Thermorheological Modeling of Channelized Lava Flows on Earth and Mars. Ian T.W. Flynn[1] and Michael S. Ramsey[1], Department of Geology and Environmental Science, University of Pittsburgh, Pittsburgh, PA 15260, itf2@pitt.edu.

Introduction: Prior quantitative modeling of individual channelized lava flows on Mars was hindered because of poor image spatial resolution, lack of coverage or obscuration from mantling of dust, sand and other flows [1,2]. With newer datasets and detailed analysis, multiple young volcanic regions have been identified on Mars [3]. One such region of interest are the flows south of Arsia Mons. These channelized flows have been extensively studied for their age relationships and unique thermophysical properties [4,5,6]. A newly-funded NASA Solar System Workings (SSW) project will extend these studies by attempting to model the eruptive conditions at the time of their formation. A thermorheological model (PyFLOWGO) developed for terrestrial flows will be constrained first at a Mars analog site (the Tolbachik volcano flow field formed during the 2012-2013 eruption), and then applied to the Arsia flows. The overarching goal of this project is to test and refine this well-developed terrestrial flow model in order to quantify the properties of these flows including eruption rate, viscosity, crystal content and flow velocity.

Terrestrial Analog: The Tolbachik Volcanic complex is located on the Kamachatka Peninsula, Russia. To the south of the complex lie ~875km^2 of basalt flows, pyroclastic deposits and an alignment of NNE cinder cones [7]. The Tolbachik complex erupted in November 2012 and continued until September 2013. The resulting flow fields cover approximately 30 km^2 [8] (Figure 1). This eruption produced the largest and most thermally radiant eruption of the modern satellite era until the recent eruption in Hawaii. Extraordinary data coverage was acquired by both high spatial resolution sensors (e.g., ASTER, ALI, Hyperion) and high temporal resolution sensors (MODIS, AVHRR). These data will be used to constrain the input parameters to the PyFLOWGO model. For example, the time-averaged discharge rate (TADR), thermal radiance, emissivity, topographic slope and channel dimensions can all be constrained with the orbital data. This large amount of satellite data coupled with the entirely subaerial erupted lava volume offers a unique modeling analog site for Arsia flows. For Mars, the constrained model can then be implemented in reverse to derive parameters such as eruption rate, that were measured at the Tolbachik flows.

Mars Dataset: The proposed study area on Mars is the SW Arsia Mons volcanic flow field (Figure 2). This flow field may represent one of the last stages of active volcanism on Mars [3]. Instruments central to our analysis are HiRISE, CTX and MOLA. Additional data from MOC, THEMIS and HRSC may also be used.

Modeling Approach: The ultimate goal of modeling these flows is to connect final flow morphologies directly to specific eruption conditions. For terrestrial flows PyFLOWGO relies on an eruption temperature, eruption rate and precise tracking of all cooling conditions to calculate the TADR. It will then propagate the flow until cooling results in a viscosity that dictates stoppage [9]. However for Martian flows the process will be run in reverse by making detailed measurements of flow morphology and modeling the TADR that created these flows. In doing so, we will also make estimates of parameters such as the flow's cooling rate, viscosity, and velocity with distance from the vent.

Future Work: The planned work can be broken into three primary tasks.

Image Based Modeling. Assess the accuracy of the PyFLOWGO model using orbital datasets (and refine if necessary) in order to replicate the final length of the Tolbachik flows produced from the 2012-2013 eruption. Initial mapping of the flows will be accomplished using the high spatial resolution data, specifically to map the extent, topography and temporal evolution of the Tolbachik flows. Mapping will be completed using primarily ASTER day and night TIR data due to its high spatial resolution and high temporal frequency. ASTER TIR data will be augmented with ASTER VNIR, ALI and Hyperion data sets to expand the spectral wavelength region and spatial resolution. Pre-flow topography will be derived from both the ASTER single-scene DEM's and the global (GDEM) product.

Field-Based Data Analysis. Field work is planned for the summer of 2019 and will focus specifically on the long channelized flows formed during the 2012-2013 eruption. Data collection will prioritize acquiring specific measurements (flow dimensions, morphology and topography) which could not be derived (or derived in sufficient detail) from the spatial resolution of the orbital data.

Lava samples will be collected from each flow site to be analyzed later by laboratory TIR emission spectroscopy, whole rock and petrographic analysis. The intent of these analysis is to constrain the percentage of vesicles and percentage/composition of phenocrysts along the flow length, which can be compared directly to the output of the model.

