

INTERPRETING VENUSIAN LAVA DOMES Michael Malin and Jonathan Fink, Geology Department, Arizona State University, Tempe, AZ 85287-1404, and Ross Griffiths, Research School of Earth Sciences, Australian National University, Canberra 2601 A.C.T. and ASU

Early Magellan images of Venus have shown several large sub-circular features interpreted to be volcanic lava domes¹. Although the observed number of such features is still small, we offer here suggestions, based on terrestrial field studies, laboratory simulations, and preliminary analyses conducted under the auspices of the Magellan Participating Scientist Program, for how lava domes eventually may be used to help decipher the tectonic and magmatic history of Venus.

Terrestrial lava domes erupt in response to a combination of magmatic pressure and favorable stress conditions. They either grow episodically, producing composite constructs with relatively irregular outlines and large aspect (height/radius= H/R) ratios, or as single thinner extrusions with more circular outlines. The latter are favored in settings where tectonic extension combines with magma pressure to facilitate rapid and long-lived extrusion, whereas episodic growth indicates that the magma has more difficulty reaching the surface. Larger domes generally require higher extrusion rates, which also inhibit crust formation and allow more uniform spreading². As shown experimentally and theoretically³, aspect ratio can be related to yield strength: $\tau_0 = 0.32 H^2 \rho g / R$.

Surface structures on domes reflect relative rates of extrusion and cooling²; for instance, under a given set of ambient conditions, formation of surface folds requires a higher extrusion rate than surface fracturing⁴. On a circular dome, the radial distance at which transitions occur between distal folds and proximal fractures can be used to quantitatively establish the extrusion rate⁴.

The alignment and elongation of domes and the orientations of adjacent fractures are commonly the best-preserved indicators of the detailed geometry of sub-surface dikes^{5,6}. When rising dikes pass through the brittle/ductile transition zone of the crust, they may break up into segments that rotate as they approach the surface. The amount that these segments twist can be related to the depth to the transition zone, which in turn is a function of the thermal gradient⁷. Thus regional variations in dome alignment may provide an indirect measure of heat flux.

Dikes propagate away from a magma source through fractures created by a combination of host-rock distension and regional tension, supplemented by magma buoyancy. In areas where tensile stresses are progressively increasing (such as might be expected around a growing mantle plume), buoyancy will allow dikes to rise through crustal rocks that would not yet have otherwise been fractured. Similarly, if tensile stresses are subsiding, then dikes may be able to rise after crustal rocks are no longer able to be faulted. Thus, cross-cutting relationships between regional fracture patterns and dike-fed domes may be used to help evaluate models of crustal evolution.

The similarity between seven large circular constructs east of Alpha Regio (Figure 1) and terrestrial domes has been noted by the Magellan Radar Investigation Group¹. Many attributes besides their circular form can be related to this interpretation. Two of the middle domes each exhibit a central zone of fractures surrounded by a marginal zone of folds, as observed on many terrestrial domes of high silica content⁶. The average radius and aspect ratio of these domes ($R=10$ km; $H/R=1:5$) indicate a yield strength of $\sim 3.6 \times 10^5$ Pa (assuming a density of 2500 kg-m^{-3}), also consistent with terrestrial silicic domes³.

Smaller dome-like features observed closer to Alpha and in other portions of Venus generally have more irregular outlines, suggesting that they may be composite extrusions that issued from sources of lower magma pressure or that rose through crust subjected to smaller amounts of tension.

Many interpretations of dome alignment are possible. Here we select one and consider its implications. If we group the Alpha Regio domes (Figure 1) into three NE to ENE-trending sets,

we find that the three dike segments that fed these clusters rotated progressively clockwise away from Alpha Regio. If we further assume that the direction of maximum regional tensile stress is perpendicular to the large and widely distributed fractures seen throughout the area, then the three dike segments appear to twist more away from this trend the further they get from Alpha Regio. The dike segmentation model would then suggest that the brittle/ductile transition occurs at greater depths further from Alpha, consistent with the idea that the dike(s) radiated away from a thermal anomaly beneath the highland. This interpretation is also consistent with the observation that all of the regional fractures (which are oriented roughly concentric about Alpha Regio) are younger than the domes, implying that the crust was not able to sustain faulting until after these magmatic intrusions were substantively complete. Other, more fluid lavas erupted from fissures parallel to the faults suggest different ages and sources for the two magma types.

