Steep Sided Domes on Venus: A Re-evaluation of Morphologies and Emplacement Mechanisms

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Introduction: Venusian steep sided domes are a class of volcanic features noted for their circularity, steep sides, large volumes and relatively flat tops. Several researchers have assessed their composition, geologic association to the surrounding terrain and origins (i.e. [1], [2], [3] and [4]). Building upon previous works, we focus on three objectives: the first is to generate high resolution Digital Elevation Models (DEMs) from stereo derived topography in order to evaluate differences in morphology within the dome population. We then combine the topography with detailed surface lineament mapping to evaluate emplacement mechanisms. Finally, treating the domes individually, we analyze possible causes for variations among the dome population, including magma viscosity, episodicity and effusion rate.

Methods: This study utilizes SAR imagery collected by the Magellan mission from 1990 to 1993 at a resolution of ~100 m/pixel (resampled to 75m/pixel). The planet was mapped in three cycles with one right looking and two left looking geometries, resulting in ~45% of the planet covered by stereo imagery [5]. DEMs produced in this study are at a horizontal resolution of 225 – 1000 m/pixel. Both left-left and left-right stereo pairs are used for this study. For the lineament analysis part of this study, the ArcGIS software suite is utilized.

Case Examples: In Figure 1, the stereo derived topography is shown overlaying the left looking image of the dome at 42˚N, 79˚E. This example shows the high resolution detail of our stereo derived DEMs. The central pit/depression is clearly resolved, as well as elevation differences between the west and east parts of the dome.

The dome located at 3˚S, 151˚E has good examples of surface lineaments and has not undergone any post-emplacement deformation (Figure 2). Two sets of lineamens are visible: one that is principly radial out from the center of the dome, and the other which is principly orthogonal to the first set, or circular around the center. These two sets of fractures could represent two different stages of cooling, or even growth and cooling. For example, the radial lineaments resemble fracturing related to growth of a dome in a study by [6]. In either case, these lineaments preserve some of the eruption histories of the domes and can give insight into the rheology of each dome's crust.

Three domes, located at 12˚N, 8˚E, are shown in Figure 3a. Despite their close proximity, cross-sections through the domes shown in Figures 3b and 3c demonstrate the range of morphologies found in the dome population. Dome B is depressed in the center with a deep central pit clearly resolved in cross section, that is believed to extend below the preexisting planetary surface. Dome C is relatively flat topped, has steeper sides, and has a much shallower central pit.

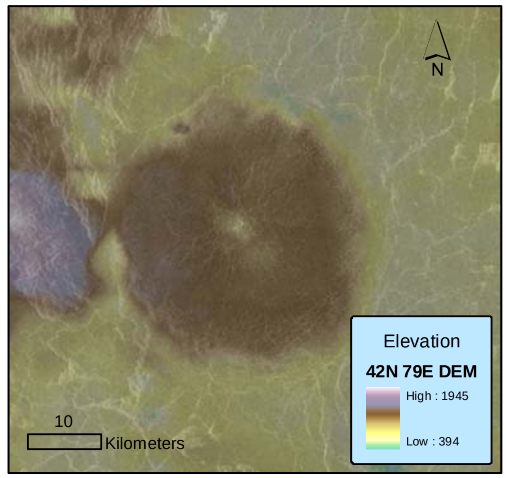

Figure 1: dome located at 42˚N, 79˚E. The orthorectified image is overlaid by the DEM derived from stereo techniques. The dome is 36.5 km in diameter.

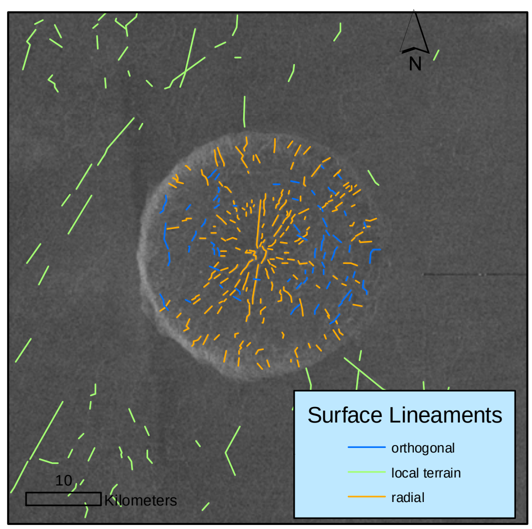

Figure 2: dome located at 3˚S, 151˚E. Radial and perpendicular (orthogonal to radial direction) lineaments are outlined , as well as lineaments in the surrounding terrain, showing that this done has not undergone local tectonic deformation after its emplacement. The diameter of this dome is 34.6 km.

