The Impact of Slope Variability on the Modeling of Martian Lava Flows

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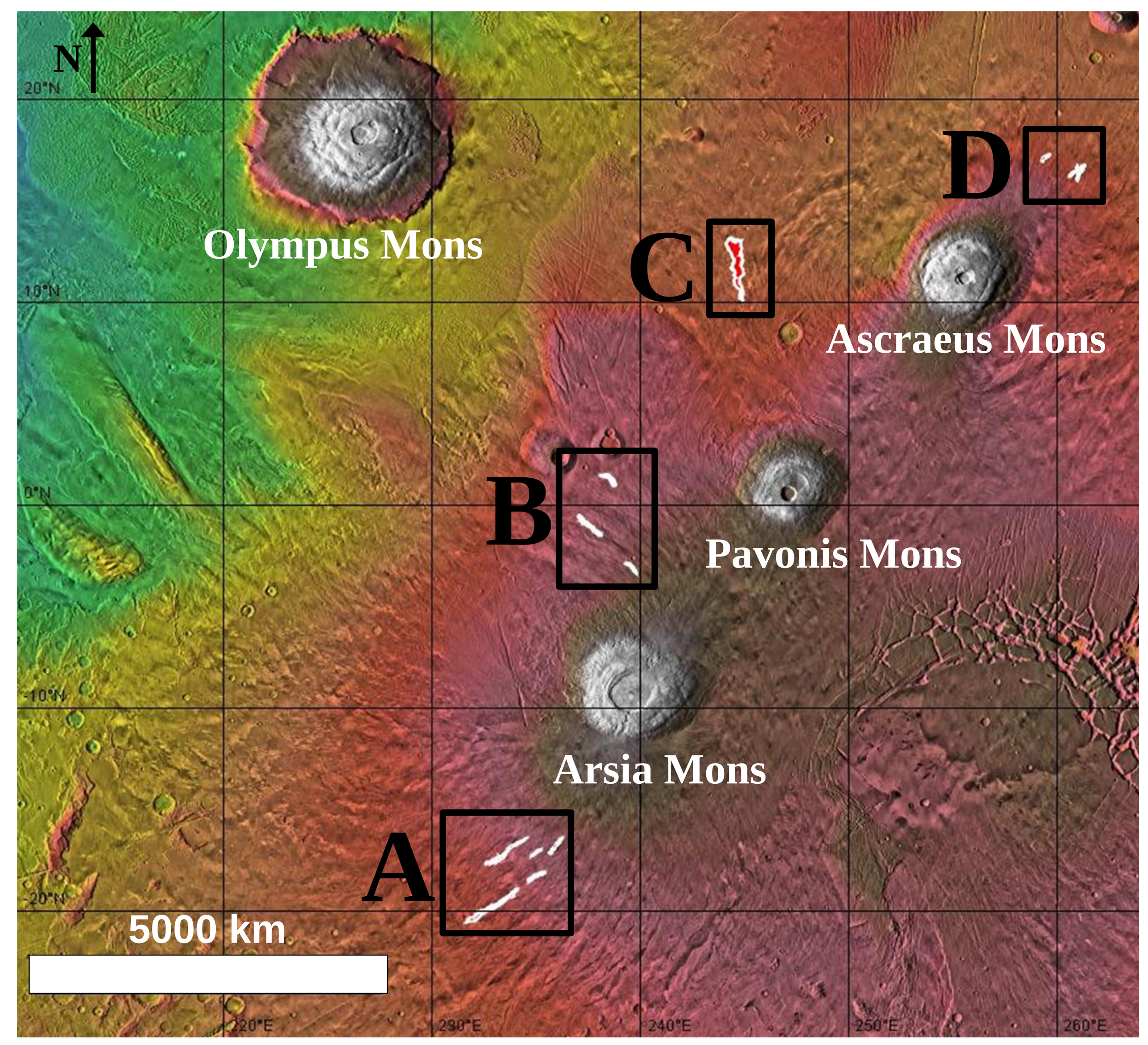
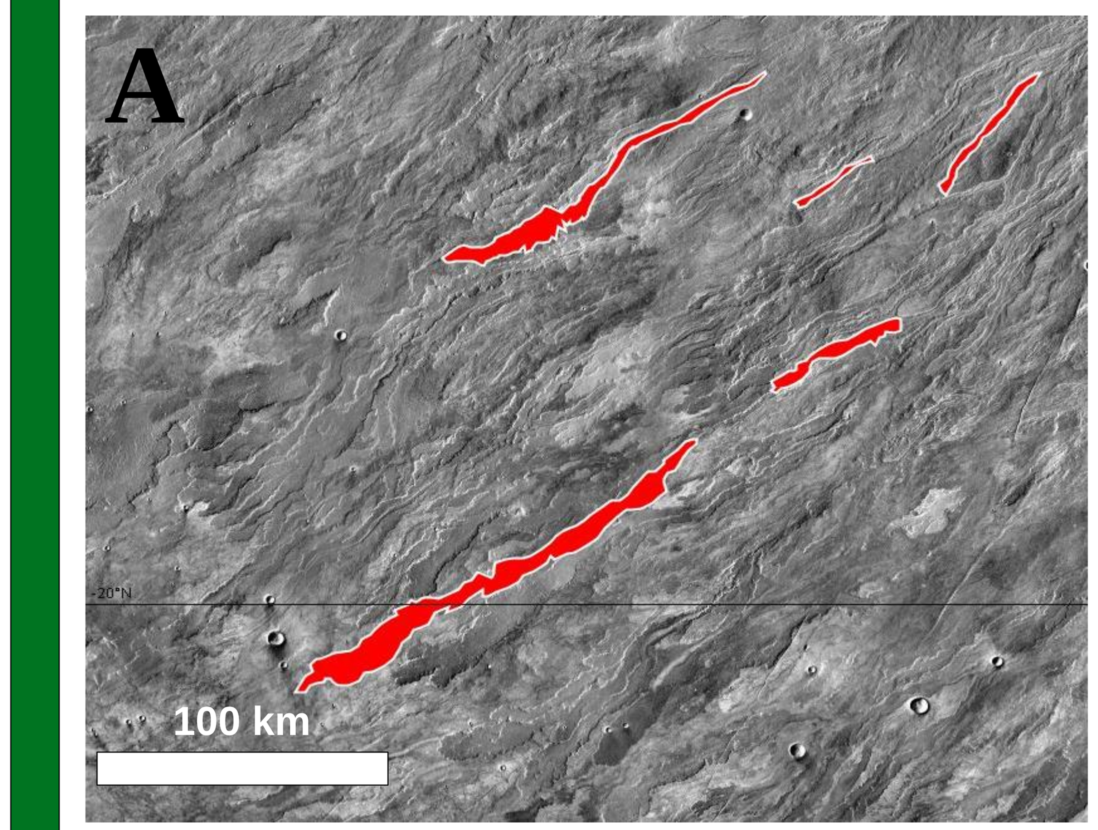
Introduction

