LAVA FLOW MORPHOLOGIES AND ERUPTION CONDITIONS ON VENUS; Lionel Wilson[1,2], James W. Head[2] and Don B. Campbell[3]. [1]Div. of Environ. Sci., Inst. of Environ. and Biol. Sci., Univ. of Lancaster, Lancaster LA14YQ U.K. [2]Dept. Geol. Sci., Brown Univ., Providence, R.I. 02912 U.S.A. [3]Nat'l Astron. and Ionosphere Ctr., Cornell Univ., Ithaca, N.Y. 14853.

Recent high-resolution images of Venus obtained by the Arecibo radar facility (Campbell *et al.*, 1989) [1] allow us to identify individual lava flow lobes with high levels of confidence, and to measure their widths and lengths. Table 1 shows these parameters for 4 flows units, together with the large-scale slopes of the topography on which they are emplaced. We have used the model of lava flow emplacement described by Head and Wilson (1986) [2] to deduce the rheological properties and emplacement conditions of these flows.

The model assumes that lava is a Bingham plastic (Hulme,1974) [3] with yield strength Y and plastic viscosity h. A flow unit then consists of a pair of stationary levees, each of which has width $w_b$ and maximum thickness $d_b$, consisting of lava within which the basal stresses are too small to overcome the yield strength of the lava, and a central channel, width $w_c$ and center-line depth $d_c$, within which lava moves down the regional slope a at a mean speed u. The lava in the channel and levees has a parabolic profile in cross-section, due to its ability to support finite lateral stresses. The total width of the flow unit is $w_t$, and the flow speed multiplied by the cross-sectional area of the central channel, A, produces a volume flux F. The flow comes to rest due to cooling effects after a time t, producing a deposit of volume V. The lava density is r (assumed to be 2600 kg/m$^3$) and its thermal diffusivity is k (taken as $7 \times 10^{-7}$ m$^2$/s). The following equations relate the above variables (Head and Wilson, 1986) [2]:

$$d_b = Y/(g\,r\,a) \quad (1)$$

$$w_b = Y/(2\,g\,r\,a^2) \quad (2)$$

$$w_c^{1/3} = (24\,F\,h)/(Y\,a^2) \quad , w_c/2w_b < 1 \quad (3a)$$

$$w_c^{1/11} = \{(24\,F\,h)^4\,g\,r\}/(Y^5\,a^6) \quad , w_c/2w_b > 1 \quad (3b)$$

$$w_t = w_c + 2w_b \quad (4)$$

$$d_c = \{(Y\,w_t)/(g\,r)\}^{1/2} \quad (5)$$

$$A = \{(2\,g\,r)/(3\,Y)\}\,(d_c^3 - d_b^3) \quad (6)$$

$$F = u\,A \quad (7)$$

$$t = d_c^2/(300\,k) \quad (8)$$

$$X = t\,u \quad (9)$$

This system of equations has been applied to the measured flows by assuming a series of values for the yield strength, Y. For each Y, values of $d_b$, $w_b$ and $d_c$ are found from (1), (2) and (5), A is found from (6), t is found from (8) and $w_c$ is found from (4). u is then obtained from (9) and substituted in (7) to give F. F is then used in (3a) or (3b) to find the implied viscosity, h. A modification to the above treatment is used when u is large: if the Reynolds number Re = (r u d)/h, where d is the local lava depth, exceeds about 2000 so that turbulence occurs in part of the central channel, we assume that the levees and outer parts of the channel have the same geometry as before but that the turbulent lava in the channel, in the region between the points with depth d, accelerates until its top surface is flat. This leads to an increase in the implied value of u and decreases in $d_c$, A and V.

The results indicate that all four of the sets of results show common patterns. The deduced viscosity at first increases as the assumed yield strength increases, with the implied effusion rate also increasing. At very high yield strengths, the implied viscosity and effusion rate decrease again. However, a trend of decreasing viscosity with increasing yield strength is not observed for

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any known terrestrial magma (Shaw, 1969; McBirney and Murase, 1984) [4,5]. This implies that the most likely set of rheological properties are those corresponding to low-viscosity, very-low-yield strength mafic magmas similar to lunar mare basalts or terrestrial archaean komatiites. The implied effusion rates are high, of order $10^5$ $m^3/s$, even for the lowest viscosities and yield strengths used. The implied flow volumes increase from the order of 1 to the order of 100 $km^3$ as the assumed yield strength increases from 1 to 10 Pa.

An eruption rate of $10^5$ $m^3/s$ taking place from a fissure of horizontal length 30 km (selected on the basis that there is no evidence for any of the studied flows being fed by a fissure that was longer than the flow is wide) would imply a flux per unit length of ~3 $m^3$ $s^{-1}m^{-1}$ and require a dike width in the range 0.6 to 1.3 m for a range of pressure gradients similar to that deduced for terrestrial fissure eruptions (200 to 2000 Pa/m - see Wilson and Head, 1981) [6]. If the fissure length were shorter, say 3 km (comparable with the lengths of basaltic fissure vents on Earth), the required flux would be higher, ~30 $m^3$ $s^{-1}m^{-1}$ and the required dike width would then be in the range 3 to 6 m. This overall dike width range, 0.6 to 6 m, is similar to that observed for terrestrial basaltic feeder dikes and implies that no unusual stress conditions are required in the plumbing systems of the volcanoes on which these flows occur; what is required is the availability of large volumes (at least a few $km^3$) of very mafic magma.

Gaddis (1989) [7] used Venera 15/16 data to carry out a similar analysis to that described here on 15 flows with lengths in the range 30 to 180 km distributed widely over the surface of Venus. She found smaller effusion rates (by a factor of order 3) and larger flow volumes (by a factor of order 10) than those we report. Her analysis assumed that the rheology of the flows could be approximated by pairs of values of yield strength and viscosity estimated by Head and Wilson (1986) [2] for an anhydrous tholeiite, and thus used larger yield strengths (by a factor of order 30) and larger viscosities (by a factor of at least 100) than those inferred here. We have re-analysed Gaddis' (1989) [7] data using our method and find that we closely reproduce her results for these shorter length flows. The difference between her approach and ours is essentially that we explore a wider range of rheologies; the consequence of restricting the rheological range is to predict rather lower effusion rates at the expense of implying substantially greater erupted volumes.

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Table 1. Basic data for the 4 Venus flows analysed.

| Flow # | Flow location | Minimum length/km | Mean width/km | Mean regional slope/radians |
|---|---|---|---|---|
| 1 | Lada terra | 500 | 16 | 0.0020 |
| 2 | Lada terra | 300 | 40 | 0.0020 |
| 3 | Sif Mons | 600 | 50 | 0.0016 |
| 4 | Sif Mons | 500 | 54 | 0.0009 |

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