

EVIDENCE OF LAVA FLOW INFLATION NEAR HRAD VALLIS, MARS. C. W. Hamilton¹, P. J. Mouginis-Mark², M. M. Sori¹, S. P. Scheidt¹, and A. M. Bramson¹, ¹Lunar and Planetary Laboratory, University of Arizona, 1629 E. University Blvd., Tucson, AZ 85721 USA (hamilton@lpl.arizona.edu), ²Hawaii Institute of Geophysics and Planetology, University of Hawaii, 1680 East-West Rd., Honolulu, HI 96822 USA.

Introduction: Aqueous flooding events appear to have occurred episodically on Mars throughout the Amazonian Period, particularly in association with outflow channels in the Elysium Volcanic Province [e.g., 1–9]. However, geologic interpretations of outflow channel formation in volcanic terrains are complicated by the potential involvement of both aqueous floods and lava flows. For instance, Hrad Vallis (Fig. 1) may have been associated with catastrophic aqueous floods and effusive volcanism [10–20], which makes determining its origin and evolution important for constraining the planet’s hydrological and thermal evolution of Mars during the geologically recent past.

Methods: We employ a two-part approach involving: (1) geologic mapping and geomorphology, and (2) thermophysical modeling. In Part 1, we develop geologic maps of Hrad Vallis and its surroundings to identify and characterize major geologic units. In Part 2, we apply thermophysical models to test the hypothesis that the smooth plains (Aps) and lobate (Apf) units (Fig. 1) are associated with former aqueous flood deposits. Parts 1 and 2 are then reconciled to determine the most plausible origin for Aps and Apf.

Results: Part 1 Results. Using ArcGIS and a regional mosaic of Mars Reconnaissance Orbiter (MRO) Context Camera (CTX) images (6 m/pixel) and High Resolution Imaging Science Experiment (HiRISE) images (0.3 m/pixel), we mapped the source region of Hrad Vallis at a digitizing scale of 1:40,000. The map supports previous results [7, 11, 12, 15, 19] for rugged (Aelc), plains-forming (Ael), ridge (Aelr), concentric ridge and trough (Aelt), flood plain (Achp), channel (Ach), and fresh crater (Ac) material. However, our results differ for the smooth plains (Aps), linear ridge (Alr), crenulated (Acr), lobate (Apf), and chaotic (Achc) materials. Here, we focus on the characteristics of units Aps, Alr, and Apf (Fig. 2).

Aps is a low-relief plains-forming unit including partially infilled craters and numerous raised knobs and domes. The latter are typically <1 km in diameter and exhibit fractured and blocky surfaces. Alr forms a series of highstanding SE–NW-trending linear ridges (up to ~35 m in height) that postdate Aps and predate Apf. Apf forms a 45–50 m thick unit with a plateau-like geometry. It also includes rimless topographic depressions with thermal anomalies that reach up to 2.3 km in diameter. The margins of Apf are lobate with linear fractures running parallel to its periphery.

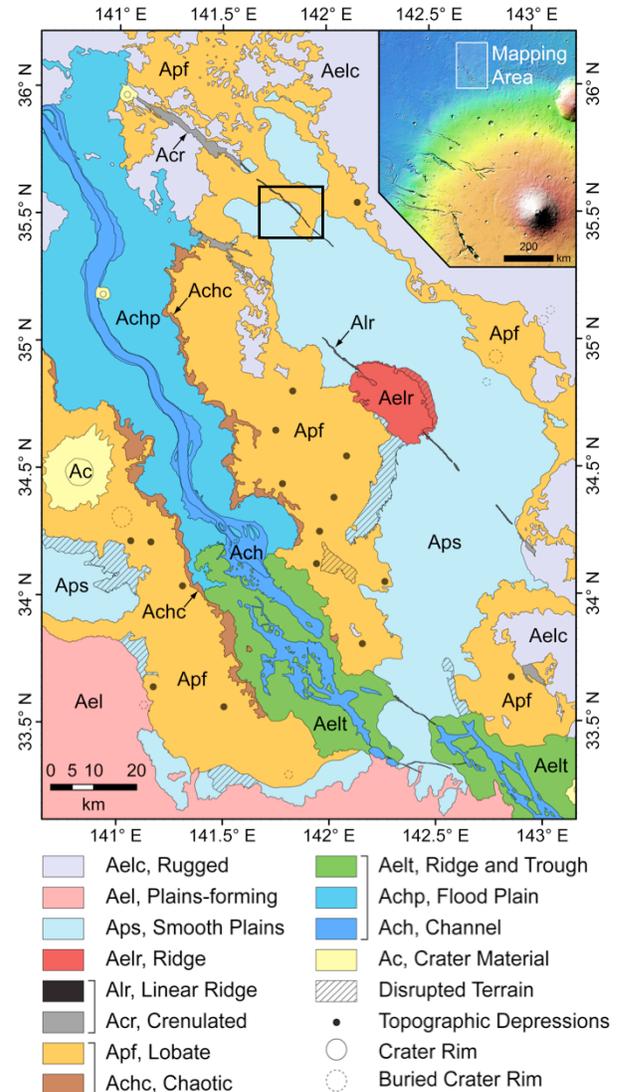


Fig. 1. Geologic mapping results for units in the Hrad Vallis region of the Elysium Volcanic Province, Mars. The inset back box shows the location of Fig. 2.

