INVESTIGATING THE FORMATION OF LAVA CHANNELS ON VENUS WITH NEW MODELS AND NEW TOPOGRAPHY. M. E. Borrelli*, D. A. Williams, and J. G. O'Rourke, School of Earth and Space Exploration, Arizona State University, Tempe, AZ, *meborrel@asu.edu

Introduction: Venus is a volcanic wonderland with many different types of lava channels. Sinuous rilles have lengths of ~10–300 km and widths up to several km. Canali are long, narrow channels that look similar to meandering rivers—over ~500 km long, ~1 km wide, and ~24 m deep on average [1]. The longest canali (Baltis Vallis) is the longest channel that has been found anywhere in the solar system. We remain unsure about the origin of these features, though they likely formed from thermomechanical erosion by flowing lava. People typically assume that basaltic lava created rilles, whereas the lava type that formed canali is uncertain.

Canali-forming lava must have had a low viscosity to create channels with extreme lengths. Such flows are rare on Earth but appear to be common on Venus. We will ultimately model lava channel (canali and rille) formation by several potential lava compositions to determine which may be viable candidates. It would be particularly impactful to conclude that carbonatite is the most likely composition of canali-forming (and/or rille-forming) lava. Carbonatite volcanism is very rare on Earth but finding that it is common on Venus signals a major difference between the two planets. The presence of large amounts of carbon in Venus's lithosphere would undermine the hypothesis that Venus and Earth formed with the same volatile content [2]. This hypothesis is based on the fact that Venus' atmospheric carbon is equal to the total amount of carbon in Earth's atmosphere and surface.

Methods: We are assembling a database of lava channels. We will use 1-dimensional models to explore all the parameters that govern channel formation. We plan to benchmark these 1-D models with more sophisticated, 2-D and/or 3-D simulations.

Assembling a morphologic database of lava channels. Many Magellan-era studies and some recent work focused on canali and rilles. However, no study of these channels has yet incorporated newly available, stereo-derived topography, which has more than an order of magnitude better resolution than the Magellan Global Topographic Data Record [3]. The stereo-derived topography data covers roughly 20% of Venus's surface, and will provide us with clearer insight into the channel dimensions. For example, we can measure the depth of Baltis Vallis using the stereo-derived topography but not with the GTDR (Figure 1). We will compare our measurements using the stereo-derived topography to those collected by Oshigami & Namiki (2007) [4] to validate their depth profiles calculated using the clinometric method. Should the results agree, we can use the clinometric measurements to fill in gaps in the stereo-derived topography and vice versa.

Modeling channel formation by flowing lava. One-dimensional models have been used to test the erosional formation mechanism for two canali and six sinuous rilles on Venus, as well as channels on other bodies [5,6]. Our models will explore different lava types and include more detailed treatments of key processes, such as thermal and mechanical erosion and the possible formation of insulating lids. We will use the Markov chain Monte Carlo (MCMC) method to statistically quantify the range of acceptable lava compositions and flow properties. We will first apply our models to previously studied channels. We will then study any additional channels for which we have depth profiles from stereo-derived topography. Overall, we need to use 1-D models because exploring the parameter space with MCMC requires running tens to hundreds of thousands of individual models. We will benchmark our 1-D models with more sophisticated simulations for channel formation by different lava types.

