PRELIMINARY THERMORHEOLOGICAL MODELING OF SILICATE MELTS IN VENUSIAN CANALI. E. Harrington[1,2], G. Williams-Jones[2] [1]Centre for Planetary Science and Exploration / Department of Earth Sciences, University of Western Ontario, London Ontario, Canada, N6A 5B7; [2]Department of Earth Sciences, Simon Fraser University, Burnaby, British Columbia, Canada, V5A 1S6. (eharrin5@uwo.ca)

Introduction: Canali are long (few 100s to over 7000 km), narrow (1-5 km wide), sinuous channels found predominantly on the Venusian volcanic plains [1]. The channels show distinctively fluvial characteristics, including point bars, oxbows, and their meander wavelengths [2,3]. Given the hot ambient temperatures on Venus (~740 K at mean planetary datum), and assuming similar ambient conditions during their formation, canali are unlikely to have contained water. As such, diverse formation mechanisms have been proposed to explain their formation including thermomechanical erosion from lava, constructive emplacement of lavas, and mechanical erosion by low temperature melts [1,2]. Any fluid capable of forming canali must be able to flow the length of Baltis Vallis (7181 km), the longest canali on Venus, without solidifying. This preliminary study uses thermorheological modeling of different silicate melts to constrain possible candidates for canali formation.

FLOWGO Modelling: This study implements FLOWGO, a 1D Excel-based, kinematic thermorheological flow model [4]. FLOWGO is designed to predict the length of channelized lavas by calculating core cooling and crystallization for an aliquot of lava. It calculates the subsequent changes in temperature, rheology and velocity of lava as it flows down an increment of distance. This process is executed until either the lava core temperature reaches the stop temperature (solidification point) or the velocity reaches zero, halting the flow.

Venusian Parameters: FLOWGO has been tested under terrestrial and Martian conditions to examine the effects of lower gravity, cooler temperatures, and thinner atmosphere on lavas flow formation [5]. This is the first application of the model to Venus with a hotter, thicker atmosphere than the Earth. Parameters specific to Venus were implemented in the model, including Venusian gravity (8.87 m/s^2), predicted ambient temperature at the elevation of Baltis Vallis (~746 K), slopes of the volcanic plains (0.03-0.16°), Venusian air density (67 kg/m^3) and atmospheric specific heat capacity (1148 J/kg/K). Melt-specific variables were adjusted through different iterations. It is hypothesized that Venus' high atmospheric pressures will inhibit exsolution of volatiles in lava, leading to lower vesicularities and higher bulk densities than terrestrial lavas of the same composition [7]. Higher bulk density lengthens flows under Venusian conditions, owing to higher initial velocities at the beginning of the simulation.

Limitations within the FLOWGO model (optimized for basalt) prevent accurate modeling of very low viscosity melts, such as carbonatite or sulphur. Thus, only silicate melts have been tested thus far.

Rhyolite: Due to its high viscosity, rhyolite was not expected to flow far under Venusian conditions, nor has rhyolite been conclusively found on Venus. Rather, rhyolite is included as a proof-of-concept to compare differences between terrestrial and hypothetical Venusian rhyolite flows, as well as for comparison with other silicate melts. As expected, rhyolite flows move extremely slowly on the flat Venusian plans, with a 150-m thick rhyolite flow travelling 12.5 km before stopping.

Tholeiitic Basalt: Basalt is a candidate for canali formation based on its effusive nature, and basaltic compositional data from the Venera 8 and 13 landers. Of the melts tested, we experimented with basalt the most in terms of vesicularity and flow depth. Flow depths explored here are 17 m, 25 m, and 50 m. 17 m was chosen because it is just below the shallowest point measured at Baltis Vallis (17.3 m) while 50 m is slightly above its average depth [6]. 25 m represents the depth of the thickest lobes of the Rajahmundry Trap flows, the longest recorded lavas on Earth at ~1000 km [8].

Flow Depth (m)	Density (kg/m^3)	Effusion Rate (m^3/s)	Flow Length (km)	Flow Time (Hours)
50	2700	449,562	7,560	149
25	3000	62,206	1806	109.8
25	2700	55,933	1488	99.4
17	2700	17,510	515	69.9

Table 1. FLOWGO iterations for tholeiite basalt of varying flow depths and densities under Venusian conditions.

