MODELING ASH DISPERSAL FROM APOLLINARIS PATERA: IMPLICATIONS FOR THE MEDUSAE FOSSAE FORMATION.

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Introduction: Apollinaris Patera (-8ºS, 174ºE), **(Figure 1)**, is a medium-sized Hesperian volcano located in a unique position near the dichotomy boundary. It is also surrounded by the enigmatic Medusae Fossae Formation (MFF) and is just north of the MER Spirit landing site. It is presumed to be composed of pyroclastic materials [1]; no large lava or pyroclastic flows are visible.

The MFF is made of fine-grained, friable deposits and has been interpreted as volcanic ash from Tharsis [2], ancient erosional debris [3], and paleo-polar deposits [4]. While the formation has been mapped as Amazonian [5,6], it has been extensively reworked by aeolian processes, which may mean that the deposits are significantly older than they appear [7,8]. Recent MARSIS results [9] indicate that the formation overlies northern plains material and has a real dialectric constant of ~2.9 ± 0.4, which is consistent with a substantial ice component, but which would require a more significant contribution from non-ice particles than the northern polar deposits.

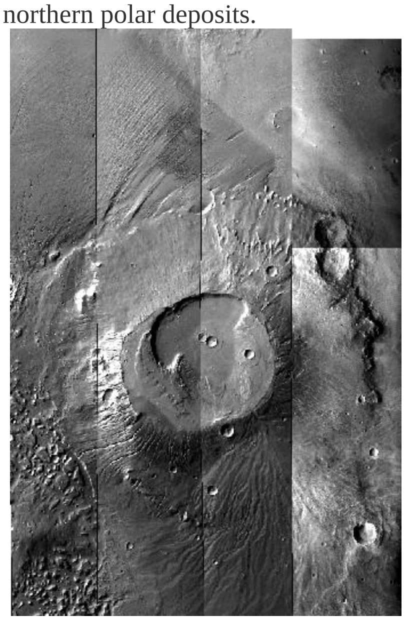

Figure 1. HRSC images of Apollinaris Patera (-8ºS, 174ºE). The deposit northwest of the volcano is part of the Medusae Fossae Formation and is heavily modified by the wind into yardangs and undulating dunes.

The presence of pedestal-like craters may also suggest a component of ice [4,10], but their unique shapes and likely wind-dominated modification separate them from normal pedestal craters at higher latitudes whose formation is dominated by sublimation [11-13].

Given that explosive volcanic eruptions are excellent sources of both fine-grained debris and volatiles, we test the hypothesis that at least part of the MFF could be composed of ashfall erupted from Apollinaris Patera.

Volcanic Modeling: This work integrates a model of a plinian eruption under Mars atmospheric conditions [14] and a Mars Global Circulation Model (GCM) [15] in order to model the dispersion of ash according to present-day wind patterns. The integration of the two models has been done in several steps: first an inertial plume was assumed, and small clasts of different sizes (0.03 mm, 0.02 mm) were introduced into the atmosphere at a height of ~51 km with a constant assumed flux, from which they could fall to the surface through the wind profile. This approach approximates the case of a large and powerful volcanic eruption in which the behavior of the plume is umbrella-shaped, a process described by [14]. In this case, the rising plume would have little interaction with the atmosphere and clasts would enter the atmosphere from the top. In the second step, a lower flux, convecting plume is assumed [14], in which case the plume begins entraining air and buoyantly rises until the atmosphere becomes too thin to continue sufficient entrainment.

The particle size distribution was estimated by using the Askja 1875 eruption size distribution and scaling it to the expected size range on Mars [14]. The GCM provides pressure, temperature, and wind profile information to the volcanic model, which returns the height at which particles of each size fall out of the plume and their flux. In the next step, the appropriate mixing ratio of atmosphere and clasts falling out of the column is calculated by comparing the density of the surrounding atmosphere and the velocity of the wind versus the mass flux of particles out of the plume. A vent radius of 200 m is assumed, with an exit speed of 300 m/s and an average magma temperature of 1500 K. An average ash particle density is assumed here to be 700 kg/m^3. In this simulation, the extent of ash dispersal may be compared to the extent of the Medusae Fossae Formation to test the ashfall hypothesis.