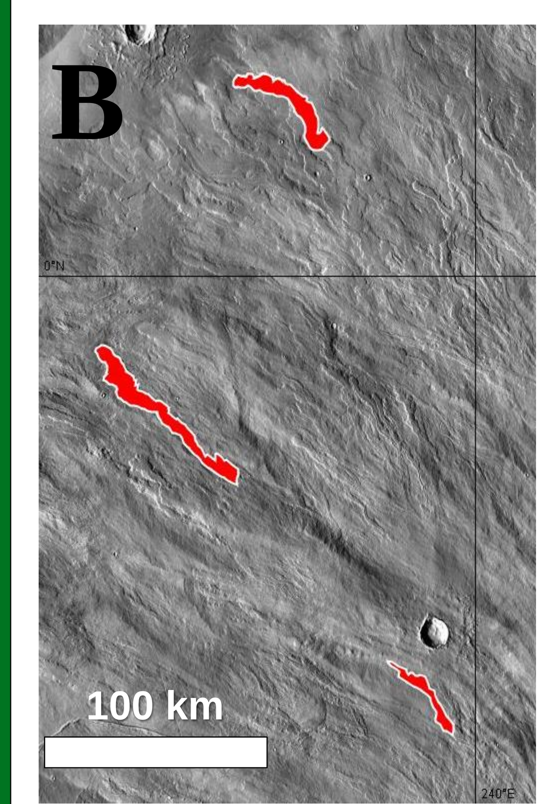
Investigation of channelized lava flows have made use of a variety of modeling techniques [1-4]. The "standard rheologic approach" is a frequently used method that has been applied to flows throughout the Tharsis volcanic province [1,2]. This approach assumes a constant slope (usually an average determined from the region) and a constant flow width (an average of values from the observable flow). These assumptions can have measurable impacts on the results [1,2]. Our study measured the individual slopes of twelve lava flows throughout the Tharsis volcanic province and examines how the minimum and maximum slope values impact the standard rheologic approach results.

