THICKNESS OF THE OLYMPUS MONS LAVA FLOWS AS MEASURED FROM THE MGS MOC AND MOLA DATA: VOLCANO CALDERA AND FLANKS. E. A. Bazilevskaya. Geological Department, Moscow State University, Vorobievy Gory 119992, Moscow, Russia, bazz_tazz@mail.ru.

Introduction. Here we report on the study of thicknesses of lava flows observed on the surface of Olympus Mons volcano (Figure 1).

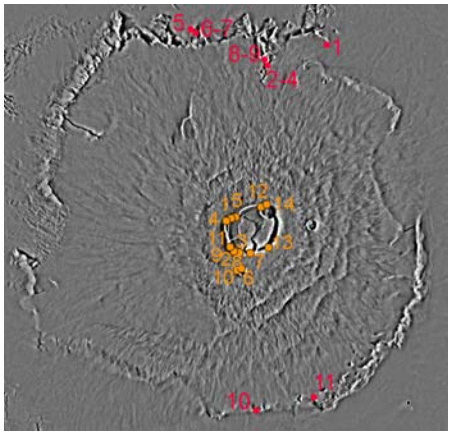

Figure 1. Olympus Mons volcano as viewed from the north. Source: http://esamultimedia.esa.int/marsexpress.

This 600 km in diameter feature was discovered in the images taken in 1972 by Mariner 9 and soon classified as shield volcano composed of accumulations of basaltic lavas [2]. Since then, this classification has been confirmed by many new missions to Mars [see, e.g., 4]. Lava flows which are subject of this study are typically 10 to 20 km long and 200 m to 2 km wide streaming down slope in directions generally radial to the volcano center. We plan to make extensive study of these lava flows based on analysis of the data taken by the Mars Express High Resolution Stereo Camera as well as Mars Global Surveyor camera MOC and laser altimeter MOLA. Here we report on the fist stage of this study that is measurements of the lava flow thicknesses.

Measurement technique. The studied lava flows are of rather small width so for their analysis the data with high spatial resolution are needed. Unfortunately the available high-resolution images taken by MOC and recently by HRSC have been taken at high Solar elevation above the horizon (typically >60^{o}), so the often used in planetary science shadow technique is practically not applicable in this case. Measurements using MOLA profiles crossing individual lava flows are possible but because MOLA footprint is about 200 m across, that is comparable with width of some flows and with significant elements of others, we decided not to use this approach. The HRSC stereo images provide reliable digital terrain models but in the routine technique its spatial resolution is also close to 200 m.

In our study, fisrt presented at the Brown-Vernadsky Microsymposium [1] we used different approach: We have been searching for MOC images on which steep scarps of the volcano are seen. We used for measurements only those images where on top of the scarp typical lava flows were observed and on the scarp itself, layers obviously consisting of these and similar lava flows were visible (Figure 2).

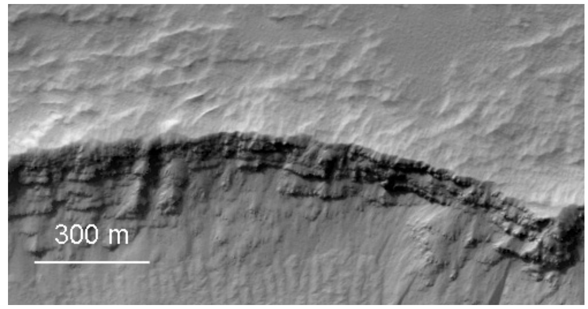

Figure 2. Lava flows forming layers seen in the scarp. Fragment of MOC image M08-05051.

On these images we have measured apparent thicknesses of the most prominent layers. For part of these images are available MOLA profiles so we could measure the slope steepness aiming to transform apparent thicknesses to true ones. However, as a rule, MOLA profiles were not going directly downslope but under some angle to it that demanded additional corrections. Moreover because MOLA profiling was being done only until the MGS MOC working stage E6, only part of scarps with the outcropped layers are characterized by MOLA profile. So, after selecting images with visibly steep scarps with prominent lava flows on them we made a search for MOLA data for any visibly steep scarps within the Olympus Mons construct. Then we determined steepness of these slopes, including corrections when MOLA profile was oblique to the slope (Figure 3), calculated mean value of the slope steepness (35.5^{o}, standard deviation = 6.4^{o}) and applied it to calculate true thickness for all our measurements.

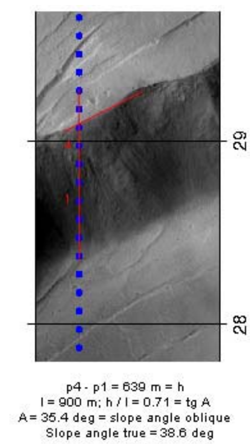

Figure 3. Example of the measurement of the slope steepness. Fragment of MOC image E01-02040.

We found that the scarp steepness does not depend noticeably on the geologic situation (collapse scarps of the volcano external slopes, summit caldera scarps, uppermost scarps of large impact crater) being probably just a repose angle. So we probably can use the mean (for the studied situations) value of the scarp steepness (α) to apply for recalculation of apparent thickness to true thickness by multiplying apparent thickness by tg α. The measured values for the sites (25 to 50^{o}) and the mean of the values (35.5^{o}) are in a good agreement with measurements for the Western scarp of Olympus Mons based on HRSC based digital terrain model [7].

