CONSTRAINING LAVA FLOW ERUPTION RATES ON MARS USING LABORATORY ANALOGUE WAX EXPEREMENTS. S. I. Peters[1], P. R. Christensen[1], and A.B. Clarke[1], [1]Mars Space Flight Facility, School of Earth and Space Exploration – Arizona State University, 201 E. Orange Mall, Tempe, AZ 85281-6305, USA, speter24@asu.edu.

Introduction: The morphology of lava flows is controlled by eruption rate, composition, cooling rate, and topography [1,2,3]. Lava flows provide insight into the formation and evolution of volcanoes, volcanic fields, and igneous provinces [2,4,5]. This is particularly important for other planets where compositional data is limited and historical context is nonexistent. Numerical modeling of lava flows remains challenging, but has been aided by laboratory analog experiments [6,7]. Experiments using polyethylene glycol (PEG) 600 wax have been performed to understand lava flows [1,2,3]. These experiments established psi (hereafter denoted by Ψ), a dimensionless parameter that relates crust formation (t_s) and lateral advection (t_a) timescales of a viscous gravity current.

$$\boldsymbol{\Psi} = \frac{\boldsymbol{t_s}}{\boldsymbol{t_a}}$$

Four primary flow morphologies corresponding to discreet Ψ ranges were observed. Those primary morphologies, from high to low eruption rate (low to high viscosity), are: Levees, Folds, Rifts, and Pillows [1,2,3]. Another morphology produced at even higher eruption rates than levees, No Crust, was also observed. Transitional morphologies are also observed, demonstrating that the morphologies are produced on a continuum [1,2]. These morphologies are analogous to surface morhopogies and textures observed in nature [1,2,3]. Subsequently, the effect of slope on flow morphology was investigated, revealing that steeper slopes increase the effective and localized effusion rates producing predicted morphologies at lower Ψ values than expected [3]. Recent studies have used wax experiments with pulsatory source flow rates to address flood basalts and the process of inflation [5]. Additional work is needed to constrain the Ψ parameter space. For this study, we used laboratory experiments to qualitatively and quantitatively investigate lava flows on Mars.

Methods: To identify and characterize lava flows for study, we used image data from CTX (~5m/px), HiRISE (~0.5m/px), and THEMIS IR (~100m/px). For topography and morphometry, we used MOLA (~300m/px) and HRSC DTMs (~50m/px). All remote sensing analyses were performed in JMars. To address the effects on flow morphology, we conducted 355 laboratory experiments to date by using a peristaltic pump to erupt dyed wax into a temperature controlled chilled bath in a tank with a roughened base. The wax was erupted at rates varying between 1–6.5 cm^3/s across a target Ψ regime. The temperature of the wax is adjusted according to the eruption rate to meet the targeted Ψ value. Substrate slopes were varied from ~5–30° in ~5° increments. For pulsatory flows, wax was erupted on a 0° slope at a reference rate, then decreased to half that rate for a time period of 10 or 50 seconds. Many experiments were video recorded to obtain quantitative time-series data and/or photographed to carefully document morphologies at different times.

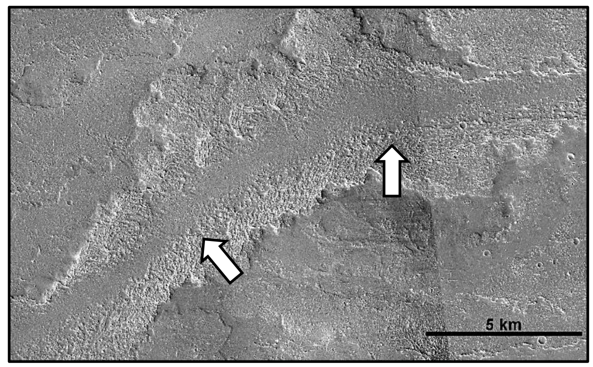

Figure 1: CTX image of a lava flow observed just south of Olympus Mons, Mars. Illumination is from the left and north is up. This flow displays a channelized portion, denoted by the white arrows. This morphology suggests a higher eruption rate and/or lower viscosity lava.

Preliminary Observations: We observed and characterized 21 lava flows to date suitable for study on and around Olympus Mons, the Tharsis Montes, and Daedalia Planum, Mars (Fig. 1). Flow lengths and widths range from 25–200 km and 0.5–30 km , respectively. All observed flows occur on slopes <5°. Flow thicknesss range from 30–80 m. Qualitative assesment of the surface morphologies reveal a narrow range of observed morphologies. Those morphologies are most analogous with the No Crust, Levee, and Fold morphologies produced in the laboratory (Fig. 2). Some observed lava flows exhibit more than one dominant morphology, with the change in morphology a function of distrance from its source.