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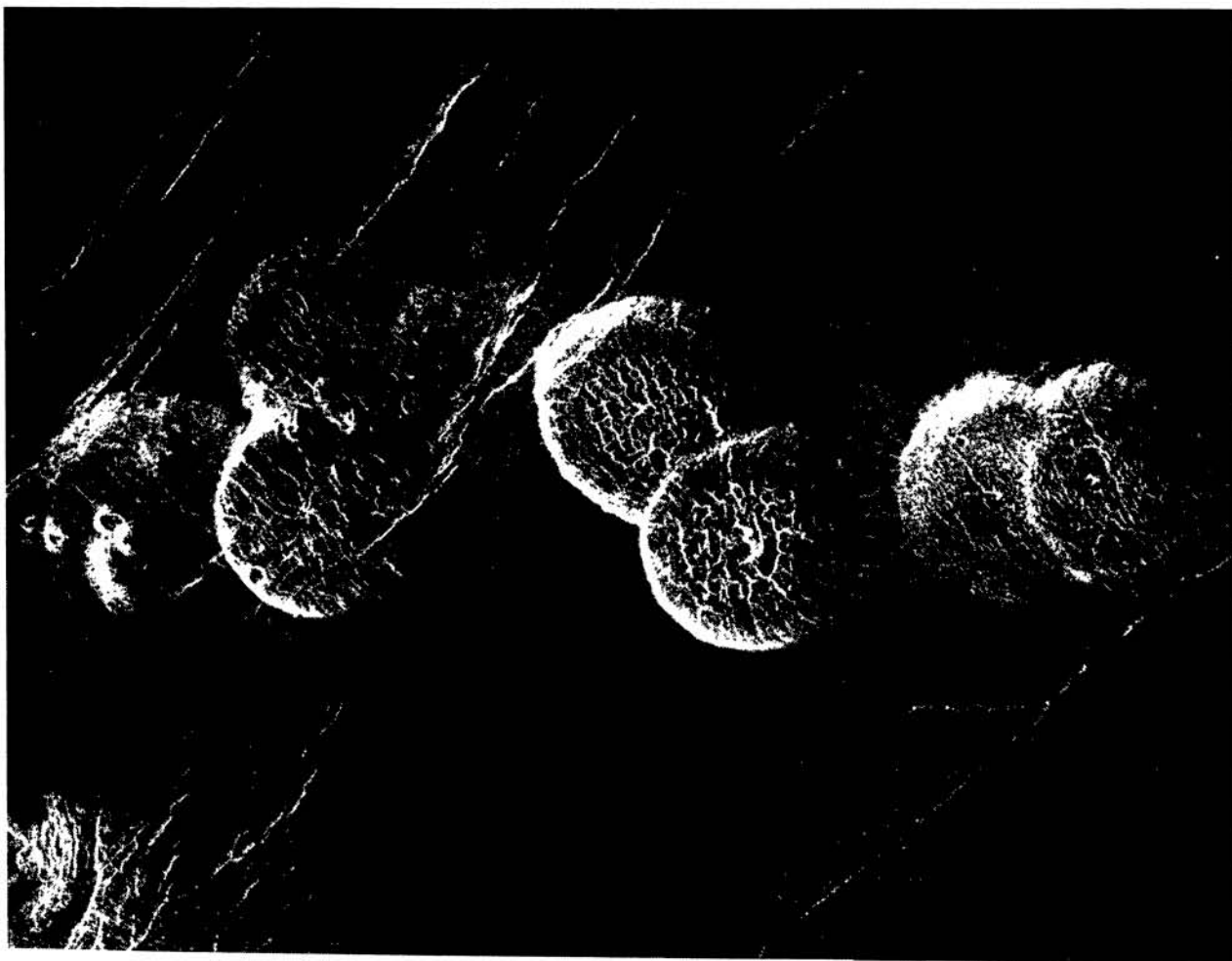


Figure 1: Partial mosaic of the F-BIDRs 545-555, SE of Alpha Regio, 30°S, 12°E.