RHEOLOGY OF LAVA FLOWS ON ELYSIUM MONS, MARS. H. Hiesinger[1], J.H. Pasckert[1], D. Reiss[1]. [1]Institut für Planetologie, Westfälische Wilhelms-Universität, Wilhelm-Klemm-Str. 10, 48149 Münster, Germany. Hiesinger@uni-muenster.de

Introduction: It is known from previous studies that in principle, the dimensions of lava flows reflect rheologic properties such as yield strength, effusion rates and viscosity [1-17]. In a previous study, we reported on such derived rheologic properties of lava flows on Arsia Mons, Pavonis Mons, and Ascraeus Mons, which are located on the extensive Tharsis bulge [1,2]. Here, we expand on our previous study of lava flows on the Tharsis Montes by calculating the rheology of lava flows on Elysium Mons in order to investigate possible similarities and differences among the lava flows of the two major volcanic provinces located in two hemispheres on Mars.

Data: We used images obtained by the High Resolution Stereo Camera (HRSC) on board ESA's Mars Express spacecraft in combination with Mars Reconnaissance Orbiter Context Imager (CTX) images and Mars Orbiter Laser Altimeter (MOLA) data to identify, map, and measure the dimensions and slopes of lava flows in order to constrain their rheologic properties. We utilized several HRSC orbits with spatial resolutions of about 12.5-25 m/pixel and CTX images with 5-6 m/pixel spatial resolutions in order to measure the length and width of the studied lava flows. The heights and slopes of the lava flows were measured in individual MOLA profiles.

Method: As in our previous studies, we make a few basic assumptions: (1) flow dimensions are related to the rheological properties of the flow, (2) rheological properties can be estimated from flow dimensions measured in remotely sensed data, (3) lava flows behave as Bingham fluids, (4) lava flows in laminar fashion, (5) no inflation of lava flows has occurred, (6) the densities of Martian volcanic rocks are on average 2,500 kg m^{-3}, (7) the Graetz number is 300, and (8) the thermal diffusivity is on the order of ~10^{-4}-10^{-8} m^2s^{-1} with an assumed value of 3 x 10^{-7} m^2s^{-1}. Moore et al. [4] and others [e.g., 5] related the yield strength τ of lava flows (Pa) to the flow dimensions by the following equations

$$\tau = \rho\, g \sin\alpha\, h \quad (1)$$
$$\tau = \rho\, g\, h^2/w \quad (2)$$
$$\tau = \rho\, g \sin^2\alpha\, 2w_l \quad (3)$$
$$\tau = \rho\, g \sin^2\alpha\, (w\text{-}w_c) \quad (4)$$

where ρ is the density (kg m^{-3}), g is the gravitational acceleration (m s^{-2}), α is the slope angle (degree), h is the flow height (m), w is the flow width (m), w_l is the total levee width (m), and w_c is defined as the width of a leveed channel (m).

The effusion rates Q (m^3 s^{-1}) can then be calculated as

$$Q = G_z\, \kappa\, x\, w/h \quad (5)$$

where G_z is the dimensionless Graetz number, κ is the thermal diffusivity (m^2 s^{-1}), x is the flow length (m), and w and h are defined as above [e.g., 3,5].

The viscosities η (Pa-s) were calculated using the relationship given for example by [6,7].

$$h = (Q\, \eta/\rho\, g)^{1/4} \quad (6)$$

Jeffrey's equation relates the viscosity of a flow to its effusion rate and its dimensions [e.g., 8-10].

$$\eta = (\rho\, g\, h^3\, w \sin\alpha)/nQ \quad (7)$$

In this equation n is a constant equal to 3 for broad flows and 4 for narrow flows.

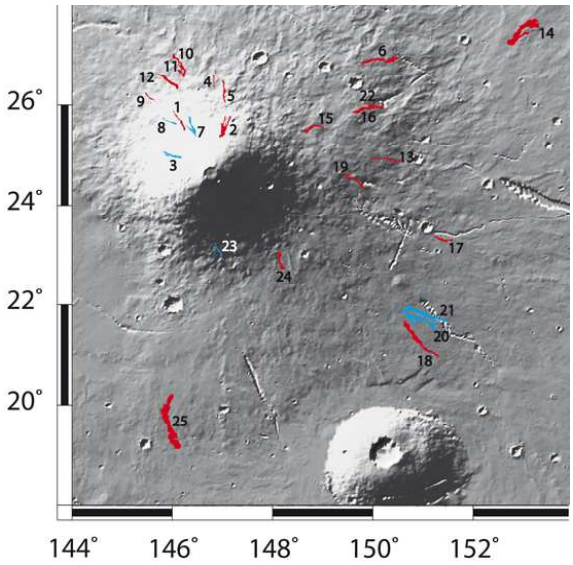

Fig. 1: Investigated lava flows in the Elysium Mons region. We have calculated the rheologic properties of the red lava flows.

