**1:175K Mapping of Hrad Vallis, Mars.** P. J. Mouginis-Mark[1] and C. W. Hamilton[2]. [1]HIGP/SOEST, Univ. Hawaii, Honolulu, HI 96822 (pmm@higp.hawaii.edu) and [2]Lunar and Planetary Laboratory, Univ. Arizona, Tucson, AZ 85721 (hamilton@lpl.arizona.edu).

## Introduction

The flows that originated from Hrad Vallis, Mars, have been studied for over 30 years [1–4], and yet numerous aspects of their formation and chronology remain unresolved. Among Amazonian-age outflow channels, Hrad Vallis is exceptional as it exhibits evidence of magma/water interactions. It is inferred [4] to have formed in association with a shallow igneous sill that melted part of the martian cryosphere and/or released water from an extensive aquifer to produce enormous lahar-like mud flows. As part of our 1:175K-scale mapping, a reappraisal of the properties of this area is underway. The map area (Fig. 1) extends from 33.3ºN to 35.7ºN, and 140.7ºE to 142.6ºE.

In the past year, we published a study of the origin of Galaxias Mons [5], which is a prominent massive within the map area (Fig. 1). We also discovered good evidence for the existence of an ice layer at the time of formation of the flows; high-standing volcanic dikes [5] and flows that do not follow the current topographic slope [6].

## Current Mapping

This year, we have focused on the sequence of the outflow events from the source fractures, and placing these events into a chronology that includes the eruption of the large flows to the NE and SW of the fractures. Multiple episodes of flow emplacement can be identified to the NW of source area (Fig. 1). Additionally, analysis of High Resolution Imaging Science Experiment (HiRISE) images of the source fractures from Hrad Vallis reveals layering which could be consistent with multiple outflow events (Fig. 2). We find two dominant types of layers: (1) relatively thin layers, which we interpret to be country rock (most likely layered lava flows) which existed before the formation of Hrad Vallis, and (2) layers with randomly oriented, larger blocks. We interpret these blocks to have originated either from the fragmentation of country-rock during the explosive origin of Hrad Vallis or the relatively recent break-up of a surface veneer of material created during the formation of Hrad Vallis.

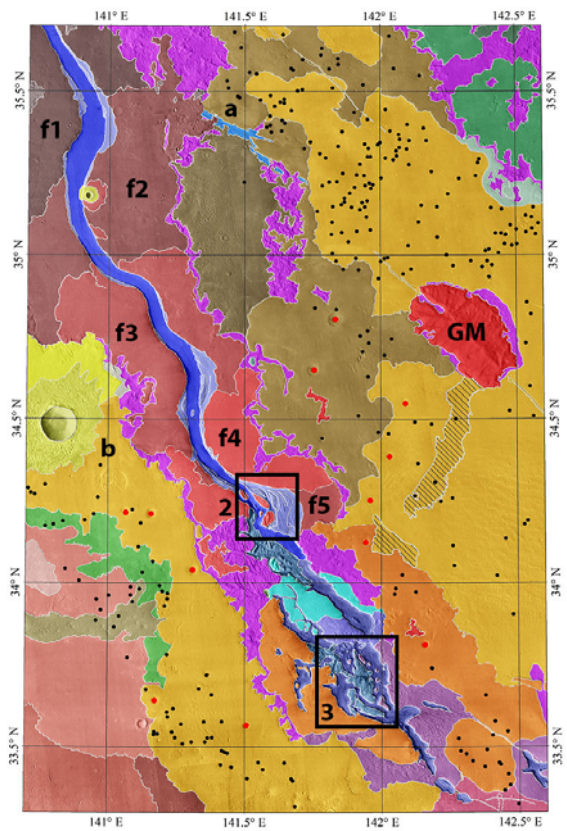


Fig. 1: Current status of our geologic map of the area center on Hrad Vallis. We have refined the northern extent of the upper flow ("a"), and recognized that the lower flow unit partially embays the ejecta blanket of the largest impact crater in this area ("b"). "GM" is Galaxias Mons. f1 to f5 identify a sequence of five outflow events (f1 oldest, f5 youngest) which originated from the source of Hrad Vallis. Locations of Figs. 2 and 3 identified, and respectively illustrate the outflow point and possible source region for the water released during the formation of Hrad Vallis.

