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

Introduction: We present results of our study of the rheologies and ages of lava flows on the Martian volcano Elysium Mons. Previous studies have shown that the geometric dimensions of lava flows reflect rheological properties such as yield strength, effusion rate and viscosity [1-8]. This work expands on our earlier studies of the rheologic properties of lava flows on Arsia Mons, Pavonis Mons, and Ascraeus Mons, and compares these two volcanic regions [1,2,3]. In addition we investigated possible changes in ages and rheologies of the lava flows with distance to the caldera of Elysium Mons.

Data: To identify, map, and measure the dimensions of the lava flows, we used images obtained by the High Resolution Stereo Camera (HRSC: 12.5-25 m/pixel) on board ESA's Mars Express spacecraft, in combination with Mars Reconnaissance Orbiter Context Imager (CTX: 5-6 m/pixel) images and Mars Orbiter Laser Altimeter (MOLA) topographic data.

Methods: To investigate the rheological properties of the lava flows, some assumptions have to be made: (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 a 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}. The equations utilized in this study have been derived by Moore et al. [5] and others [e.g., 6, 7, 9] and have also been used in our previous studies [1, 2, 3, 10].

To derive the ages of the lava flows, crater size-frequency measurements were carried out, by using the chronology function from Hartmann and Neukum [11] and the production function from Ivanov [12]. For reliable crater counts it is important to exclude secondary craters, i.e., craters that were formed by the impact of material ejected by primary craters. At CTX resolution (5 to 6 m/pixel), this proved to be difficult because of the large number of small craters on the relatively small count areas of the lava flows. In particular, in some cases separating small secondary from primary craters was difficult because of the generally rough appearance of the flow surfaces and possible subsequent modification of the craters.

Results: In total, 35 lava flows on and around Elysium Mons with distances from the caldera between 53 and 640 km were mapped. The rheological properties of 32 of these flows were determined. Three of the flows were too small in width to yield reliable heights from the MOLA profiles. The lengths of the Elysium flows vary between 9.9 and 118 km, with widths on the order of 430 m to 13.7 km. The MOLA profiles of the investigated flows indicate heights of 5 to 34 m and slopes of 0.06 - 6.9° of the flows. Using the results of these morphometric measurements of each individual lava flow, estimates for the yield strengths (τ), effusion rates (Q), and viscosities (η) of the studied lava flows were made (Tab.1). The yield strengths of the Elysium Mons lava flows range from ~3.8 x 10^2 Pa to ~1.5 x 10^4 Pa, with an average of ~3.0 x 10^3 Pa. These values are in good agreement with estimates for terrestrial basaltic lava flows. The effusion rates are on average ~723 m^3 s^{-1}, ranging from ~100 to 4450 m^3 s^{-1}. The viscosities show an average of about 4.0 x 10^6 Pa-s with a range of 1.6 x 10^5 Pa-s to 2.5 x 10^7 Pa-s. The eruption durations of the flows were calculated to be between 6 and 175 days, with an average of ~50 days.

	τ (Pa)	Q (m^3 s^{-1})	η (Pa-s)	T (days)
Terr. Basalt	10^2-10^6	1-10^3	10^3-10^7	-
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	3.0 x 10^3	723	4.0 x 10^6	50

Table 1 Comparison on average rheologies of lava flows on the Tharsis Montes, Elysium Mons and terrestrial basalts. Data for the Tharsis flows are from [2,3] and data for terrestrial basalts are from [5, 9].

These determined rheological properties are in general very similar to those of other volcanic regions on Mars, such as the Tharsis Montes [2]. The calculations of the yield strengths and viscosities point to a basaltic/andesitic composition of the lava flows, similar to basaltic or andesitic a'a lava flows on Earth (Fig. 1).

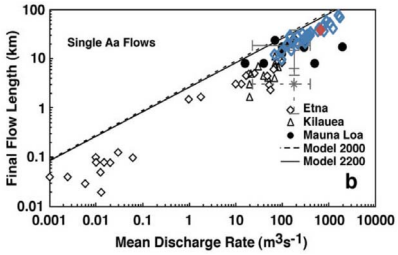

Figure 1: Correlation between the effusion rate and the final flow length of terrestrial and Martian lava flows. The blue diamonds show the results from this study. The red diamond responds the average value of all flows of Elysium Mons. The results for Ascraeus Mons lava flows calculated by [2] were plotted in gray. (modified from [2])

