LAVA FLOWS ON OLYMPUS MONS, MARS: ESTIMATES OF FLOW SPEEDS AND VOLUME FLUXES FROM MOC, THEMIS AND MOLA DATA. B.C. Bruno[1], S.A. Fagents[1], E. Pilger[1], S. Rowland[1] and H. Garbeil[1], [1]University of Hawaii, HIGP, 1680 East West Road, Honolulu, Hawaii 96822 (barb@hawaii.edu)

Introduction: This research aims to characterize the eruptive behavior of lava flows on Olympus Mons, Mars. In particular, we are interested in: characterizing lava emplacement style (tubes vs. channels); estimating flow speeds and volume fluxes based on assumed input parameters; and identifying correlations, if any, among variables such as flow velocity, emplacement style, location on the edifice, topographic slope and flow dimensions.

Methodology: Our methodology involves: (1) Identifying lava tubes and channels that are relatively pristine and undegraded from MOC and THEMIS visible images. (2) Projecting the MOC images into a planetocentric, simple-cylindrical coordinate system using the USGS software package ISIS in order to facilitate comparison with the Mars Orbiter Laser Altimeter (MOLA) digital elevation data. (3) Measuring the widths and depths of lava tubes and channels on the processed images. Tube and channel depths were calculated from shadow measurements, and lava flow depth was estimated as a percentage of tube and channel depth. (4) Constructing a slope map of Olympus Mons from the interpolated MOLA 1/128° DEM (Fig. 1) and extracting the average ground slope along the lava tubes and channels of interest. (5) Calculating flow velocities and total volume fluxes from the laminar flow equations [1, 2]

$$u = \frac{g \sin\theta \rho h^2}{3\eta}$$

where g=gravitational acceleration on Mars (3.73 m/s^2), θ=ground slope (degrees), ρ=flow density (assumed 2000 kg/m^3), h=flow thickness (m) and η=dynamic viscosity (assumed 3000 Pa s). (6) Perform statistical analyses. Correlations in x-y (scatterplot) data are done by comparing the Pearson correlation coefficient (r) to the critical value. Means are compared through a t-test, after first running an F-test to determine whether the population variances are equal. All statistical tests are performed at the 0.05 significance level.

Data: To date, we have examined 64 lava channels and 26 lava tubes on Olympus Mons from 19 high-spatial-resolution (3-10m/pixel) MOC images of the summit area, flanks and basal scarp. We measured the widths of all 90 lava tubes and channels. Depths were estimated from shadow measurements where possible (49 channels and 21 tubes). This data set is currently being expanded to include more MOC images as well as THEMIS images, which have lower spatial resolution (~20m/pixel) but broader coverage.

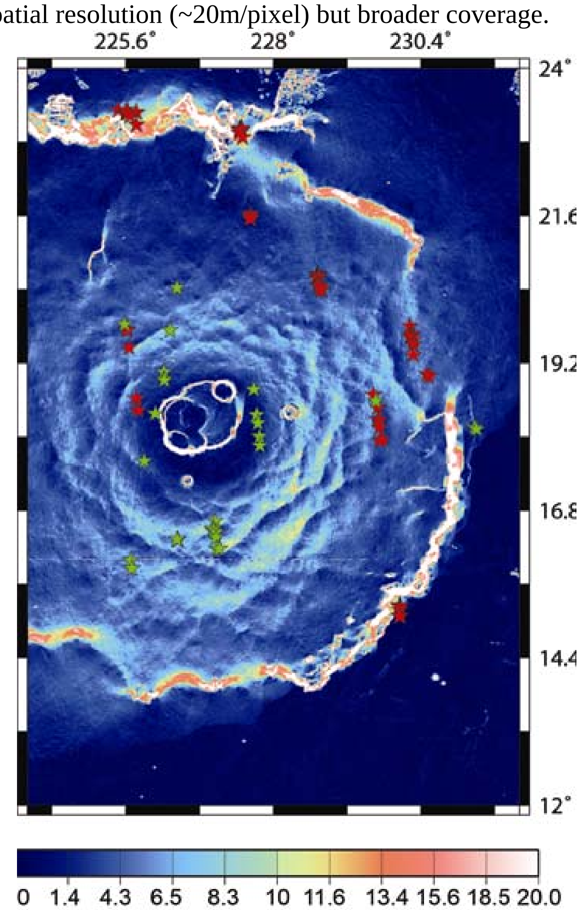

Fig. 1 Slope map of Olympus Mons, constructed from interpolated MOLA data (1/128° DEM) using a script written by F. Scott Anderson (University of Hawaii). Colorbar gives slopes in degrees. Stars show the locations of lava tubes (green) and channels (red) identified from MOC images.