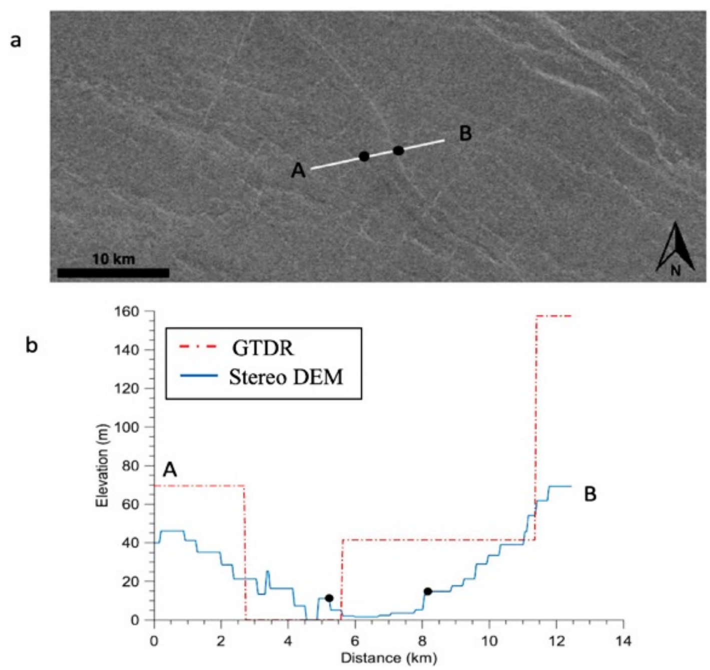

Figure 1: Stereo-derived topography allows us to measure depths of lava channels. a) Image from Magellan of one profile across Baltis Vallis, centered at 32.065°, 165.456° E. b) Baltis Vallis is resolved in the new topographic data but invisible in the GTDR.

Discussion: Our preliminary results show that models assuming various lava types, including carbonatite, can match the depth profiles of rilles (Figure 2). Our model also returns values of flow thickness, flow duration, and total lava volume. For the example shown in Figure 2, the total lava volume necessary to erode the observed depth profile of the rille is 8 ± 1 km^3. We will use this model to determine the total lava volume required to erode all of Venus' rilles and canali. If carbonatite lava is a good match to all profiles, this can give us an updated estimate for the amount of carbon that could have been sequestered in Venus' lithosphere.

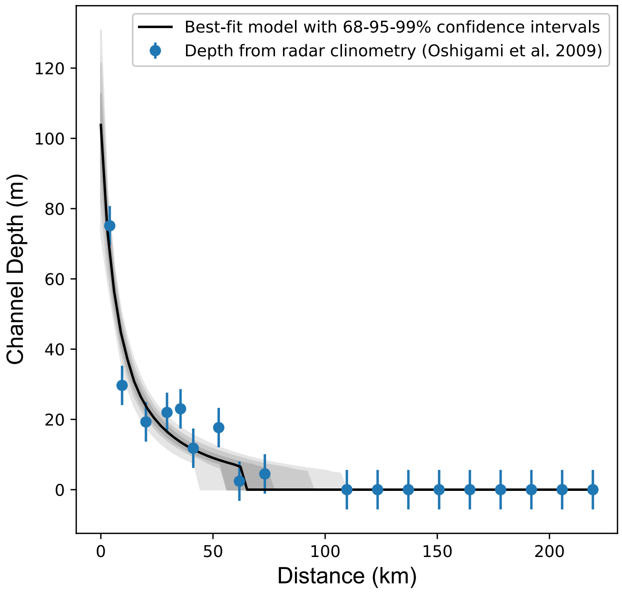

Figure 2: Our 1D model of carbonatite lava thermally eroding a carbonatite substrate is able to match the depth profile of a sinuous rille from Oshigami et al. (2008).

Recent studies have found that large amounts of carbon could be concentrated within Venus' lithosphere even without the presence of plate tectonics. Foley & Smye (2017) show that a carbon budget similar to Earth's can result in a habitable climate on a stagnant-lid planet [7]. Höning et al. (2021) also state that carbon on early Venus would have been concentrated in the crust until the temperature rose enough to evaporate all liquid water [8]. These models of stagnant-lid planets and early Venus can help inform our model parameters and contextualize our simulation results. We can in turn estimate the production rate of carbonatite lava on Venus to assess new methods of crustal carbonation and decarbonation.

Our work will also be compared to studies of carbonatite volcanism on Earth. For example, Muirhead et al. (2020) find that carbonatite volcanism serves to release carbon from concentrations along cratons along the East African Rift [9]. Additionally, Ernst & Bell (2009) observe that carbonatites are often associated with Large Igneous Provinces [10]. We can use these Earth analog studies to determine if Venus' carbonatites may have formed in a similar manner.

Future Work: We will continue to develop a more complete database of rilles and canali and will use the stereo-derived topography when possible. Additionally, we will incorporate mechanical erosion into these models. Including mechanical erosion will allow us to test more combinations of lava and substrate. Since carbonatite is such a low temperature lava, it is unable to erode basaltic substrate. However, it may be efficient enough to mechanically erode basaltic material.

Ultimately, we eagerly await vastly improved measurements of channel morphology and composition from the new generation of Venus missions. The data from these missions will allow us to test these models using improved topographic profiles as well as compositional data.

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