GEOMETRY AND FLOW PARAMETERS OF LAVAS OF OLYMPUS MONS VOLCANO: MARS. E. A. Bazilevskaya[1] and G. Neukum[2], [1]Geological Department, Moscow State University, Vorobievy Gory 119992, Moscow, Russia, Ek_Bazilevs@mail.ru, [2]Freie Universitat Berlin, Berlin, Germany

Introduction: This work is a continuation of our previous study when using the MGS MOC images and MOLA profiles we have measured the thickness of lava flows in several localities of Olympus Mons volcano on Mars [1]. This time we report on the study of other geometric characteristics of lava flows observed on the surface of Olympus Mons volcano, such as their length, width and also slopes of the surface on which the lava flows flowed. Combining them with the earlier measured thickness values we estimate some parameters of the lava eruption: yield strength, effusion rate and viscosity of the lava.

Lava flows, which are subject of this study, are streaming downslope in directions generally radial to the volcano center. Some of them are cut by the basal scarp of the volcano, others extend over it onto the surrounding plains. Many of the individual flows have axial channels similar to those of the channel-fed terrestrial basaltic lava flows. We studied these flows, analyzing HRSC, MOC and MOLA data.

Morphology and Dimensions: We studied the mentioned parameters of lava flows on the southern slope of Olympus Mons volcano. For that we have made a schematic geologic map based on the analysis of the HRSC image 0037 with resolution of 20 m. This mapping allowed us to divide the southern slope into 4 zones (Figure 1).

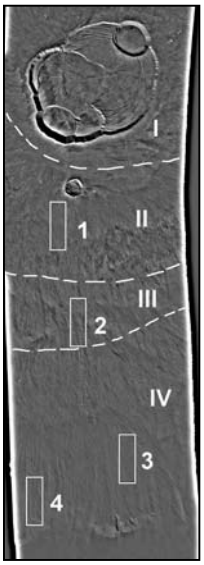

Figure 1. Fragment of HRSC image 0037, on the basis of analysis of which a schematic geologic map has been made. I to IV – zones, 1 to 4 – study areas each 8.9 x 27.9 km.

Zone I is characterized by individual flows that originate from the caldera scarps and flowed towards west and east. Width of the flows (~500 m) generally exceeds values for other zones. Zone II (extends 70 km down slope) – zone of flows, which outlines are significantly camouflaged by wind erosion and airborn dust deposition so only several flows could be well seen. Among them, two unusually wide, short and thick palmate flows are observed. Specific distinction of Zone III (40 km down slope) are areally extensive complex flows (~1 km wide), composed of tens of overlapping individual flows with vague outlines. Zone IV (110 km down slope, terminates at the foot of Olympus Mons) presents a net of clear-cut individual flows, mostly channel-fed. Within Zones II – IV collapsed lava tubes could be locally recognized as chains of pits ~150m wide and up to 1.7 km long.

On the geologic scheme, within Zones II-IV, we have outlined four 8.9 x 27.9 km areas where the measurements of lava width and length as well as the slope steepness have been made (Figure 2).

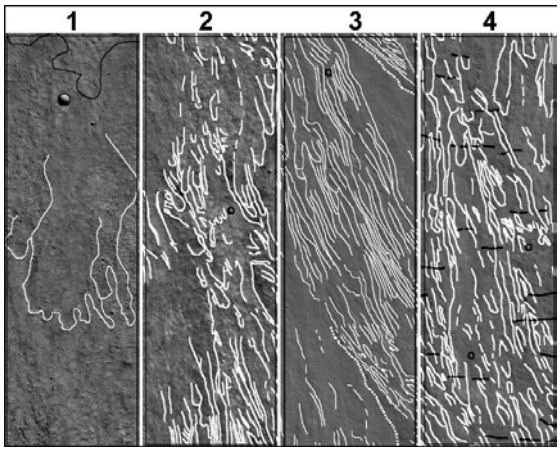

Figure 2. Four study areas on southern slope of Olympus Mons with lava flows outlines. Fragments of HRSC image 0037.

Measurements of width of the flows have been made for each of the four selected areas. The whole flow width (W) and the width of the leveed flow channel (w) have been determined if seen. *Measurements of length* of 30 individual lava flows of southern slope of Olympus Mons have been mostly made within the selected zones although in some cases we have traced the flow outside of the area. The average *slope steepnesses* have been measured using the MOLA database as mean values for each of four selected areas. The results of measuremens are summarized in Table 1.

Table 1. Results of measurements of geometric characteristics of lava flows of Olympus Mons

Area	Mean flow width (W)	Mean channel width (w)	Length (L)	Slope
1	~4.8 km; ~2 - 1.4 km	-	22.2 km	3.4°
2	377 m	-		4.9°
3	395 m	144 m		4.4°
4	484 m	220 m		6.9°

Measurements of lava flow thickness have been done in our previous work [1]. We have been searching for MOC images on which steep scarps of the volcano are seen: in any places of volcano, not only on the southern slope. In these places the

apparent thickness of the outcropped flows was measured and using MOLA measurement of the slope steepness, the apparent thickness was recalculated into the true one. The resulting mean values for true thickness are ~6.7 m for the volcano flanks and ~11 m for the caldera slopes.

