CONSTRAINING CONTROLS ON THE EMPLACEMENT OF LONG LAVA FLOWS ON EARTH AND MARS THROUGH MODELING IN ARCGIS. K. B. Golder[1], D. M. Burr[1], L. T. Tran[2], [1]University of Tennessee Knoxville, Dept. of Earth and Planetary Sciences; [2]Dept. of Geography, 1621 Cumberland Ave., 602 Strong Hall, Knoxville, TN, 37996 (kgolder@vols.utk.edu).

Introduction: Volcanism shaped many planetary surfaces in the Solar System, often by 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 and references therein]. Terrestrial examples of this type of lava flow (e.g., Columbia River Basalt Group in Washington, USA, Eldgjá and Laki in Iceland, and McCartys in New Mexico, USA) are used as analogous terrains for investigations of martian flows, including those within the circum-Cerberus channels, Athabasca, Grjótá, and Marte Valles [1-3]. This analogy is based on similarities in lava morphology and extent, and inferred eruptive style. However, the difference in boundary conditions (e.g., gravity) on difference planets raises the question of why these lava flows appear comparable in size and morphology.

Parameters that influence the areal extent and morphology of silicate lavas during emplacement can be categorized as intrinsic or extrinsic to the volcanic system. Intrinsic parameters include the yield strength, density, composition, water content, crystallinity, exsolved gas content, pressure, and temperature [4-8]. Each intrinsic parameter affects the viscosity of the lava, and for this work will be incorporated in the viscosity parameter [7,8]. Extrinsic parameters include effusion rate, total erupted volume, regional slope, and gravity [5,6,9-14].

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

We use a computational model to simulate terrestrial analogues, for calibration and validation purposes, then apply it to the three martian lava flows. This work will be accomplished through four tasks: **(1)** developing an ArcGIS lava flow model incorporating governing equations [e.g., Navier-Stokes flow equation] and each parameter to be tested; **(2)** numerical analyses comparing the fit of the mapped terrestrial flows to the model outputs from Task (1), to calibrate and validate the model; **(3)** application of the model to martian lava 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.

The model is cellular-automata-based, 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 is being performed on the McCartys lava flow (Fig. 1), to identify the parameter combination(s) capable of reasonably reproducing the

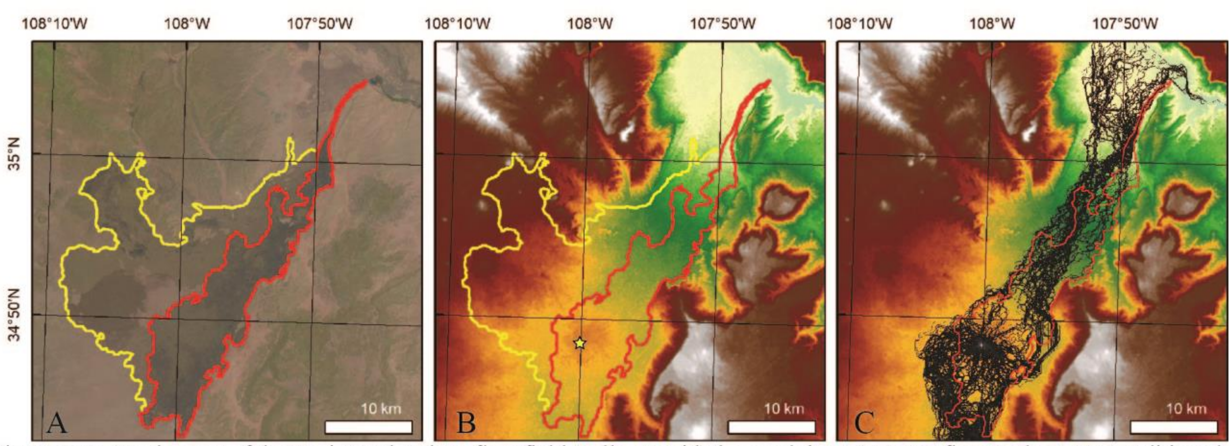

Figure 1: A: Areal extent of the Zuni-Bandera lava flow field (yellow), with the overlying McCartys flow (red). B: Preconditioned DEM surface with 10 m of lava removed within the red boundary, and the location of the source vent (yellow star). C: Model output (black lines) after 1000 iterations. The model approximates the final length and areal extent of the McCartys flow, but generates a relatively highstanding volcanic edifice at the location of the source vent.

observed flow. 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 fit of the model will be determined using a fitness function and Percent-to-Length Ratio (PLR), to compare the overall area and length of the modeled and mapped flows [17]. Validation will use the parameter values of the calibrated model to reproduce the Laki lava flow. Once calibrated and validated, the model will be applied to the martian lava flows. To test the effect each parameter exerts on the final morphology of the martian flows, we will use the same fitness function and PLR as for the terrestrial flows. 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. Each parameters relative effect will likely change based on the parameter combinations, but we will infer trends based on the specific simulation conditions.

