THERMAL AND MECHANICAL EROSION BY LOW-VISCOSITY LAVA FLOWS AT HRAD VALLIS, MARS

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The Hrad Vallis outflow channel heads on the northwestern flanks of Elysium Mons, one of the largest volcanoes on Mars. The system consists of a single sinuous channel over much of its 1450 km length. Channel floors are typically 50 to 200 m below adjacent plains, with channel depths progressively diminishing as the distal parts of the system fade into the plains of Utopia Planitia. Hrad Vallis possesses a range of characteristics typical of Martian outflow channels, including anastamosing reaches, streamlined erosional residuals, and channel terraces. Problematically, much of the Hrad Vallis region is thinly mantled by sediments of aeolian or other origin, concealing features of interest. Nevertheless, local exposures of channel floors show landforms including shear zones, longitudinal ridges, and wake forms. Adjacent upland plains show abundant evidence for the past emplacement of lobate-margined overflow deposits. The Hrad Vallis system has been previously interpreted as having developed through catastrophic aqueous outbursts from the subsurface, but such origins are not congruous with observations made in this study, including the absence of deposits of clear fluvial or diluvial character. Characteristics of the Hrad Vallis system appear instead to be most consistent with origins involving incision by low-viscosity lavas. Specifically, the system heads on the flanks of a large shield volcano, terminates at extensive ridged volcanic plains, shows evidence for having been a conduit for large volumes of lava, and possesses properties analogous to those of large volcanic channels of the Moon, Venus, and Mercury. Crude thermal estimates suggest that Hrad Vallis could have been formed through effusion of as little as ~10,000 cubic kilometers of magma. Despite the widespread presence at Hrad Vallis of channel slopes of less than 0.1 degrees, daily incision rates of tens of centimeters to several meters are estimated for mechanical and thermal erosion processes involving lava flows with depths of 5 to 20 m and dynamic viscosities on the order of ~1 Pa s. These rates of incision are estimated to have been associated with lava discharges as great as ~100,000 to 600,000 cubic meters per second and Reynolds numbers well in excess of 10,000, suggesting fully turbulent flow. Consistent with the findings of recent modeling efforts (Hurwitz et al., 2012, Journal of Geophysical Research-Planets, v.117), incision rates by thermal mechanisms are estimated to have been especially significant at Hrad Vallis as a result of the low channel slopes typical of this system, and should have exceeded mechanical incision rates for slopes less than 0.09 degrees. A volcanic origin for the Hrad Vallis system is in accord with the volcanic origins recently suggested for other Martian outflow systems, and correspondingly has important implications regarding our understanding of the past nature of surface conditions on Mars, and the planet's near-surface volatile content.