CONSTRAINING THE CONTROLLING PARAMETER(S) FOR THE EMPLACEMENT OF LONG LAVA FLOWS ON MARS: A QUANTITATIVE MODELING APPROACH.

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Introduction: Regional volcanic processes shaped many planetary surfaces in the Solar System, often through the emplacement of long, voluminous lava flows. These "flood lavas" are characterized by sheet-like flows that inundate a large area, resulting in relatively smooth plains with features <100 m in height [1]. Terrestrial examples of this type of lava flow (e.g., Columbia River Basalt Group, Eldgá and Laki in Iceland, and McCartys in New Mexico, USA) have been used as analogous terrains for the investigation of extensive martian flows, including those within the the circum-Cerberus outflow channels, Athabasca, Grjótá, and Marte Valles [1-3]. This analogy is based on similarities in morphology, extent, and inferred eruptive style between terrestrial and martian flows, which raises the question of why these lava flows appear comparable in size and morphology on different planets.

The parameters that influence the areal extent of silicate lavas during emplacement may be categorized as either inherent or external to the lava. The inherent parameters include the yield strength, density, composition (silica content), water content, crystallinity, exsolved gas (bubble) content, pressure, and temperature [4-8]. Each inherent parameter affects the overall viscosity of the lava, and for this work can be considered a subset of the viscosity parameter [7,8]. External parameters include the effusion rate, total erupted volume, regional slope, and gravity [5,6,9-14].

In order to investigate which parameter(s) may control(s) the development of long lava flows on Mars, a quantitative approach can be applied. Computational numerical-models can be used to reproduce the observed lava flow morphologies, to investigate their emplacement conditions. Basing this work on terrestrial analogues provides an informed understanding of the factors that may result in long flows on Mars.

Methodology: Since both inherent and external parameters influence the final morphology of lava flows, we will test the relative effect of each factor under specific simulation conditions. First, we expect that *the inherent properties of lava (e.g., viscosity) are the primary controlling parameter affecting the development of long lava flows on Mars.* Alternatively, one or more of the external parameters, **(1)** *effusion rate*, **(2)** *erupted volume of lava*, **(3)** *regional slope*, or **(4)** *gravity*, is (are) the primary controlling parameter(s).

We are testing which internal and external parameters play a more or less important role in the development of long lava flows on Mars, using a model to first simulate terrestrial analogues, then applying it to the three channelized Cerberus lava flows. Specifically, this work will be accomplished using four interrelated approaches: **(1)** development of an ArcGIS lava flow model incorporating governing equations [e.g., Navier-Stokes equation of flow] and each parameter to be tested; **(2)** numerical analyses comparing the fit of the mapped terrestrial fissure flows to the model outputs from (1), to calibrate and validate the model; **(3)** application of the model to martian fissure flows and; **(4)** numerical analyses of the model outputs to determine the effects of the input parameter(s) on the development of long lava flows on Mars. During the testing of these parameters, non-unique solutions may be identified, requiring further analyses of the outputs to determine the preferred set of parameter values.

The model is cellular-automata-based, in order to simplify the governing differential equations, and decrease processing time [e.g., 15]. Several assumptions are made in this model, based on [16]. The flow is modeled as a non-Newtonian fluid, requiring the flow to exceed the yield strength prior to propagation. The lava is homogeneous and isothermal, lacking variation in composition, density, crystallinity, volatile and bubble content, or temperature. The modeled effusion rate is uniform. No cooling occurs during the eruption, due to the formation of a surface crust; therefore the modeled flows behave as volume-limited systems.

Model calibration will be performed on the McCartys lava flow (Fig 1), in order to identify the ideal parameter combination capable of reasonably reproducing the observed flow. The fit of the model to the observed flow extent will be determined using a fitness function and Percent-to-Length Ratio (PLR), to compare the overall area and length of the modeled and observed flows [17]. Validation will use the ideal parameter values of the calibrated model in order to reproduce the Icelandic Eldgá and Laki lava flows. Once calibrated and validated, the model will be applied to the martian lava flows. To determine the effect each parameter exerts on the final flow morphology, we will use the fitness function and PLR. We will vary a single parameter at a time, with respect to a combination of the other parameters, and calculate the fit of the model output to the observed flow. The relative effect of each parameter will likely change based on the parameter combinations used, but we will infer trends based on the specific simulation conditions.

