POSSIBLE RHYOLITE FLOWS IN THE ARCADIA PLANITIA REGION OF MARS: 
EVIDENCE FROM SURFACE RIDGE GEOMETRY. Jonathan H. Fink, Department of Geology, 
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Ridges on lava flows have been modeled as folds which form due to the compression of a fluid whose viscosity decreases with depth (1). The spacing of ridges reflects the rheology and deformational history of a flow. Regularly spaced ridges in the Arcadia Planitia region of Mars are here interpreted to be lava ridges. The measured ridge spacings and heights are compatible with flow viscosities and emplacement strain rates appropriate to flows of rhyolitic composition.

The folding model assumes that the lava is a Newtonian fluid whose viscosity decreases exponentially from a surface value, \( \eta_0 \), through a thermal boundary layer of thickness \( H \) to a constant interior value, \( \eta_i \). The thickness \( H \) was found to be roughly equal to the observed heights of ridges, \( A_r \), on terrestrial basalt and rhyolite flows (1,2).

We may describe the growth of a ridge to final height \( A_f \) from an initial surface irregularity of height \( A_o \) by:

\[
A_f = A_o \exp (q \, \dot{\varepsilon} \, t) \tag{1}
\]

where \( \dot{\varepsilon} \) is the compressive strain rate and \( t \) is time. \( q \) is an analytically determined dimensionless function of the properties of the lava and the geometry of the channel. In order for regularly spaced folds to develop, \( q \) must be greater than a minimum value, usually taken to be 10 (3). This restriction on \( q \) constrains two additional dimensionless groups:

\[
\left( \frac{L_d}{H} \right) \ln R \geq 30 \tag{2}
\]

\[
\rho \, g \, H / (4 \, \pi \, R \, \dot{\varepsilon} \, \ln R \, \eta_i) \geq 0.02 \tag{3}
\]

where \( L_d \) is the average ridge spacing, \( R = \eta_o / \eta_i \) is the ratio of the surface to interior viscosities, \( \rho \) is the density and \( g \) is the acceleration due to gravity (1).

These relations allow us to crudely estimate the composition of a flow based on observations of ridge spacings and heights. By assuming that \( A_f = H \) and using values of \( L_d \) and \( A_f \) measured from photographs, we can use (2) to determine a minimum value for \( R \). This value along with appropriate values of \( \rho \) and \( g \) can then be substituted into (3) to yield a minimum value for the product of interior viscosity and surface strain rate, \( \eta_i \dot{\varepsilon} \). This product takes on characteristic values for lavas of different compositions. Basalt flows with viscosities of \( 10^2 \) to \( 10^3 \) (all units are c.g.s.) and strain rates (1) of \( 10^{-1} \) to \( 10 \) would have a minimum value for \( \eta_i \dot{\varepsilon} \) of 10. Rhyolite flows with viscosities (4) of \( 10^10 \) to \( 10^{12} \) and minimum strain rates (2) of \( 10^{-6} \) would have a minimum product of \( 10^4 \). Thus larger values generally indicate more silicic compositions.

Figure 1 shows two lava flows with surface ridges. For the rhyolitic obsidian flow on the left \( L_d = 5 \times 10^{-3}, H = 10^3, \rho = 2 \) and \( g = 10^3 \), so that from (2), \( R \geq 3 \times 10^2 \) and from (3), \( \eta_i \dot{\varepsilon} \geq 2 \times 10^4 \). In the pahoehoe basalt flow on the right, \( L_d = 10, H = 3, \rho = 2 \) and \( g = 10^3 \) so that \( R \geq 4 \times 10^3 \) and \( \eta_i \dot{\varepsilon} \geq 20 \). Here we see the predicted correlation between higher values of \( \eta_i \dot{\varepsilon} \) and more silicic composition.
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Figure 2 shows a portion of the relatively young Arcadia Planitia region, northwest of Olympus Mons. The surface structures have the curvature and regular spacings characteristic of ridges on terrestrial lava flows. The ridges have spacings of about $7 \times 10^4$ and heights of about $5 \times 10^3$. Using the values (5) $\rho = 2$ and $g = 4 \times 10^2$ implies $\eta \dot{\epsilon} \gtrsim 4 \times 10^6$. This high value suggests flows of rhyolitic composition. The presence of nearby structures resembling silicic domes is consistent with this interpretation.

The flows in Figures 1 and 2 each exhibit ridges with more than one prominent spacing. On terrestrial flows, short wavelengths form first. Subsequent cooling increases the thickness of the thermal boundary layer, $H$, so that for the same strain rate and viscosity, later ridges form with larger spacings (1). Thus the pronounced scarps parallel to the flow ridges in Figure 2 could represent the limits of longer wavelength surface folds on a single flow. This contrasts with Scott's (6) interpretation that these features represent the fronts of successive flow lobes.

REFERENCES
RHYOLITE FLOWS IN THE ARCADIA PLANITIA REGION OF MARS

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Fig. 1. Ridges on lava flows. (left) Big Glass Mountain rhyolite flow, California. Scale Bar = 500 m. (right) Ropy pahoehoe basalt flow, Kilauea Volcano, Hawaii. Scale bar = 2 m.

Fig. 2. Viking Orbiter photo of Arcadia Planitia showing ridges and domes. Photo area is about 60 km wide.