Part 2 Results. Ice retreat rates were calculated using the methods of [22] for 40 m, 45 m, and 50 m thick deposits composed of 99%, 95%, 90%, 80%, and 70% ice. Fig. 3 shows results for a 45 m thick layer as an example. The results demonstrate that ice-rich units would rapidly sublimate at the latitude of Hrad Vallis, which is consistent with the interpretation that Aps unit is the relic of an eroded/sublimated mega-lahar deposit, but inconsistent with the interpretation that the ~45 m thick Apf unit is a stable ice-rich deposit.

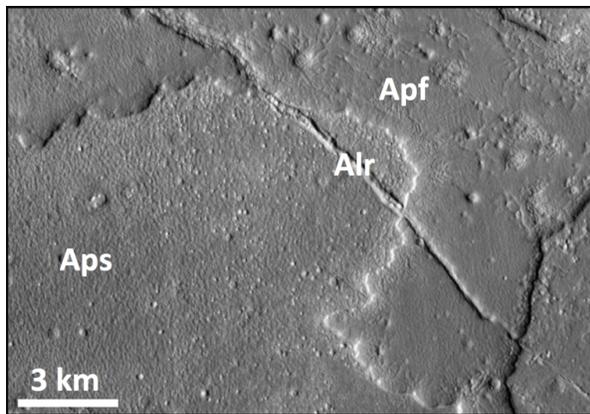


Fig. 2. CTX image B22_018168_2159_XN_35N218W showing the relationships between Aps, Alr, and Apf.

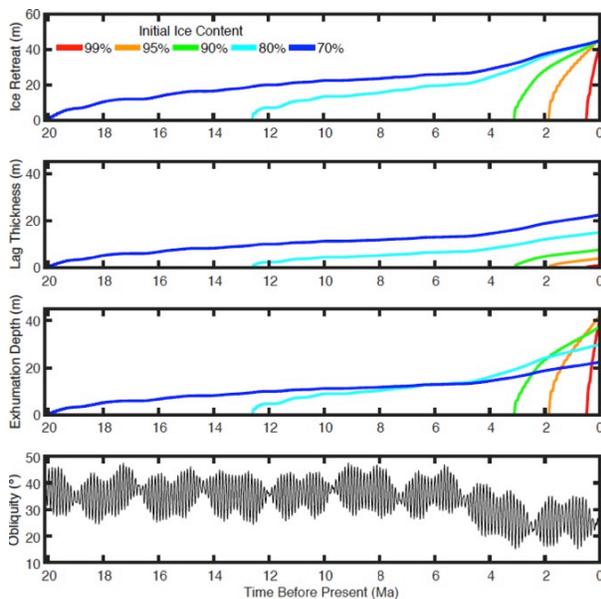


Fig. 3. Results showing the time necessary to completely sublimate a 45 m thick layer, which initially contains 99–70% ice (with the remainder being silicate sediment). Results are solved at a latitude of 36°N using orbital constraints from [23] over the past 21 Ma.

Synthesis: The morphology of Aps is consistent with that of an ice-rich flood deposit, which has been eroded/sublimated, and the timescales of sublimation for this layer are rapid enough to be easily reconciled with its geologically recent (i.e., Late Amazonian) age. Alr is interpreted to be the remains of a series of igneous dikes that were intruded into an easily erodible unit. This eroded unit may have been Aps, or a subsequent layer of ice, which has been hypothesized to have covered the Hrad Vallis during the geologically recent past [21] and enabled the formation of subglacially emplaced volcanic structures such as Galaxias Mons [7, 15]. Contrary to previous interpretations [7, 11, 12, 15, 19], we infer that Apf is not a frozen mega-lahar de-

posit, but is instead a pāhoehoe-like lava flow that was locally obstructed by Alr and inflated to form a lava-rise plateau [24]. Rimless depressions within Apf are interpreted to be lava-rise pits and peripheral fractures are interpreted to be inflation clefts.

Conclusions: Late Amazonian-age flow units near Hrad Vallis are attributed to a multi-stage history involving the emplacement of: (1) an initial aqueous flood deposit (Aps) that was triggered by a large intrusion beneath Hrad Fossae; (2) intrusion of igneous dikes (Alr) into a regional layer of ice; (3) subsequent effusive volcanism that produced a lava-rise plateau with lava-rise pits (Apf) through the process of inflation; and (4) formation/modification of Hrad Vallis and a series of flow units (Aelt, Achp, Ach) that are interpreted to be the products of another episode of magmatic intrusion and aqueous flooding from Hrad Fossae. Our results suggest that Amazonian-age outflow channels in general are the products of multiple stages of activity, including lava emplacement and aqueous flooding, and not formed during only a single event.

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