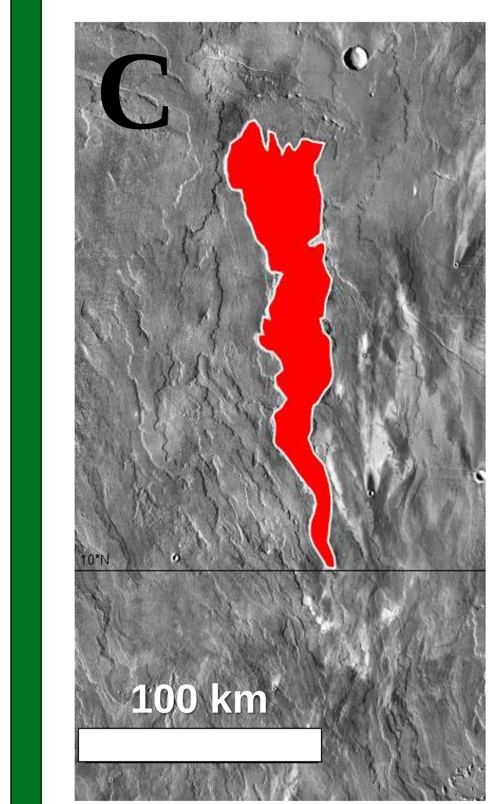
Data Collection & Calculations

- This study modeled twelve channelized flows around Arsia Mons, Ascraeus Mons, and Pavonis Mons (Fig. 1).
- Width measurements of the lava flows were taken using data from the Context Camera (CTX) (~6 m/pixel).
  - *Step 1:* Each lava flow was mapped down the central channel, with measurements of the channel and total flow widths taken every 1000 m (Fig. 2).
  - *Step 2*: Mars Orbiting Laser Altimeter (MOLA) Precision Experimental Data Record (PEDR) (~160 m spot size, ~300 m along track spacing and 37 cm effective vertical resolution) data were used to calculate the thickness of each flow along the observable flow length.
  - *Step 3:* Slopes were then calculated utilizing the MOLA/High Resolution Stereo Camera (HRSC) (~200 m/pixel; ± 3 m vertical resolution) blended Digital Elevation Model (DEM) [5]. Slope transects was taken adjacent to each flow.
- All values for effusion rate, viscosity, and yield strength were calculated using the standard rheologic equations [1].
- Calculations were also done for the average and standard deviations (SD) for the slope and channel width of each flow (Table 1).
- The results for four of the flows studied here are directly comparable to those from a prior study [2].