Preliminary Efforts: The model has been constructed, including all governing equations and parameters to be tested. Initial implementation and calibration has been performed. The results show that the model is capable of generating a lava flow that propagates along a pathway governed by the local topography (Fig. 1). We also successfully tested model functionality on a fissure sourced eruption on Mars, in Athabasca Valles (Fig. 2).

Future Work: Validation of the model using the Laki lava flow is required, where we seek to reasonably reproduce the observed lava flow using the input parameter values from the calibrated McCartys model. The model will then be applied to the martian flows in the circum-Cerberus channels and the results analyzed.

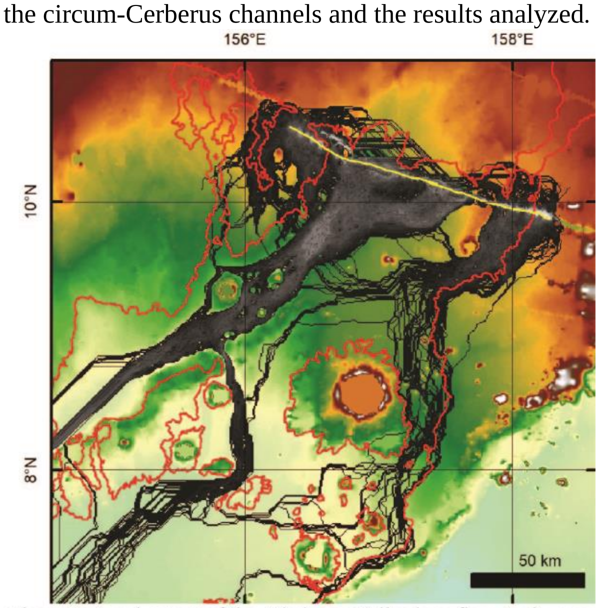

Figure 2: Areal extent of the Athabasca Valles lava flow (red), near the source fissure (yellow line). Model output (black lines) after 200 iterations. The model follows topography and fills the existing channel, as observed [14].

Implications: Ultimately, the model results may yield several possible interpretations and corresponding implications for martian volcanism. Results suggesting that viscosity exerts a greater control on the emplacement of long lava flows relative to extrinsic parameters would imply one of the subset-parameters of viscosity has a strong effect on the emplacement of these flows. Further investigation of these subset parameters would necessitate modifying the flow model to include their relevant governing equations. If the intrinsic properties of the lava are the controlling parameter(s), this result would suggest that basaltic volcanism produces long lava flows based on similar initial conditions, regardless of external factors.

If the results indicate an extrinsic parameter has a greater control on lava flow development, various interpretations and implications are possible. If the slope of the region is a significant factor, then a range of slope values may affect the emplacement of long lava flows. If the volume or effusion rate are found to be the controlling parameter, then magma availability would be a limiting factor. Finally, if gravity is found to be the controlling parameter, then the development of long lava flows would be specific to each terrestrial planet. Flows on low gravity worlds should be similar to each other, and the inverse should hold true for higher gravity worlds. Gravity may also affect magma availability, as magma stalls at greater depth in low gravity planets, and requires a higher driving pressure to force it to the surface, with correspondingly higher volumes and effusions rates [12].

References: [1] Keszthelyi, L. et al. (2000), *JGR: Planets, 105*, 15027-15049. [2] Keszthelyi, L. et al. (2004) *GGG, 11*. [3] Bleacher, J.E., et al. (2010), *AGU Abstracts*, 1387. [4] Walker, G.P.L. (1967) *Nature*, *213*, 484-485. [5] Walker, G.P.L. (1973) *Philosophical Transactions of the Royal Society of London, 274(1238)*, 107-118. [6] Hulme, G. (1974) *JGI, 39(2)*, 361-383. [7] Harris, A.J.L. (2013) *Lava flows. Modeling volcanic processes: the physics and mathematics of volcanism*, pp.85-106. [8] Cordonnier, B., et al. (2015) *Geological Society, London, Special Publications, 426*, SP426-7. [9] Walker, G.P.L. (1971) *Bulletin Volcanologique, 35(3)*, 579-590. [10] Wilson, L. and Head, J.W. (1994) *Reviews of Geophysics, 32(3)*, 221-263. [11] Keszthelyi, L. (1995) *JGR: Solid Earth, 100(B10)*, 20411-20420. [12] Miyamoto, H. and Sasaki, S. (1998) *JGR: Solid Earth, 103(B11)*, 27489-27502. [13] Wilson, L. and Head, J.W. (2002) *JGR: Planets, 107(E8)* [14] Jaeger, W.L. et al. (2010) *Icarus, 205*, 230-243. [15] Schiff, J.L. (2001) *Cellular automata: a discrete view of the world.* [16] Dragoni, M. et al. (1997) *Annals of Geophysics, 40(5).* [17] Spataro, W., et al. (2004) *Cellular Automata*, pp. 725-734.