The results of the width, length and slopes measured for the southern flank of Olympus Mons have been combined with the measurements of thickness made for different flanks and caldera and then jointly used for estimates of the parameters of eruption.

Estimates of the parameters of eruptions:

Yield strength. Lava flows are often modeled as a Bingham plastic controlled by two parameters, the yield strength and the plastic viscosity. Several geometric parameters, measurable from images, give an opportunity to determine the yield strength of lava flow Y:

$Y_1 = \rho g H \sin \alpha$

$Y_2 = \rho g H^2/W$

$Y_3 = \rho g (W-w) \sin^2 \alpha$

Gravity g is known as 3.7278 ms^{-2} and density ρ was chosen to be 2,500 kgm^{-3} following Hiesinger et al. [2], Zimbelman [9], H – is thickness of lava flow. Depending on the equation used, we find a minimum yield strength of ~0.9 x 10^3 and a maximum yield strength of ~3.6 x 10^4 Pa, with the average 7.9 x 10^3 Pa.

Effusion rate. The effusion rate (R) is given as

$R = 300\ k\ w\ L/H$,

where k – is thermal diffusivity of the fluid (taken 7 x 10^{-7} m^2s^{-1} for mafic lavas following Zimbelman [9]), L is the flow length (m), and w and H is defined as above. For calculating effusion rate we took mean length of lava flows (22.2 km) for regions 2-4. As a result we find that effusion rates range from ~24 to ~137 m^3s^{-1}, averaging about 53 m^3s^{-1}.

Viscosity. Viscosity (η) of a flow can be calculated with the estimated yield strengths and effusion rates obtained above [8].

$r = w/(W-w)$

$\eta = w^3 Y \sin^2 \alpha /24 R$ for $r < 1$

$\eta = w^{11/4} Y^{5/4} \sin^{6/4} \alpha /24 R\ g1/4\ \rho 1/4$ for $r \geq 1$

where r – is ratio of the channel width to the total levee width. As a result we calculated average viscosities of ~6 x 10^5 Pa-s. Minimum viscosities are on the order of 1.4 x 10^3 Pa-s, maximum viscosities are about 2.8 x 10^7 Pa-s.

Discussion:

Geometric characteristics of lava flows. Calculated lengths of Olympus Mons lava flows (average ~22.2 km) are in good agreement with results of Hiesinger et al. [2] for flows of Ascraeus Mons (average length ~19 km). According to [4] typical values for length of basaltic lava flows of Hawaiian volcanoes do not exceed 50 km.

Results of our measurements of the Olympus Mons lava flow thickness (mean values = ~11 m for the caldera scarps and ~6 m for the volcano flanks) are in a good agreement with Schaber et al. measurements [7] for different localities of Tharsis region of Mars and with typical thicknesses reported for the terrestrial basaltic flows (3-20 m [4]).

Estimation of rheologic properties. Our results of estimation of yield strength (average ~7.9 x 10^3) are in good agreement with estimates for terrestrial basaltic and adesitic lava flows (~10^3-10^4 Pa and ~10^4-10^6 Pa correspondingly), and are comparable with estimates of Hiesinger et al. (~2.7 x 10^4 Pa) [2] and Zimbelman (~2.1 x 10^4 Pa) [9] derived for lava flows on Ascraeus Mons.

On the basis of our calculations we derived the values of effusion rate for studied lava flows of Olympus Mons – average ~53 m^3s^{-1}. These results are within the range of 5-1000 m^3s^{-1} effusion rates typical for Hawaiian basaltic eruptions [6] and are in excellent agreement with results of Hiesenger et al. [2] for lava flows of Ascraeus Mons (average ~68 $м^3с^{-1}$)

We estimated average viscosities of studied lava flows on Olympus Mons to be ~6 x 10^5 Pa-s. According to Macdonald [5] field measurements of basaltic lavas indicate viscosity of 10^2-10^4 Pa-s. Hulme [3] reported viscosities of 1.7 x 10^7 Pa-s for andesites of the Paracutin volcano in Mexico. Previously published values for viscosity of Martian lava flows range from 5.2 x 10^5 to 2.1 x 10^8 Pa-s [2, 3, 9].

Conclusions: Calculated yield strengths, effusion rates and viscosities for flows on Olympus Mons are similar to values obtained for flows on other Martian shield volcanoes. Values for yield strength and effusion rates are in good agreement with data for terrestrial shield volcanoes, and calculated viscosities of the Olympus Mons lava flows partly coincide with the results of field measurements of viscosities of terrestrial basalts. On the basis of our investigation we conclude that the lava flows investigated are likely to be basaltic to andesitic in composition.

References:

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