SURFACE CHARACTERISTICS OF STEEP-SIDED DOMES ON VENUS AND TERRESTRIAL SILICIC DOMES: A COMPARISON

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A silicic composition for steep-sided Venusian domes has recently been proposed on the basis of similarities in thickness, planform, and gross topographic profile to terrestrial rhyolitic and dacitic domes [1-4]. However, there are significant morphologic, volcanologic, and remote sensing characteristics that do not support direct comparison. For example, domes on Venus lack typically observed structures and morphological units, are an order of magnitude or more larger in volume and have smoother surfaces than terrestrial silicic lava domes [5-7].

In order to evaluate the validity of the silicic model for Venusian domes, we measured and analyzed topographic profiles, boulder-size distributions, and structural elements present on the surfaces of recent rhyolitic and dacitic domes in the western United States. These data show that steep-sided domes on Venus lack the progression in surface morphologies, characteristic large block size, and topographic variability found on terrestrial dome surfaces. Our study suggests that these discrepancies preclude direct comparison of domes on Venus and Earth, and that a re-evaluation of the silicic model for the origin of Venusian domes is required.

Lava domes at the Medicine Lake Highland Volcano and Long Valley Caldera

Our study concentrates on two large eruptive centers in the western United States. The Medicine Lake Highland volcano in northern California contains several rhyolitic and dacitic lava domes, with volumes ranging from <3000 m^3 to >1 km^3 [8,9]. The largest of these domes, Glass Mountain, shows a progression from early dacitic to late rhyolitic compositions. Many of the domes have little or no vegetation present on their surfaces and have been emplaced within the past 10000 years [9]. The Inyo dome chain in eastern California consists of 5 rhyolitic domes erupted along an en echelon dike [10]. Three of these domes, Obsidian, Deadman, and Glass Creek, were erupted 550-650 years ago [11]. The domes vary in volume from approximately 0.04 km^3 to 0.3 km^3 [11,12]. Anderson and Fink [8] calculated effusion rates ranging from 0.03 to 106 m^3/s for rhyolitic domes in these two areas.

Surface Morphologies and Structures on Terrestrial Silicic Domes

Surface morphology maps of lava domes at Medicine Lake and Inyo have been compiled from aerial photographs as a basis for comparison to Venusian domes and for later field characterization. We have mapped four distinct morphologies consistently present on the various domes. **Vent regions** are characterized by high relief (>10 meters), the presence of fractures, and divergence of flow paths. Vent regions may also contain one or more crease structures, fractures indicative of spreading [8]. **Ridged areas** are characterized by regularly-spaced compressional ridges, with wavelengths between 10 and 15 meters and amplitudes of 1 to 5 meters. Small crease structures (1-10 meters in length) are typically present on ridge crests, with axial valleys oriented parallel to the direction of maximum compression [8]. **Jumbled regions** have more subdued topography and lack the characteristic structures present in vent regions and ridged areas [6]. Jumbled areas appear to represent a transitional zone between vent and ridged areas. **Flow fronts** on silicic domes typically have tens of meters of relief. They are commonly steeper than the angle of repose, owing to numerous, nearly vertical cliff faces. Most domes show a spatial progression of morphologies from vent regions in dome interiors, to jumbled regions, to ridged areas, to flow fronts, although the aerial extent of the various units may vary between domes.

Silicic lava domes exhibit three main surface lava textures. **Finely vesicular pumice** (FVP) is a carapace-forming unit that may occur in all of the morphologic units. The thickness of the FVP unit varies from 1-20 m, and is formed by vesiculation of the lava flow surface during eruption [12-14].

Coarsely vesicular pumice (CVP) is a volatile-rich layer of magma from the flow interior that may rise buoyantly to the surface in the form of diapirs [12,13]. The CVP unit forms as volatiles released during crystallization concentrate beneath the flow's cooled crust [12,13]. CVP is rarely found in the vent or jumbled regions, but is common in ridged areas and flow fronts. **Dense obsidian** is found in minor amounts on the flow surface and at flow fronts, and is commonly associated with CVP. Obsidian forms in the interior of the lava flow at depths where the weight of overburden prevents the vesiculation of magma, and is typically sandwiched between FVP and CVP units [12,13].

We have further characterized the vent, jumbled, and ridged morphologic units on the basis of their topographic profiles (measurements made at 25 cm intervals) and boulder-size distributions. We measured ~25 meter orthogonal transects at 19 different vent, jumbled, and ridged areas on silicic lava flows at Inyo and Medicine Lake Highland. Calculated RMS heights and average boulder sizes range from 30-82 and 30-82 cm respectively in vent regions, 30-56 and 27-71 cm in jumbled regions, and 43-187 and 18-36 cm in ridged areas. We consider RMS height and boulder-size measurements in vent regions to be minimum values, as many vent features are larger than the scale of the transects. The RMS height calculations confirm interpretations from aerial photographs that jumbled areas have the most subdued topography. Boulder-size measurements from Obsidian dome show a decrease in average boulder size with distance from the vent, suggesting that large features produced in the vent region become progressively degraded during surface flow, due to increased fracturing during cooling and transport.

Surface Characteristics of Steep-sided Venusian Domes

Preliminary analysis of the geologic characteristics of steep-sided Venusian domes using Magellan SAR images and altimetry data indicates that domes are typically characterized by smooth surfaces, pits, and radial, concentric and polygonal fractures [5]. Domes are circular to highly irregular in plan view with generally steep margins. Typically, domes are flat-topped or concave, but variations in relief on the upper surfaces are common. Two types of pits are observed: 1) centrally located collapse pits that may have concentric fractures, and 2) pits with prominent raised rims that are randomly located on dome surfaces and are most likely indicative of secondary eruptions.

Many aspects of Venusian dome morphology do not directly support comparisons with terrestrial silicic domes. For example, domes in southern Guinevere Planitia are generally comparable in radar roughness to their surroundings, whereas the surfaces of silicic domes on Earth are extremely rough [5,7]. Venusian domes are also directly associated with volcanic vents from which thin, lobate flows of similar morphology to terrestrial basaltic flows emanate. The domes also occur in groups with low shields, which are interpreted to be due to basaltic volcanism. Thin, lobate flows appear to originate from some domes, a relationship not observed at terrestrial silicic domes.

Conclusions

These results show that Venusian and terrestrial silicic domes have significantly different surface morphologies. Surface morphologies at silicic domes in the Inyo chain and at the Medicine Lake Highland volcano appear to exhibit complex relationships between cooling, fracturing and flow. Our study questions direct comparisons between terrestrial and Venusian domes based simply on morphology, and suggests that the silicic model for Venusian domes can only be validated through analysis of the relationships between morphology and emplacement mechanisms.

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