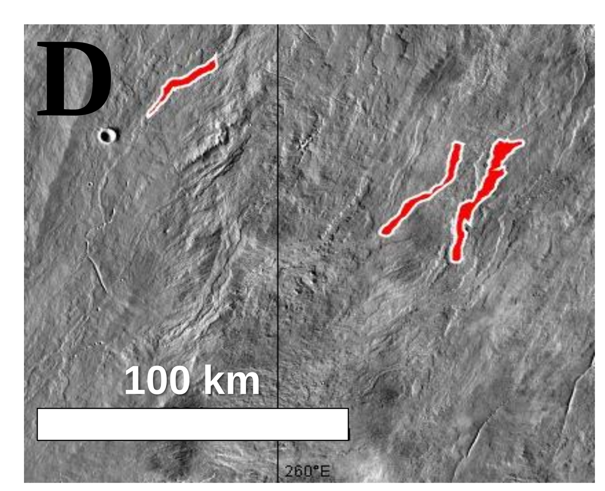


Figure 1: Location of the studied Tharsis lava flows. The colorized MOLA topography image has flow outlines overlaid. Insets provide a higher resolution view using CTX data. Inset A (AM1, AM4, AM5, AM6, and AM7), B (AM2, AM3, PM1); C (AsM3); D (AsM1, AsM2, AsM4). Insets are the same orientation as main figure.

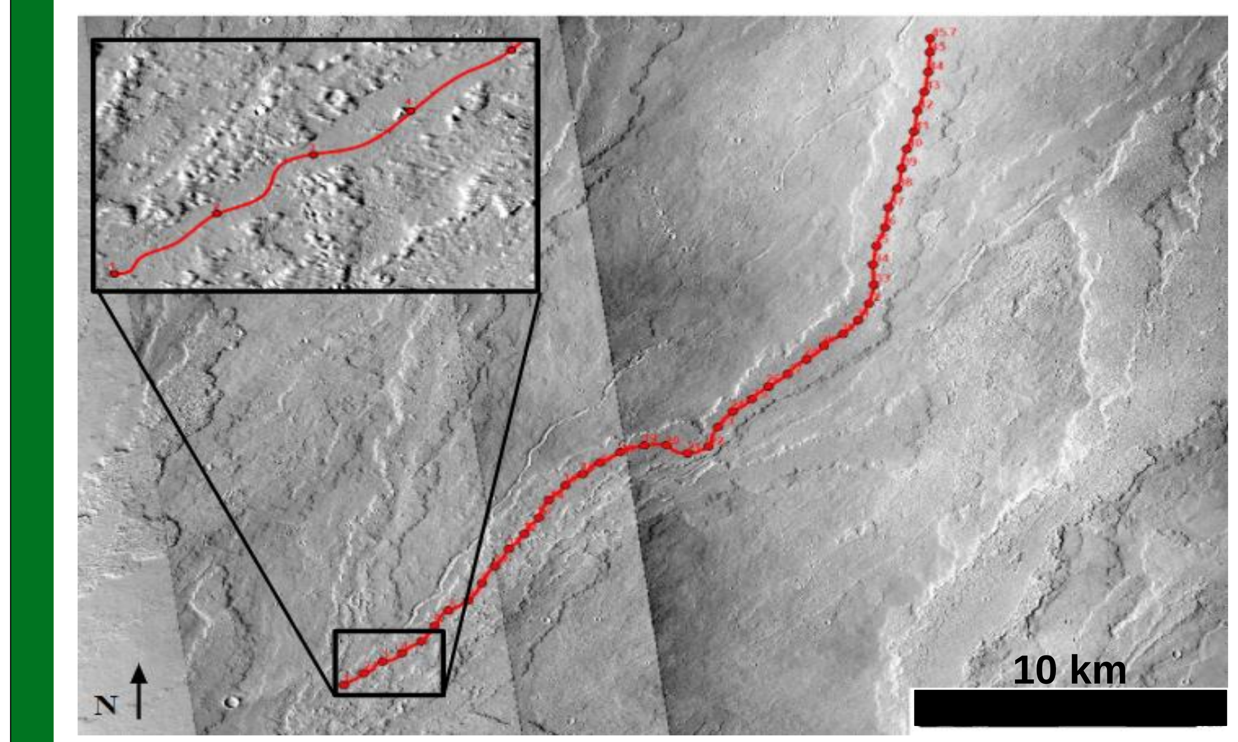


Figure 2: The AsM1 mapped lava flow located at 16.408°N, 260.884°E. Each flow was measured down the central channel, with data points every 1000 m (indicated by the red line and dots). Base images are from CTX.