Preliminary Efforts: The basic model framework

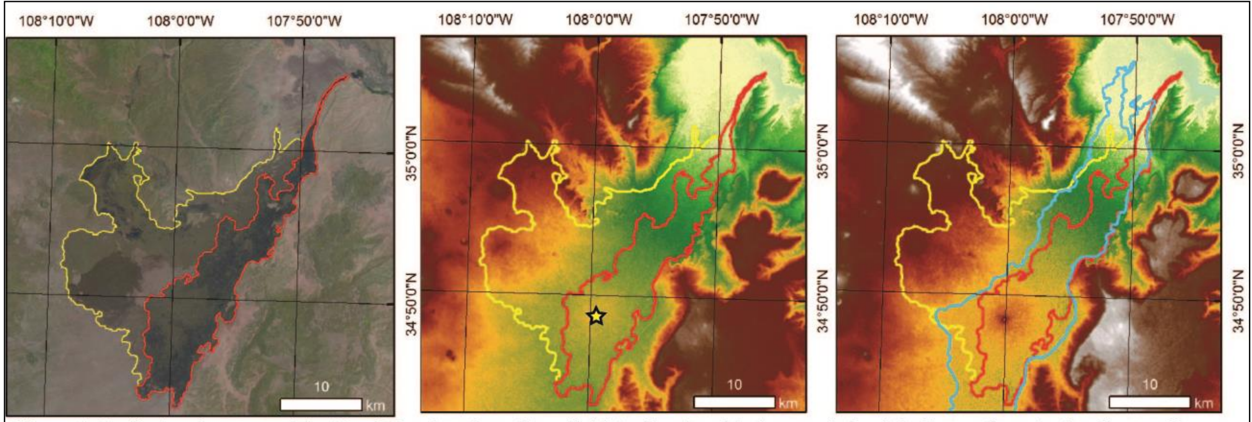

Figure 1: Left: Areal extent of the Zuni-Bandera lava flow field (yellow), with the overlying McCartys flow (red). Center: Preconditioned DEM surface with 10 m of lava removed within the boundaries of the lava flow field, with the location of the source vent (yellow star). Right: Initial model output extent (blue). This model output overestimated both length and areal extent, but follows topography. In addition, the model resulted in a highstanding volcanic edifice at the location of the source vent.

has been constructed, including all governing equations and parameters that we seek to test, and initial implementation and calibration has been performed. The base model is currently capable of generating a lava flow that propagates along a pathway governed by the local topography (Fig. 1). Further modification of the flow propagation pathway is required, to simulate spreading of the lava from the vent source rather than propagation along a single flow pathway.

Implications: Ultimately, this work may have several possible interpretations of the potential model results and their implications for martian volcanism. If the final results suggest that the inherent properties of the lava exert a greater control on the emplacement of long lava flows relative to external parameters in their inferred ranges on Mars, one of the subset-parameters of viscosity may have a strong effect on the emplacement of these flows. Further investigation of these subset parameters will include modifying the flow model to include their relevant governing equations. A finding that these inherent properties are the controlling parameter(s) would suggest that basaltic volcanism across the terrestrial planets produces long lava flows based on similar initial conditions of the lava, regardless of external factors.

If the results indicate one external parameter has a greater control on lava flow on Mars than other external and/or internal parameters, various interpretations and implications are possible. For example, if the slope of the region is a significant governing parameter, then a range of slope values may affect the emplacement of long lava flows. If either the volume or effusion rate are found to be a more substantial controlling parameter, then the magma availability would be the limiting factor. Finally, if gravity is found to be a more important controlling parameter, then the development of long lava flows is specific to each terrestrial planet, and long lava flows on low gravity worlds should be similar to each other, and the same relationship should hold true for higher gravity worlds. The effect of gravity may also impact the magma availability, as magma will stall at greater depth in low gravity planets than on Earth, and require a higher driving pressure to force the magma to the surface, resulting in correspondingly higher volumes and effusions rates [12].

Future Work: Final coding and calibration of the model needs to be accomplished. This step will be followed by validating the model using the Eldgá and Laki lava flows. Finally, the model will be applied to the target martian flows and the results analyzed.

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