ERUPTION CONSTRAINTS FOR A YOUNG CHANNELIZED LAVA FLOW, MARTE VALLIS, MARS

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INTRODUCTION Lava flow emplacement is a fundamental geologic process on Mars and other planets. By studying the morphology of lava flows we can gain insight into eruption parameters and ultimately a region's geothermal history. Images from the Mars Orbiter Camera (MOC) [1,2] on the Mars Global Surveyor (MGS) spacecraft reveal lava flows emplaced within shallow fluvial channels in the Marte Vallis region of Mars, located in the Cerberus Formation of Elysium Planitia. These lava flows, estimated to be ~10 Ma [3], appear to be some of the youngest volcanic features on the planet, and their presence suggests that Mars may have been volcanically active much more recently than was previously believed [4].

In this study we attempt to constrain flow rates for a specific channelized lava flow in Marte Vallis, shown in MOC image SP240703 (at 18.47 m/pixel). Using Mars Orbiter Laser Altimeter (MOLA) [5,6] topographic data, we measure slope gradient, channel width, and channel depth. From these, we calculate flow rates using a rectangular channel flow model [7-9]. We then compare our results with other calculations for Martian flows as well as estimates of terrestrial flow rates.

METHODS Five topographic profiles of the channel were created from MOLA data gridded at 64x256 pixels/degree using the program *Gridview* [10]. With the current data grid, the footprints of our profiles are between 600 and 700 meters apart, and the topography is accurate to within a meter. These profiles reveal the channel levees and can be used to measure channel width; the elevations recorded at the flow's center in each profile help constrain local slope. Another profile collected along the center of the channel places constraints upon the regional slope. A final profile across the terminus of the lava flow was used to determine flow thickness, and lava flow volume was calculated from flow thickness, lobe width and the surface area of the end-flow. Then, from the total volume and flow rates we estimated the time required to emplace this terminal portion of the flow.

We used an analytical model [7-9] to characterize flow rates of lava flows within pre-established channels based on a channel's width, depth, and floor slope. The model assumes a laminar, steady, gravity-driven Newtonian flow in a rectangular channel, a reasonable approximation for Marte Vallis' fluvial channel geometries. Flow rates are calculated for a given channel width and depth, gravitational acceleration, flow density, channel slope and range of viscosities.

When calculating volume, we assume a gradual decrease of flow thickness as a function of distance from the toe and complete drainage in the channels. We assume the lava emptied out of the channel, leaving a thin lava veneer seen as an area with low albedo. The precise thickness of the lava veneer is likely a function of lava composition, channel dimensions, cooling rate and length of flow. Further study might constrain exactly how much material remains in the veneer for varying viscosities for terrestrial models.

RESULTS The measured depth of the drained lava channel is 5 ± 1 m, and the width is 6.5 ± 1.0 km. When comparing the MOLA profile across the channel with the MOC image, what first appear to be channel levees in the topographic profile are actually knobs and ridges, visible in the MOC image, that are cut by the lava flow. The albedo differences in the MOC image suggest the flow of lava did not reach the top of the levees. Eruption parameters are shown in Table 1. Our MOLA analysis suggests a very shallowly sloping terrain of 0.04° ± 0.01°.

Table 1: Lava Velocity & Flow Rate from Channel Dimensions

width = 6500 m depth = 5 m slope = 0.04 deg

Density (kg/m^3)	Viscosity (Pa-s)	Velocity (m/s)	Flow rate (m^3/s)
1200	100	0.390	8.4×10^3
1200	400	0.097	2.1×10^3
1200	800	0.049	1.1×10^3
1200	1000	0.039	0.8×10^3
2000	100	0.650	14×10^3
2000	400	0.162	3.5×10^3
2000	800	0.081	1.8×10^3
2000	1000	0.065	1.4×10^3

Table 2: Emplacement Duration

Density (kg/m^3)	Viscosity (Pa-s)	Flow rate (m^3/s)	Volume (km^3)	Duration (hr)
1200	100	8.4×10^3	0.65	21
1200	400	2.1×10^3	0.65	84
1200	800	1.1×10^3	0.65	160
1200	1000	0.8×10^3	0.65	210
2000	100	14×10^3	0.65	13
2000	400	3.5×10^3	0.65	51
2000	800	1.8×10^3	0.65	100
2000	1000	1.4×10^3	0.65	130

The volume calculation yields a minimum total volume of 0.65 ± 0.25 km^3. Emplacement-duration calculation results are shown in Table 2. Flow-rate calculations based on a viscosity of 100 Pa-s yield duration values of close to 20 hr for a flow density of 1200 kg/m^3 and 13 hr for a flow density of 2000 kg/m^3.