Results for Elysium Mons: We have mapped 25 individual lava flows in the Elysium Mons region (Fig. 1). These lava flows occur both on the flanks of Elysium Mons, as well as on the plains surrounding the main edifice. So far, we have measured the dimensions and calculated the rheologic properties of 19 of those flows. All morphometric parameters were measured several times along each flow and were averaged for the calculation of the rheologic properties. Figure 2 shows lava flow 6 as an example of our measurements. The average lengths of the investigated Elysium flows vary between 13.2 and 60 km and the average widths are on the order of 790-5700 m. Based on individual MOLA profiles that cross the lava flows, we derived average thicknesses of 5-24 m. Slope measurements were performed in the im-

mediate vicinity of the flow and on top of the flow in order to get best estimates of the topography/slopes prior to the emplacement of the lava flows. These measurements revealed average slopes of 0.06-6.9°.

Our estimates of the yield strengths of flows on Elysium Mons range from ~1.1 x 10^2 Pa to ~2.7 x 10^4 Pa, with an average of ~5.8 x 10^3 Pa if calculated with equation (1). Calculations of the yield strengths with equation (2) yield similar yield strengths of ~3.5 x 10^2 Pa to ~4.1 x 10^3 Pa, with an average of ~1.5 x 10^3 Pa. These values are in good agreement with estimates for terrestrial basaltic lava flows. The effusion rates are on average ~358 $m^3 s^{-1}$, ranging from ~99 $m^3 s^{-1}$ to ~975 $m^3 s^{-1}$. Applying equation (6), viscosities were calculated to be on average ~5.0 x 10^6 Pa-s, ranging from ~4.0 x 10^4 Pa-s to ~2.0 x 10^7 Pa-s. We also calculated the viscosities with equation (7) and found similar results. In this case, the viscosities varied from ~2.0 x 10^4 Pa-s to ~3.6 x 10^7 Pa-s, with an average of ~5.4 x 10^6 Pa-s. On the basis of our effusion rates and the flow dimensions, we calculated that the time necessary to emplace the flows is between 4 and 75 days, with an average of ~41 days.

	τ (Pa)	**Q ($m^3 s^{-1}$)**	**η (Pa-s)**	**T (days)**
Ascraeus	2.1 x 10^4	185	4.1 x 10^6	26
Pavonis	3.4 x 10^3	242	1.6 x 10^6	22
Arsia	2.2 x 10^3	567	2.5 x 10^6	30
Elysium	3.7 x 10^3	358	5.2 x 10^6	41

Table 1: Comparison of average rheologies of lava flows on the Tharsis Montes and Elysium Mons. Data for the Tharsis flows are from [1,2].

Comparison to Tharsis Montes lava flows: Our results for lava flows on Elysium Mons are principally similar to our results for the Tharsis Montes lava flows. Average yield strengths and effusion rates of the Elysium flows are within the range of the Tharsis flows; the viscosities are slightly higher but on the same order of magnitude (Table 1).

Conclusions: On the basis of our study we conclude that our results for the yield strength, effusion rate, eruption duration, and viscosity are consistent previously published results for Martian and terrestrial basaltic lava flows. In particular, the studied flows on Elysium, Ascreaus, Pavonis, and Arsia Mons show very similar rheologic properties. We do not see significant differences in rheologic properties between the flows in the eastern and western hemisphere, suggesting a similar basaltic composition of the flows of the major volcanic complexes on Mars.

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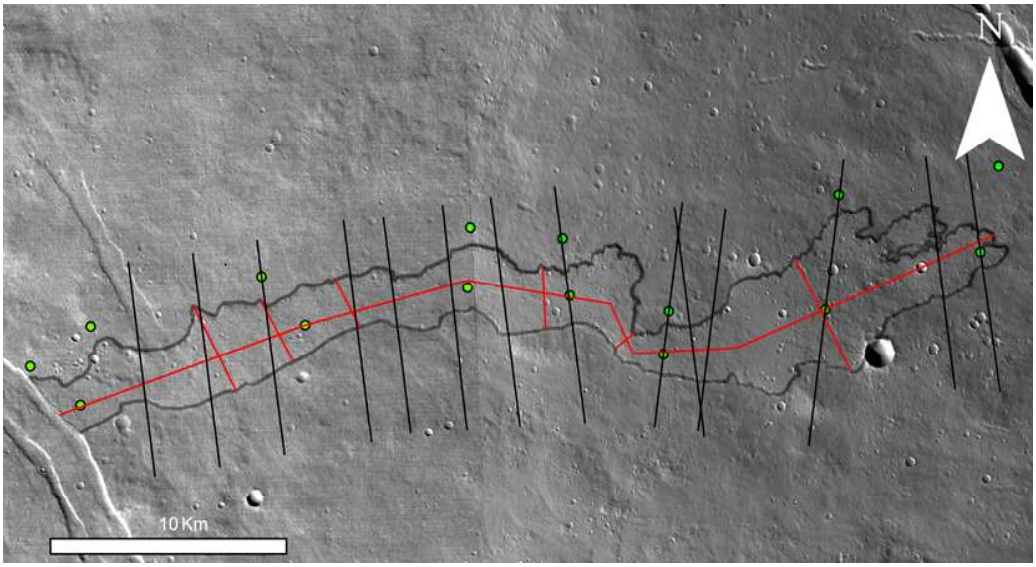

Fig. 2: Example of measurements for lava flow 6 northeast of Elysium Mons. Green dots represent the locations where the slope has been measured; red lines indicate the locations of length and widths measurements; straight black lines are sections of individual MOLA profiles used to calculate the height of the flow. For the location of lava flow 6 see Fig. 1