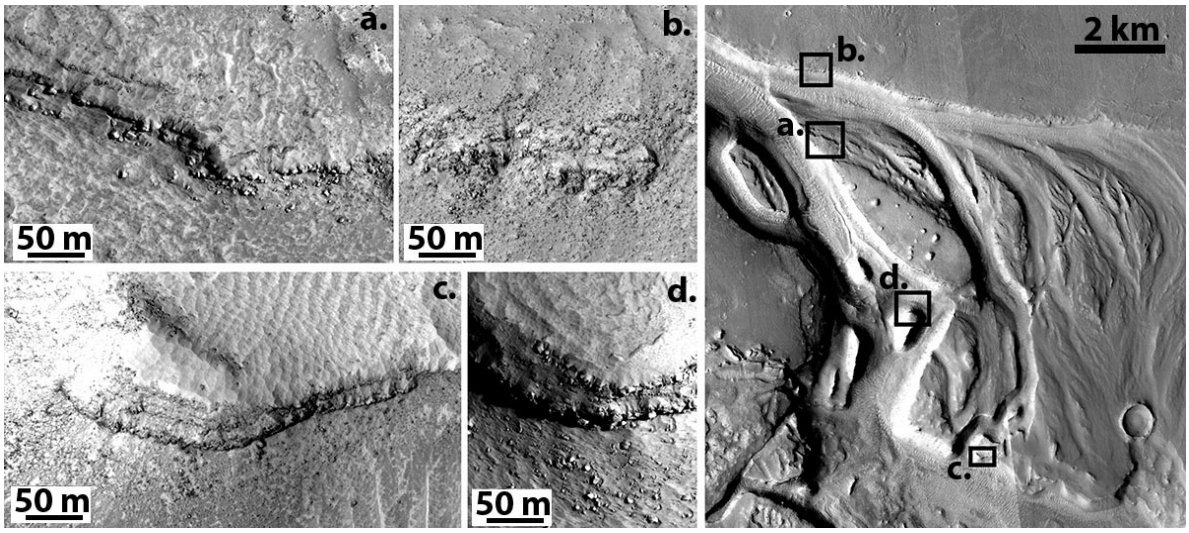


Fig. 2: Images at left (a–d): Layers within the outflow channels at the distal end of the source of Hrad Vallis. Massive boulders can be seen in "a" and "d", corresponding to the central streamlined islands, while in "b" and "c" thinner layers interpreted to be lavas. Notice the thick layers of sediment on the surface in "a", "c', and "d". Subscenes are segments of HiRISE image PSP_007738_2145. Right image shows location of images "a" to "d", and is a mosaic of Context Camera (CTX) images P18_008028_2149 and D17_033675_2142. See Fig. 1 for location.

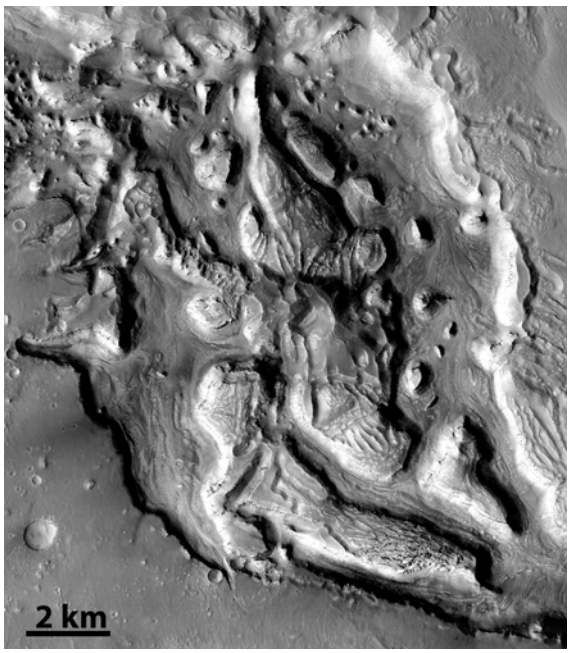


Fig. 3: The main depression that forms central Hrad Vallis. Many of the blocks within the depression are most likely remnants of pre-eruption bedrock. Note the lack of clear evidence for water release from specific sites. Part of CTX image D21_035587_2140. See Fig. 1 for location.

We have also examined the upper flow unit ("a" in Fig. 1) and considered two hypotheses for its formation: emplacement as a sediment-rich aqueous flood deposit, or emplacement as an inflated lava flow. The flow unit exhibits symmetrical margins on its north- and south-facing sides. We have modeled rates of viscous relaxation for the margins of the flow unit as a function of ice content and aspect, the latter of which controls the insolation on the surface, its temperature, and flow velocities. Based on these results, we conclude that the deposit must either be very young (less than tens of millions of years old) or be composed of less than ~30% ice. Alternatively, the unit may be composed of lava, which was emplacaced as pahoehoe-like lava flow, which would imply a complex emplacement history for flow units in the Hrad Vallis region, alternating between episodes of aqueous flooding events and volcanic eruptions.

**References:** [1] Mouginis-Mark, P. J. (1985). *Icarus* 64: 265 – 284. [2] De Hon, R. A. (1992). *Proc. Lunar Planet. Sci. Conf.* 22, 45 – 51. [3] De Hon, R. et al. (1999). *U.S.G.S Misc. Map* I-2579. [4] Wilson, L. and P. J. Mouginis-Mark (2003). *J. Geophys. Res.*108, doi. 10.1029/2002JE001927. [5] Mouginis-Mark, P.J. and L. Wilson (2016). *Icarus* 267, 68 – 85. [6] Mouginis-Mark, P. J. and C. W. Hamilton (2015). Fall 2015 AGU abstract P44B-04.