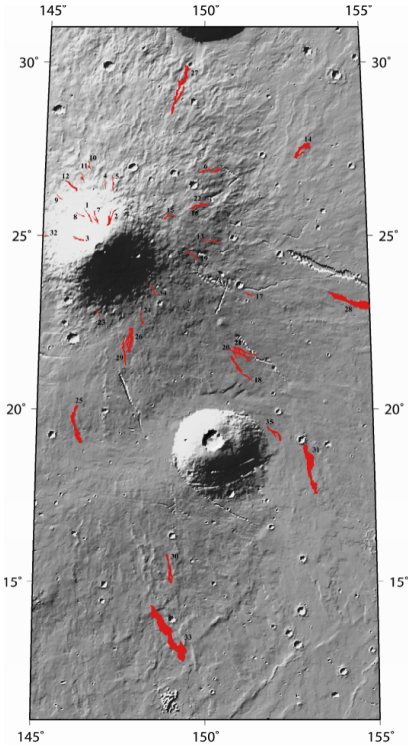

Figure 2: Investigated lava flows in the Elysium Mons region.

The ages of all 35 lava flows on Elysium Mons were measured. The derived absolute model ages show a wide variation from about 530 Ma to 3500 Ma. The crater size-frequency measurements of the Elysium Mons caldera show an age of ~1500 Ma, which is consistent with the crater counts performed by Werner et al. [13]. However, the crater counts on HRSC images by Werner et al. [13] also indicate an age of 3500 Ma years with a resurfacing event at 1600 Ma. They interpreted this resurfacing event to be of eolian origin. However, in CTX images we did not find evidence for eolian processes or deposits such as dunes. Consequently, we interpret the 1500-1600 Ma age to represent the last volcanic activity in the Elysium Mons caldera (Fig. 3).

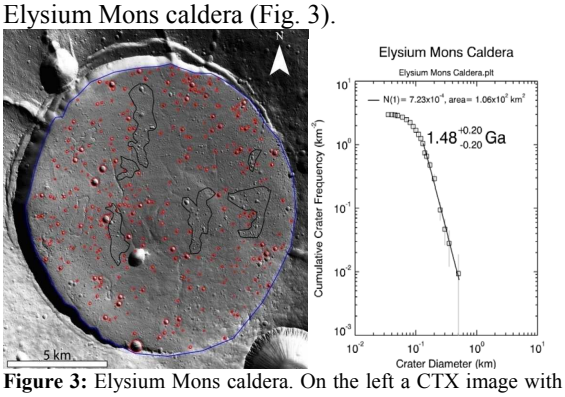

Figure 3: Elysium Mons caldera. On the left a CTX image with the mapped caldera in blue and the counted craters in red. The areas outlined in black have been excluded because of secondary cratering. The crater size-frequency plot on the right shows an age of 1.48 Ga for the Elysium Mons caldera.

A significant change of the rheologies over time could not be observed. Also, while there appears to be a decrease in the viscosities and yield strengths with increasing distance from the caldera, the correlation is statistically very weak. A diagram of the distance versus the age appears to show a possible decrease in age of the flows with increasing distance to the caldera. While on the basis of our data this trend is highly speculative, crater counts of lava flows in Elysium Planitia from Hartmann and Berman [14] showed much younger ages (10 - 300 Ma) and hence might be consistent with this hypothesis (Fig. 4). However, we can not be certain that all of the studied flows were formed by eruptions of Elysium Mons. Consequently, it is impossible to argue that flows at larger distances to the caldera are systematically younger.

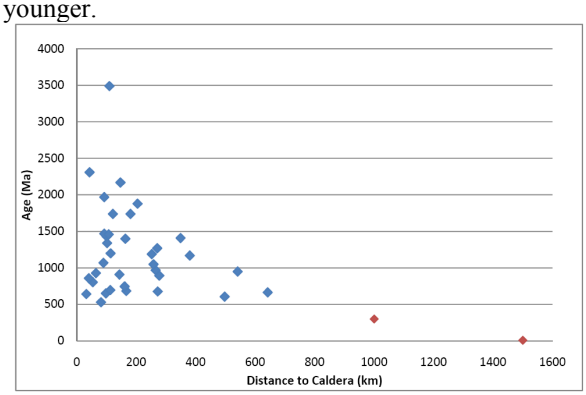

Figure 4: Ages of lava flows versus their distance to the caldera of the Elysium Mons. The blue diamonds show the results from this study and the red diamonds were taken from [14].

Conclusions: On the basis of our studies we conclude that the rheological properties of lava flows in the Elysium Mons region point to basaltic or andesitic a'a flows, very similar to those of the Tharsis Region [2,3]. In terms of rheologic properties, there is no significant difference between lava flows in the eastern and western hemisphere of Mars. We do not see evidence for systematic changes of the rheological properties with the distance to the caldera on Elysium Mons or with the age. The derived absolute model ages of the lava flows indicate volcanic activities of Elysium Mons over nearly the whole geological history of Mars.

References:

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