Preliminary results:

Lava emplacement style. To date, we have examined 64 lava channels and 26 tubes. Tubes and channels appear to have distinct spatial distributions: tubes tend to be found at or near the summit, whereas channels are more prevalent on the lower flanks and near the basal scarp. A t-test showed a significant difference in the mean distance to the summit between tubes (mean distance =103 km) and channels (mean distance =206 km). The calculated t-statistic 6.3 exceeded the critical value of 2.0.

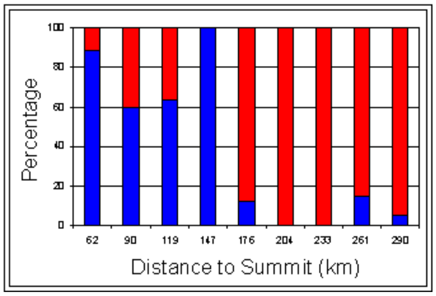

Fig. 2. Histogram of percentage of tubes (blue) and channels (red) vs. distance to summit. Distances are binned in 35km intervals and are labeled by their central value.

Flow velocities. Using Jeffreys' (1925) equation for laminar flow, we estimated flow velocities. Channel velocities range from <1 to 18 m/s (mean = 5). Tube velocities range from <1 to 11 m/s (mean = 3). This difference in means is not statistically significant. We note that all estimated flow velocities are highly dependent on our choice of input parameters, some of which are poorly constrained (e.g., viscosity).

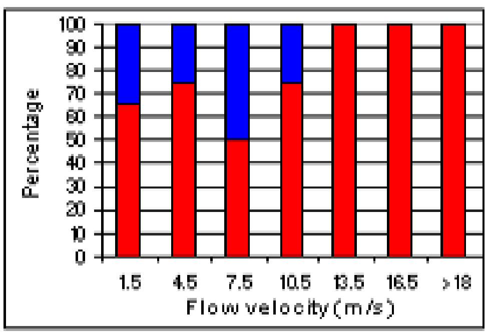

Fig. 3. Histogram of percentage of tubes (blue) and channels (red) vs. flow velocity. Flow velocities are binned in 3m/s intervals and are labeled by their central value.

Ground slopes. Channels were found on a wide variety of slopes (0-17º), with the steeper slopes corresponding to the basal scarp surrounding Olympus Mons. Tubes were found only on slopes <10º. However, there was no statistical difference between the mean slopes of tubes (4º) vs. channels (5º), indicating a greater variance of channel slopes. F-test results indicate that the channels are indeed statistically more likely to be found at steeper slopes.

Figure 4 (below) plots the widths of (a) lava channels and (b) tubes as a function of slope. The inverse relationship between width and slope is statistically significant only for channels (R>Rcrit). Tubes do not appear to significantly narrow with slope (R<Rcrit)

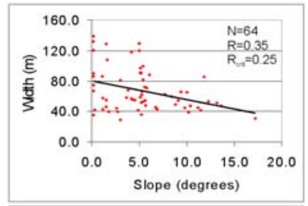

Fig. 4a.
Channel width vs. slope

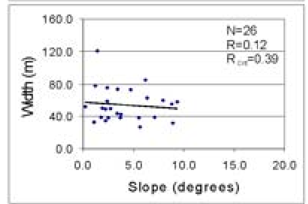

Fig. 4b.
Tube width vs. slope

Discussion & Conclusions: Based on the limited data collected to date, we have found both channel-fed and tube-fed lava flows on Olympus Mons. Channel-fed flows appear to be more common, particularly with increased distance from the summit. Tube-fed flows become more prevalent close to the summit area. We speculate that this spatial distribution might be attributed to the different dike driving pressures associated with channel-fed (high-pressure) and tube-fed (low-pressure) eruptions. To reach the flanks, dikes must travel greater distances, which may require the higher driving pressures typically associated with channel-fed eruptions (Fig. 5)

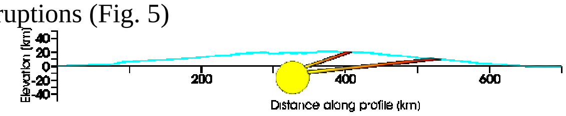

Fig. 5. Profile of Olympus Mons, showing a schematic of the magma chamber (yellow) and likely dike paths for summit and flank eruptions.

Mean lava velocities are estimated to be 5 m/s (channels) and 3 m/s (tubes), although these values are highly sensitive to our assumed values of input parameters.

Both lava channels and tubes are found on gradual slopes, but only channels are found on slopes >10°. Channel width was found to narrow with increased slope, as expected from volume conservation considerations. Tube width was not correlated with slope, perhaps because tubes form well behind the active flow front and therefore have less opportunity to evolve. Channel formation is much more intimately related to flow front width, and to flow width as a whole.

References: [1] Jeffreys H.J. (1925), Phil. Mag., 49, 793-807, 1925. [2] Shaw H.R. and Swanson D.A. (1970), Second Columbia River Basalt Symposium, 271-299.