Model Refinement and Mars Application. Once the model is sufficiently constrained it will be applied to older Tolbachik flows as well as the Arsia Mons flows that share similar morphologies to those at Tolbachik. Applying PyFLOWGO to the Arsia flows using Mars-specific environmental conditions has already shown promising results [10]. However, there are still a number of subtle parameters that need further refinement.

Perceived Impact: Our results will provide a more complete understanding of the eruptive processes that produced the flow fields SW of Arsia Mons. A comprehensive study of a terrestrial analog site has not been attempted before and therefore will be highly impactful to the study of future terrestrial flows as well as future applications to other planetary surfaces such as Venus [11].

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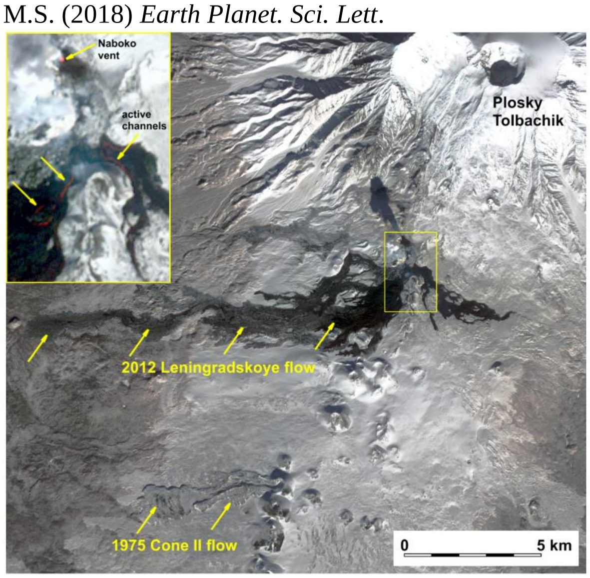

Figure 1: ASTER VNIR image acquired on 2 March 2013 centered on the Tolbachik Dol (“valley”), with channels 3 (0.807 μm), 2 (0.661 μm), 1 (0.556 μm) in red, green, blue, respectively. Spatial resolution is 15 m/pixel. During the first three months of the 2012-2013 eruption, numerous flows were emplaced, with some having cooled and later covered with light snow. The longest flow emplaced early in the eruption is the 2012 Leningradskoye flow. Inset image is the vent region (brightened with a histogram equalization stretch) shown at full resolution. The active vent and channels shown in red are denoted by arrows. Taken from [8].

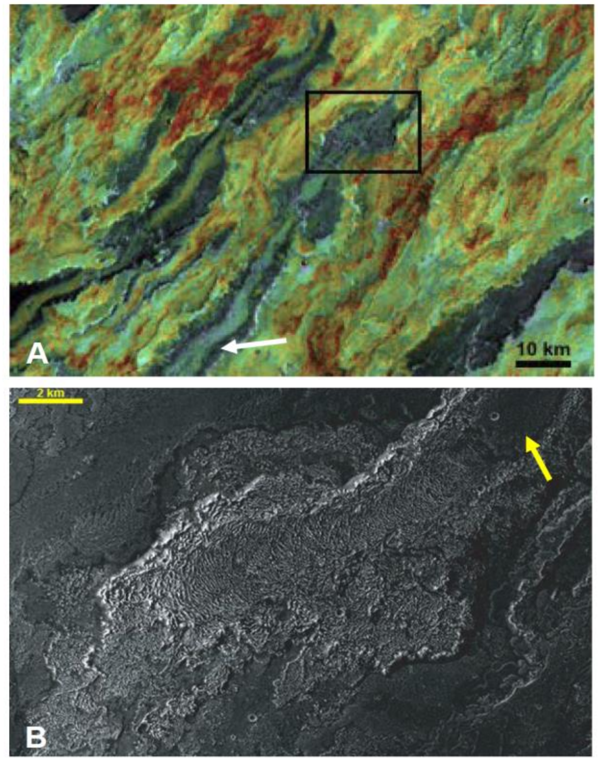

Figure 2: Individual flows in the Arsia Mons flow field (centered at 238.3°W, 22.3°S). (A) THEMIS nightime IR (colorized) over daytime IR showing a wide distribution of surface temperatures and flow morphologies (warmer colors indicate rocky/less mantled surfaces). The black box denotes the area shown in (B). The white arrow shows a channelized flow that can be modeled in this study. (B) CTX image of a higher albedo (rougher) flow showing a prominent central channel, levees, flow folds, and the lower albedo flows surrounding it with one younger flow pirating the central channel (yellow arrow).