Results: With current parameters, Apollinaris Patera is a plausible candidate for the formation of at least part of the MFF. While most large particles fall close to the volcano, sub-millimeter particles can travel a significant distance from the vent, due to their small mass and high release height from the plume. Simulation results are shown for 0.03mm particles **(Figure 2)**, and 0.02 mm particles **(Figure 3)** for a convecting plume. The proximal MFF deposits appear to be in the range of fine-grained ash fall from the volcano, and higher air pressures in the past could have contributed to an even wider dispersal range. The model runs simulated a volcanic eruption with a duration of three days; a periodic or sustained eruption of Apollinaris would thicken the deposits and possibly create layers but likely not affect the overall grain-size distribution.

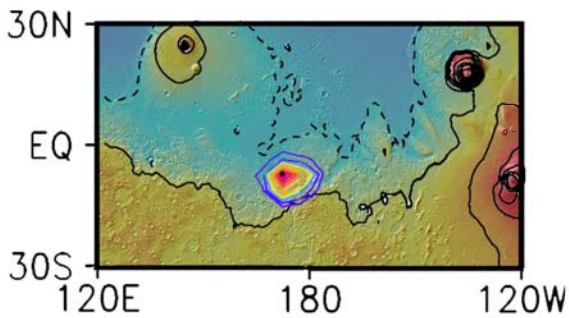

Figure 2. Dispersal of 0.03 mm particles at Ls=0. As expected, larger particles settle closer to the vent (indicated by black dot). Eruption is three days in duration.

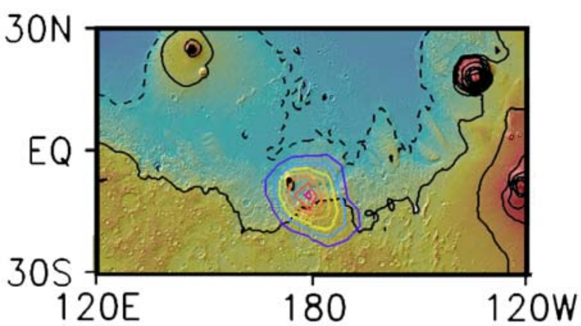

Figure 3. Dispersal of 0.02 mm particles at Ls=0. The highest accumulation in this case is southeast of the volcano. This size particle is among the smallest expected to be dispersed on Mars, given theoretical predictions of likely bubble sizes [14].

Implications: The extent of the deposit and its distribution depends on which clast size is examined, as well as what time of year the eruption takes place and whether the plume is assumed to be inertial or convecting. Obliquity variations and differences in atmospheric pressure that may have existed in the Hesperian are also contributing factors that could affect the distribution. These simulations are consistent with the dispersal of tephra from Apollinaris into surrounding regions and suggest that fine-grained tephra from martian edifices could be a major part of the deposits that mantle the subjacent terrain (e.g. the MFF and regional mantling units in Arabia).

Furthermore, in the work of Durant and Rose [16] on volcanically-formed hydrometeors, it is shown that ash particles serve as nuclei for ice particle formation. The term hydrometeor includes any combination of liquid or solid water particles that are precipitated by the atmosphere or blown about by the wind. Slushy hydrometeors may aggregate and fall to the surface earlier than individual particles [16], but not as soon as accretionary lapilli [14]. On the Earth, the ice crystals may melt or sublime before reaching the surface [16]. Thus depending on the temperature and pressure in the atmosphere, the ash deposit may fall wet or dry. Extremely cold temperatures in the martian atmosphere make ice particle formation possible despite low pressures. The formation of ice crystals in a volcanic cloud on Mars would be further facilitated by the use of ash as nucleation sites and an increase in atmospheric vapor pressure due to volatiles released from the volcano. The local increase in temperature from the volcano itself would tend to increase sublimation rates, but cooling induced from the relationship between the plume cloud and incoming solar radiation would lead to a decrease in temperature and a decrease in sublimation rates regionally. Possibly higher atmospheric pressures in the past would lead to even more favorable stability regimes for falling ice-covered ash. These falling hydrometeors would not likely be stable on the ground for long periods of time if exposed to direct solar radiation [17], but in a volcanic eruption with a high flux of particles, hydrometeors that reached the ground without evaporating or subliming would be quickly buried by more ash, protecting them from subsequent changes in stability regimes on the martian surface. Such deposits might help to explain the unusual character of mantle deposits such as those in Arabia Terra (e.g. [18])

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