DISCUSSION Our calculations of flow rates assume the channel has emptied out. However, a thin layer of lava must have been left behind to produce the low-albedo area seen in the MOC image. Figure 1, with a vertical exaggeration of 500, shows the eastern side of the channel one meter lower, locally, than the western side. We believe that this depression was either originally a fluvial feature that has been preserved by a very thin draping of lava or a last frozen lava rivulet running along the western side of (and freezing along) the channel bottom. Velocity, flow rate, volume and duration values are minima because our measurements do not account for this residue. Comparisons with Hawaiian flows down pre-existing channels, however, suggest that this lava veneer could be as thin as a few centimeters [11]. Given the well-preserved veneer of lava remaining within the fluvial channel and revealed here with the paired MOLA/MOC data, we suggest there may be additional drained lava channels with a thin veneer of lava preserving the original fluvial topography. In-depth study of additional similar sites will need both MOLA and MOC coverage.

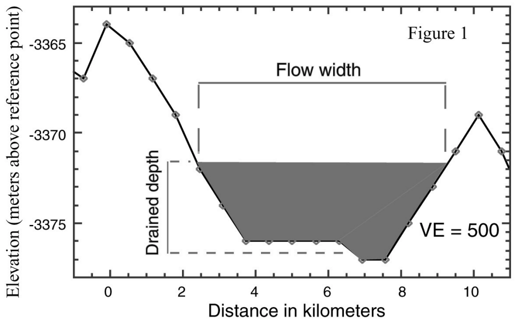

Figure 1. This topographic profile generated using MOLA data shows where measurements were acquired for drained channel depth and width. Individual MOLA data points are marked as black squares. From albedo and textural variations visible in MOC image SP240703, we infer that the lava flow (dark gray shading) did not reach the top of the pre-existing fluvial channel levee.

Table 3 compares similar flow rates. The maximum values for our flow rates are comparable to these mean values, but because the slopes we measured in our region are shallower our flow rates are lower. Depending on flow rate, the duration is on the order of tens of hours, possibly as long as 200 hr. This is a relatively short period of eruption; however, it only accounts for one very small part of the larger lava flow system of the Cerberus Plains.

Table 3: Comparison of Recent Studies of Lava Flow Rates

study & year	slope (deg)	viscosity (Pa-s)	average velocity (m/s)	flow rate (m^3/s)
Keszthelyi et al.	~1.4	100	~0.75	10^4 - 10^6
(2000)		1000	~0.33	
This Study (*)	~0.04	100	~0.65	(1.1-1.7) x 10^4
		1000	~0.07	(1.1-1.7) x 10^3
Gregg & Sakimoto	7.7 x 10^{-3}	100	0.2 - 0.4	(1 – 7) x 10^4
(2000)		1000	(2 - 4) x 10^{-2}	(1 – 7) x 10^3

(*) flow rates for this study are the Table 1 values ± 20%.

CONCLUSIONS Accurate channel dimensions, including channel depth, width and regional slope, can be measured and used as model inputs to obtain flow velocities and flow rates. If a flow's terminus is resolvable in MOC images, topographical profiles and high-resolution images can be used to arrive at a flow's surface area, a total volume for the flow, and a time duration of eruption. For our flow we found a velocity between 0.04 and 0.4 m/s and a flow rate near 8.4 x 10^4 m^3/s. These results are similar to those found in other recent studies [8,12,13] which supports the idea that these flows share many of the characteristics of long, terrestrial basaltic flows.

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