Comparing to [1] we have made additional measurements: one more measurement on the volcano flanks and 23 in the scarps of Olympus caldera. So we have 9 stations of observation with 14 measurements at the volcano flanks (red symbols in Figure 1) and 14 stations with 23 measurements in the upper parts of the caldera scarps and in the scarp of nearby impact crater (orange symbols in Figure 1). Resolution of MOC images used for the measurements of lava flow thickness varied from 2 to 9 m/px. In each station we measured thickness of the most prominently seen flow in several localities and then calculated the mean value. In some stations two prominent flows of noticeably different thickness were seen and they treated separately.

Results. Our work showed that mean values of true thickness of the Olympus Mons lava flows, measured in the MOC images of steep scarps of volcano flanks, vary from site to site from 4 to 11 meters and from 4 to 26 meters for caldera measurements. We found that the thickness distribution is asymmetric so it may be approximated both by normal (Gaussian) and lognormal distributions. Thickness of lava flows in scarps, in upper parts of caldera's slope, has mean arithmetic value X_A = 11.1 m with standard deviation S = 5.8 m, and mean geometric value X_G = 9.8 m with standard multiplyer = 1.65. Thickness of lava flows on the volcano flanks, has mean arithmetic value X_A = 6.7 m with standard deviation S = 2 m, and mean geometric value X_G = 6.4 m with standard multiplyer = 1.35. From this it follows that mean thickness of lava flows in scarps in the caldera is greater than on the volcano flanks and this difference is statistically significant with the probability of more than 95 %.

Discussion. Determinations of lava flow thickness on Mars are not numerous. We found only one determination of the lava flow thickness for Olympus Mons by shadow technique (=22 m) [9]. These authors have also determined the flow-scarp heights in 23 other localities in the Tharsis region of Mars: between ~ 5 and 20 m for the steeper shield slopes and between 20 and 65 m for the flatter terrain. Other determinations of lava flow thicknesses on Mars include the MOLA measurements of the Ascraeus Mons flows (13 to 33 m, mean = 19 m, [8]); the shadow measurements of Ascraeus Mons flows (15 to 45 m, [10]). Glaze et al. [3] using MOLA profiles determined the following thicknesses of lava flows: Elysium Mons, 15 m in the beginning of the flow, 19 m at its distal end; Alba Patera, 40 m and 130 m, correspondingly; Ascraeus Mons, 20 m and 30 m; Pavonis Mons, 30 m and 55 m. They have also found out that thickness of the Mauna Loa main lava flow of the 1984 eruption is 4 m in the flow beginning and 19 m at its distal end. Head et al. [5] also used MOLA profiles and found out that thicknesses of lava flows in Arsia Mons are 80 m, 108 m and 270 m; in Alba Patera 80 m and 220 m; Elysium Mons, 40 m and 70 m; and Syrtis Major, 38 m.

Typical thickness of terrestrial lava flows of basaltic and basalt-andesitic composition is 3 to 20 m and typical thickness of terrestrial andesitic, dacitic and trachytic flows is 20 to 300 m [6]. The above results show that lava flow thicknesses for Mars are typically larger than those typical for basaltic flows on Earth. Head et al. [5] suggest that the largest thickness values measured by them could be related to ponding, inflation, and multiple breakouts in the vicinity of the distal end of the flow. Glaze et al. [3] suggest that larger lava flow thicknesses on Mars may be due to higher viscosity of lavas, larger vents, higher effusion rates or post-emplacement inflation. We find these suggestions to be plausible, but we think that in reality of rather rugged surface of lava fields, the MOLA profile determinations of lava thickness are reliable only for the flows thicker than 20 or so meters. So, the larger thicknesses of Martian lava flows could partially be due to observational effect. This suggestion is partly supported by relatively small lava thicknesses measured by [9] by the shadow technique.

Summary. Results of our measurements of the Olympus Mons lava flow thickness (mean values = ~10 m for the caldera scarps and ~6 m for the volcano flanks) are in a good agreement with Schaber et al. measurements [9] and with typical thicknesses reported for the terrestrial basaltic flows (3-20 m [6]). We believe that factors suggested by other investigators as a cause of typically larger thicknesses of Martian flows measured by them did not work in the places we studied. We also suggest that lava flows of Olympus Mons studied by us could be basaltic and similar in the eruption style to the basaltic flows of the Hawaiian volcanoes.

References: [1] Bazilevskaya E. 40th *Vernadsky_Brown microsymposium*, abs. M3, 2004. [2] Carr M., *JGR*., 78, 4049-4062, 1973. [3] Glaze et al., *LPSC XXXIV* (2003), #1315. [4] Greeley R. & Spudis P., *Rev. Geophys. Space Phys.*, 19, 13-41, 1981. [5] Head et al., *LPSC XXIX* (1998), # FRFR. [6] Kilburn, in *Encyclopedia of Volcanoes*, Acad. Press. 2000, 291-305. [7] Neukum G. et al., *Nature*, 2004. Dec 23. [8] Peitersen et al., *LPSC XXXII* (2001), #1472. [9] Schaber et al., *Proc. Lunar Planet. Sci. Conf. 9th* (1978), 3433-3458. [10] Zimbleman, *Proc. Lunar. Planet. Sci. Conf. 16th* (1985), *JGR*, 90, D157-162, 1985.

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