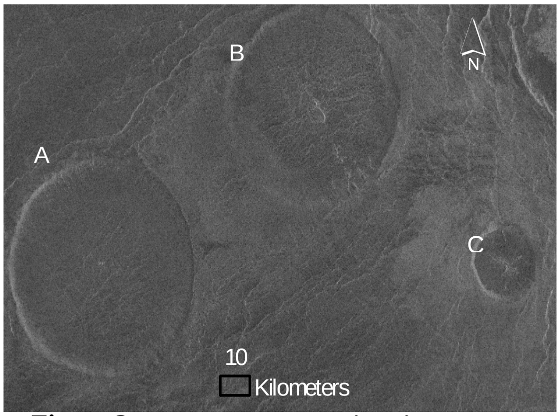

Figure 3a: domes located at 12˚N, 8˚E. Dome A has a diameter of 61.9 km, dome B has a diameter of 58 km and dome C has a diameter of 20.6 km.

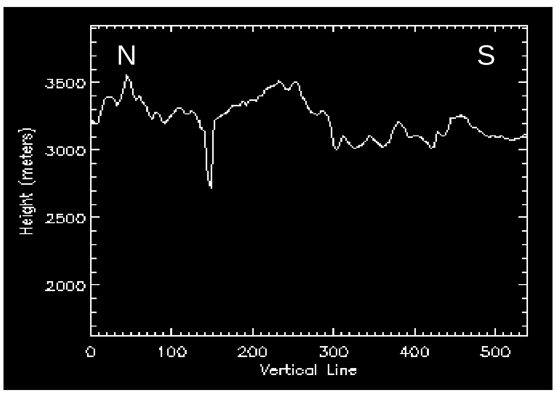

Figure 3b: Vertical profile across the center of dome B (Figure 3a). The dome has a height of 500m and side slopes of 8-11˚. The center of the dome is depressed with respect to the rim, with a deep central pit located in the center of the dome. This pit has a depth of ~530m and extends below the surface of the surrounding terrain.

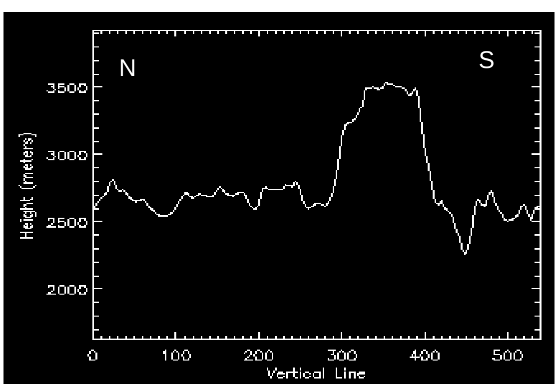

Figure 3c: Vertical profile across the center of dome C (Figure 3a). This dome has a height of 1400m and side slopes of 12-16˚. This dome has a flat topped morphology. The central pit of this dome, not seen in this profile, has a depth of 200m.

Results and Discussion: Although opposite side geometry stereo pairs are in general more challenging, both left-left and left-right look geometry stereo pairs have yielded useful results for this study. This is significant because more than 75% of the domes covered by stereo only have left-right stereo coverage.

Preliminary results show that the sides of the domes have slopes of ~10-16˚ and that the surface has slopes of 1-2.5˚. The domes display a range of morphologies, from convex to flat-topped to concave. In general, the largest domes have low topographic relief above their surrounding area and/or are depressed in their centers. Initial results may also indicate that some domes undergo polygenetic growth.

In most cases in our study, central pits can be resolved. For those domes where a central pit is not readily identified in cross section, they generally have a convex upper surface. For those domes that do have resolvable central features, the depth of the central pit is on the order of 50-100s of meters deep. However, it should be noted that these heights are interpolated from stereo techniques. These central pits in many cases can be explained by late stage cooling/slumping of the surface, or material draining during the cooling stage. However, in one case, (Figure 3a and 3b, dome “B”), this central feature is ~530m deep with side slopes of 27˚ and extends below the pre-existing planetary surface. Geometric methods give a height of 400m +/- 50m for this central depression. This feature could be interpreted as evidence of the source vent for this dome. If that is the case, this may confirm that these domes are formed from a single source.

Overall, our initial conclusions are that the differences observed in morphology are primarily due to slight variations in magma viscosity. Domes that are depressed in the center and have lower relief are expected to have a lower viscosity, whereas domes with convex morphologies and steeper slopes are expected to have a slightly higher viscosity. This variation in viscosity could be explained by either a small variation in silica content, or higher crystal contents.

References: [1] Ivanov, M.A., and Head, J.W. (1999) *JGR*, *104*, 18907-18924. [2] McKenzie, D. (1992) *JGR*, *97*, 15967-15976. [3] Pavri et al. (1992) *JGR*, *97*, 13445-13478. [4] Stofan et al., (2000) *JGR*, *105*, 26757-26771. [5] Ford, J.P. (1993) *Guide to Magellan Image Interpretaion*, 1-6. [6] Blake, S. (1990) *Lava Flows and Domes, Emplacement Mechanisms and Hazard Mitigation*, 47-69.