Flow Number	Avg. Effusion Rate (m^3/s)	Avg. Viscosity (Pa s)	Avg. Yield Strength (Pa)	Min. Viscosity (Pa s)	Min. Yield Strength (Pa)	Max. Viscosity (Pa s)	Max. Yield Strength (Pa)
AM1	9.55×10^2	1.42×10^4	2.1×10^3	9.46×10^5	1.4×10^3	1.89×10^6	2.8×10^3
AM2	3.94×10^2	1.63×10^7	4.15×10^3	9.89×10^6	2.52×10^3	2.27×10^7	5.77×10^3
*AM3	3.26×10^3	9.33×10^5	2.1×10^3	2.44×10^5	5.49×10^2	1.62×10^6	3.65×10^3
AM4	4.66×10^3	3.13×10^5	9.76×10^2	8.66×10^4	2.7×10^2	5.4×10^5	1.68×10^3
AM5	1.93×10^3	2.71×10^5	1.29×10^3	1.81×10^5	8.63×10^2	3.6×10^5	1.72×10^3
AM6	2.0×10^3	4.05×10^6	2.8×10^3	2.42×10^6	1.68×10^3	5.66×10^6	3.91×10^3
AM7	1.6×10^3	7.72×10^4	8.02×10^2	5.18×10^4	5.38×10^2	1.03×10^5	1.07×10^3
AsM1	6.5×10^2	7.52×10^5	1.24×10^3	4.22×10^5	6.98×10^2	1.08×10^6	1.79×10^3
*AsM2	1.93×10^3	2.56×10^5	2.31×10^3	1.37×10^5	1.24×10^3	3.75×10^5	3.39×10^3
AsM3	1.13×10^4	7.04×10^6	5.24×10^3	1.98×10^6	1.48×10^3	1.21×10^7	9.01×10^3
*AsM4	1.75×10^3	4.9×10^5	2.23×10^3	3.67×10^5	1.67×10^3	6.12×10^5	2.79×10^3
*PM1	5.85×10^3	9.52×10^3	3.56×10^2	3.17×10^3	1.19×10^2	1.59×10^4	5.93×10^2

Table 1: Modeled values for effusion rate, viscosity, and yield strength for the mapped lava flows using the standard rheologic approach. The minimum viscosity and yield strength values were calculated using the slope with standard deviation subtracted, and the maximum values were calculated using the slope with the standard deviation added. *Indicates flows studied in [2].

Results

- Twelve lava flows have been modeled using the standard rheologic approach thus far in the study and the effusion rate, viscosity, and yield strength have been calculated.
- Of these lava flows, four were mapped and analyzed previously [2]. The average effusion rates, viscosities, and yield strengths for the four flows (AM3, AsM2, AsM4, and PM1) were of the same order of magnitude and comparable to the results of the prior study.
- Slope and by extension topography can cause large variability in the results using standard rheological modeling.
- The entire range of slopes should be incorporated into all rheological modeling in order to capture the full dynamic range of the eruption parameters.

Conclusions & Ongoing Work

Initial assessment of the results indicate that the standard rheologic modeling approach is sensitive to the slope value used. This work is ongoing and expanding to employ other models; however, initial results are promising. For example, comparison of the results for four of the flows examined here to those produced using the PyFLOWGO model [7,8] shows that both produce similar effusion rates, whereas the viscosity and yield strength are different. Future modeling will compare the results from PyFLOWGO and the Self-Replication model [9] for all the flows examined here. Utilizing two additional models to constrain the effects of slope variation on the derived eruption parameters provides a more robust test of the standard rheologic approach.

References

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