Basaltic flows 17 m deep traveled 100s of km, comparable to Venus' shortest canali. Flows 25 m in depth, at vesicularities of 0-10% (density = 3000-2700 kg/m^3) are capable of flowing >1000 km, longer than the Rajahmundry Trap flows, and comparable to intermediate length canali (Table 1). At 50 m depth, flow length exceeds the length of Baltis Vallis. However, such a flow would require effusion rates of ~ 450,000 m/s^3, or almost 12 times peak effusion of the Deccan Traps and would thus necessitate a planetary-scale volcanic event. Such an event could be related to a global resurfacing event, but would be unlikely if the volcanic plains were formed via numerous smaller flows.

Komatiite: Komatiite lavas can be 1-2 orders of magnitude less viscous than basalt (0.1-10 vs 800 Pa·s), and have been proposed for canali formation because of their thermomechanical erosion potential. Komatiite can flow turbulently and is hot enough to thermally erode a basaltic substrate. Due to the lower viscosities, komatiites flow at significantly higher velocities, even at shallow flow depths and low slope angles. When attempting to model the lower viscosity komatiite endmember, we encountered the same problem when modeling carbonatite: modeled flow velocities and effusion rates were unrealistically high, causing us to abandon some of the earlier trials. However, later results suggest that a 5 m deep komatiite flow at 10 Pa·s could flow 390 km on the Venusian plains. A shallower, 2 m deep 5 Pa·s flow would travel 30 km, while a 1 Pa·s, 2 m deep komatiite would flow 117 km; deeper flows resulted in impossibly high velocities in the FLOWGO model. Flow velocity in these simulations reached zero before the internal core temperature reached the komatiite solidus temperature. This suggests that the flows are becoming more crystalline as they cool, increasing the internal yield strength, until they are too viscous to move on the near-flat slopes of the Venusian plains, despite not being fully solid. Ultimately, komatiite lavas appear to cool too quickly to travel the distances required to form Venusian canali.

Venusian vs Terrestrial Flows: All the flow trials were tested under both Venusian and terrestrial conditions. Although flows on Venus have lower gravitational acceleration than those on Earth, Venusian lavas will have lower vesicularity, and therefore higher bulk densities than terrestrial flows, causing them to flow more rapidly in our simulations. Given the hotter ambient conditions, Venusian lavas lose less radiative heat than terrestrial lavas, but more heat from convection due to the thicker atmosphere which ultimately plays a larger role in heat-loss. For a lava of the same bulk composition, Venusian lavas travel faster and farther, whereas for a lava of the same bulk density, terrestrial lavas cooled more slowly, allowing them to overtake Venusian equivalents and travel farther.

Channel Dimensions: Modeling using the present channel dimensions of Baltis Vallis [6] as though it were filled with lava provides improbably high flow velocities and effusion rates. It is unlikely that Venusian canali were ever filled across their present widths. Rather, they likely formed from lower volume input via a long duration sustained flow or through multiple pulses. Sustained erosion can account for canali width without appealing to extreme effusion rates, as with terrestrial canyons.

The modelled 50-m deep tholeiitic basalt traveled over 7500 km, which is beyond the length of Baltis Vallis. However, although Baltis Vallis has an average depth of 46 m, its minimum measured depth is 17.3 m [6]. Thus, at present channel dimensions, lava in Baltis Vallis could not have been greater than 17.3 m deep at that section, lest it spill over to form levees. It is possible that the channel used to be deeper and has since been filled with cooled lava or transported materials. However, this depth restriction questions whether our models for achieving sufficiently long lava flows to form Venusian canali fit the empirical evidence from the actual canali.

Conclusions: Of the modelled melts, the 50-m deep tholeitte flow reached the >7000 km extent of Baltis Vallis. The conditions required to achieve such a flow are problematic for multiple reasons, including present-day channel morphologies, and the fact that these effusion rates would require planetary-scale volcanism. Shallower flows can achieve lengths >1000 km at shallower depths, and an order of magnitude lower effusion rates, which could explain average length canali. Nonetheless, it remains inconclusive if basalt can flow turbulently to carve out canali morphologies, and a lower viscosity non-komatiitic melt, such as carbonatite, may still be the best candidate.

Problems and Future Work: One concern with applying the FLOWGO model to Venusian canali is that the model increases flow width downflow as velocity decreases. This is to keep effusion rate constant and model how effusive lavas naturally fan out. However, canali do not widen downslope (Baltis Vallis even narrows towards its terminus), meaning that the physical dimensions being modeled do not match the true channel morphology. Future work will explore methods to better model channel morphology and explore more advanced flow models, e.g., Q-LavHA QGIS plugin [8], which incorporates FLOWGO with probabilistic steepest slope modelling.

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