The observed morphologies are tied to specific eruption conditions. The eruption rate can be calculated if reasonable assumptions about the lava flow are made. Assuming a density (ρ=2800 kg/m^3) and solidification temperature (950°C) characteristic of basalt as well as eruption into a 0°C atmosphere, we can estimate the eruption rates of the observerd lava flows using Ψ. In

Daedalia Planum, the observed lava flows (n = 7) exhibit eruption rates of 50–450 m^3/s based on their surface morphologies.

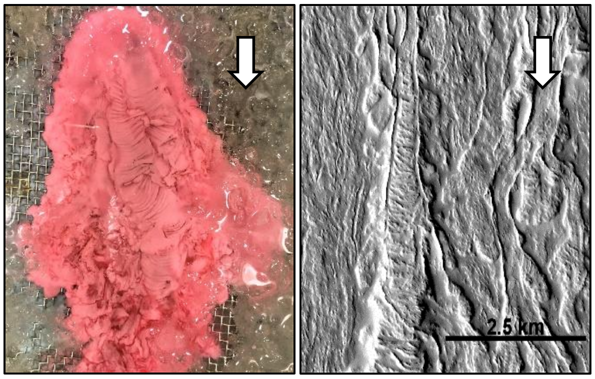

Figure 2: Example of the folded morphology produced in the lab and an analoguous corrugated texture observed on a Martian lava flow. White arrows denote downslope direction. North is up in CTX image. (Left) A folded flow morphology. Source is at the top of the image. Blurry white zones in image due to ice. (Right) A lava flow on Olympus Mons displaying a corrugated morphology analogous to fold morphology produced in the lab.

Preliminary Discussion: Our preliminary results suggest that effusive volcanism in the Amazonian featured lava flows with moderate to high eruption rates and/or moderate to low viscosities. The eruption rates determined from the surface morphology are similar to terrestrial values and congruent with values estimated by other studies for Mars [8].

Surface Morphology. The preliminary observations of our study suggests that lava flow eruption rates can be estimated without morphometric data. Previous studies have relied on morphometric data in conjuction with dynamical equations to estimate eruption rates. However, the values we have calculated were derived without flow thicknesses. This may allow flow conditions on other planetary bodies lacking morphometric data to be estimated. The morphologies we observed were biased to higher eruption rates (and/or lower viscosities), primarily due to limited spatial resolution, dust cover, and degradation. While levees are easily observed from orbit (e.g. Fig. 1), pahoehoe toes (which are analogous to the pillow morphology produced in the lab) tend to be meter-scale features on Earth and are easily obscured by surface conditions and unresolvable from orbit. Other methods aimed at determining a lava flow's texture might address this issue [9].

Martian Eruption Rates. The surface morphologies observed in this study suggests moderate to high eruption rates. The flows observed in this study were all created during the Amazonian (≤ 3 Ga) and represent some of the most recent volcanism on the surface of Mars. Although it is generally agreed that volcanism on Mars has reduced in volume and spatial extent over time, our results suggests that recent volcanism has produced high eruption rates and/or low viscosity lavas capable of producing expansive flows. This analysis suggests less evolved parent magmas, a large volume of available magma, and/or high driving pressures. Our eruption rates are reasonable for Earth and Mars. Further constraining the range of eruption rates (and other eruption characteristics) is possible by incorporating additional data, such as composition.

Planetary Applicability of Ψ. Ψ is numerically derived from first principles [1]. One of the underlying assumptions made in the derivation is that heat removal from the surface of the flow is primarily done by convection. Subaerial lava flows on the Earth, Moon, and Mars remove heat primarily via radiation, with losses via conduction to the substrate being minimal [1,2]. Convection is the dominant process of heat removal for underwater terrestrial eruptions and on Venus due to its thick atmosphere. As a result, estimates of subaerial eruption conditions for the Earth, Moon, and Mars may not be as accurate as those for Venus or submarine terrestrial eruptions. The approach can be improved by revisiting the Ψ derivations and/or by using other available datasets to constrain our estimates.

Ongoing and Future Work: We are continuing laboratory experiments to address the questions in this work as well as other questions about lava flow morphology and propagation over variable slopes and with unsteady eruption rates. Additionally, we are continuing to assess the applicability of Ψ to subaerial conditions in the hopes of further constraining eruption conditions on planetary bodies where convection does not dominate at the surface.

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