flows within Gusev Crater [16-17], and a potential site for hydrothermal deposits [18]. Detailed mapping of Apollinaris Mons by [19-20] suggests that ancient, large-scale explosive volcanic activity formed the main edifice and that the southeastern apron was composed of later, relatively low eruption rate lavas. After the main volcanic activity waned, the apron may have been covered by lahars due to drainage of a lake formed in the summit caldera [18].

Data and Methods: To provide context for future analysis of Apollinaris Mons flank degradation using HiRISE images and a stereo-derived DTM [21], we are currently mapping the geology of a 1° latitude x 1° longitude portion of the northeast flanks (6.9-7.9° S, 174.3-175.4° E; 4095.5 km^2) using ~5-6 m/pixel CTX images (Figure 1). For slope and topographic relief estimates of material units, we use individual MOLA PEDR tracks with ~300 m shot spacing. In addition to these analyses, we also compile crater size-frequency distributions (CSFD) for each unit and map specific erosional features such as small valleys or channels.

For mapping, topography and crater counts, we utilize both ESRI ArcGIS for Desktop 10.4 software and the CraterTools 2.1 add-on tool for ArcGIS [22]. For CSFD age estimates, we use CraterStats II software for IDL Virtual Machine [23]. Ages are based on a best fit line to crater bin size ranges that follow established isochrons using the Hartmann production and chronology functions [24]. Secondary crater chains and clusters were avoided and only craters > 175 m in diameter were counted to minimize the influence of background secondaries.

Results:

Mapping. Eight geologic units have been defined (Fig. 1): Apollinaris Mons upper flank material (*Amfu*), Apollinaris Mons mid flank material (*Amfm*), Apollinaris Mons lower flank material (*Amfl*), Medusa Fossae lower member (*Mfl*) [25], crater material (*c*), mantling material (*m*), knobby material (*k*), and plains material (*p*). Much of the eastern third of the map area (~1203 km^2, 29.4%) is covered by lobate ejecta material produced from two impact craters, each ~18 km in diameter. The central third of the map area (~1266 km^2, 30.9%) is covered primarily by *Amfl* materials. The total area of *Amfl* is much larger than the combined area of *Amfu* and *Amfm* (~1280.3 km^2 vs. ~585.1 km^2), indicating a significant portion of the original volcano surface has been modified. In the northern portion of the map area, the lower flanks of Apollinaris Mons are covered by mantling material (~364.0 km^2, 8.9%). Units *Mfl* (~161.9 km^2, 3.9%) and *p* (~142.5 km^2, 3.5%) cover the areas beyond the flanks of Apollinaris Mons.

Topography. From MOLA PEDR tracks across the study area, slopes near the summit of Apollinaris Mons (within ~13 km) are ~6°, but then decrease to ~3° along the flanks to near the base of the volcano. The exposed thickness of *Amfu* plateaus varies between the southern and northern plateau margins with ~100-150 m of relief along the south and ~300-500 m of relief along the north. When comparing units *Amfm* and

Amfl, the former is consistently higher in elevation (~10-20 m) near the contact between the two units.

Crater Counts. Age estimates from CSFDs for each unit in the study area are: *Amfu* (~3.4±0.5 Ga), *Amfm* (~1.9±0.7 Ga), and *Amfl* (~1.6±0.3 Ga). The plains age is estimated to be ~0.92±0.4 Ga, and the combined age for all crater units is ~0.86±0.2 Ga. Ages for units *Mfl*, *m*, and *k* were not estimated due to poor fits to the CSFD data or lack of craters. From previous mapping by [25], *Mfl* is estimated to be Amazonian though more specific age constraints were not available.

Discussion and Future Work: From our mapping and topographic analyses, we estimate a minimum of 100 m of material has been removed along the northeastern flanks of Apollinaris Mons in most places, which have been potentially re-distributed downslope beyond the flanks of the volcano. We interpret *Amfu* plateau materials, ~3.4 Ga from CSFD data, to be relatively stable remnants of the original volcano surface that have not been significantly modified. Erosion of the northeastern flanks (represented by *Amfu* materials) waned at ~1.9-1.6 Ga, resulting in the current erosional surface units *Amfm* and *Amfl*.

From the relief along the distal (i.e., northern) margins *of Amfu* plateaus, erosion appears to be greater north of these features. However, the relief may be overestimated due to MOLA tracks crossing local low points (e.g., troughs). Future work using more MOLA tracks, gridded data, and a HiRISE DTM will be done to better constrain the amount of eroded Apollinaris Mons material. Eroded *Amfu* materials may have been deposited downslope beyond the margins of the volcano up until ~0.92 Ga (plains age), as well as in areas now covered by units *Mfl* and *m*.

Results from this work will provide context for detailed analyses of Apollinaris Mons sequence units using HiRISE data. The HiRISE data will allow for more detailed slope measurements, detection of layers, and observation of fine-scale erosional features along *Amfu* plateau walls. This information will provide greater insight into the formation and erosional history of the volcano.

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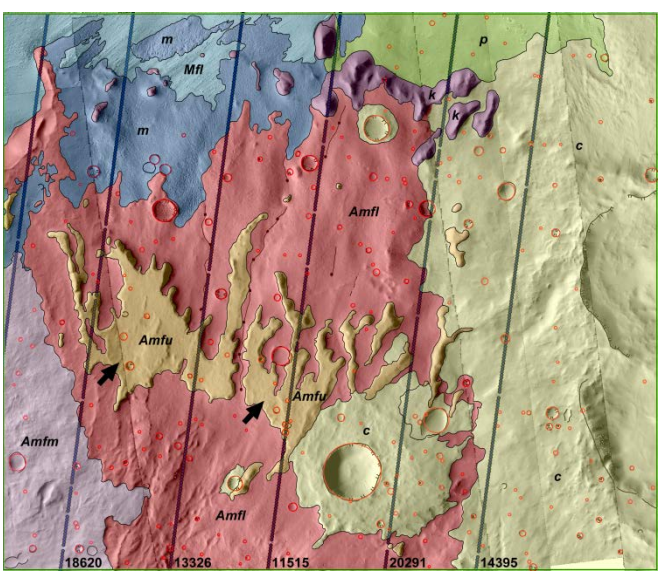

Figure 1. Preliminary geologic map of the northeastern portion of Apollinaris Mons between 6.9-7.9°S and 174.3-175.4°E. Eight material units have been defined: Apollinaris Mons upper flank materials (*Amfu*, orange), Apollinaris Mons mid flank materials (*Amfm*, pink), Apollinaris Mons lower flank materials (*Amfl*, red), Medusa Fossae lower member (*Mfl*, light blue), crater materials (*c*, yellow), mantling materials (*m*, dark blue), knobby materials (*k*, purple), and plains materials (*p*, green). MOLA PEDR tracks (NE-SW dotted lines) 18620, 13326, and 11515 across the study area show that the exposed thickness of *Amfu* plateaus (black arrows) along their southern margins are minimally ~100 m and up to ~300-500 m along their northern margins. Impact craters down to 175 m in diameter (red circles) were counted on all units for age estimates. Basemap consists of a mosaic of ~5-6 m/pixel CTX images. North is up and sun illumination is from the lower left.