RESOLVING THE VOLCANIC HISTORY OF VENUS: DATA NEEDS AND CURRENT LIMITATIONS.

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Introduction: Venus is the only accessible planet that is like Earth in terms of size, density and composition [e.g., 1]; yet Venus currently stands in dramatic contrast to Earth in terms of its atmospheric properties and its geologic record. How two bodies with such similar planetary pedigrees could evolve to be so fundamentally different stands as one of the great enigmas in modern planetary science. The answer to this question could cast new light on the conditions that determine whether planets discovered elsewhere in the observable universe are likely to have evolved habitable environments – and for how long they might be maintained. Yet Venus remains the least understood of all the terrestrial planets.

Even the fundamental issue of Venus's volcanic history is mired in uncertainty and controversy. Assuming Venus generates about the same amount of internal heat as Earth, it should have a record of geological activity through which that heat is removed. As Venus exhibits no signs of a global system of plate tectonics [2] (accounting for the majority of heat loss on Earth), and its crustal composition and lithospheric thicknesses do not favor effective conductive heat loss, volcanic resurfacing seems to be the only viable heat loss mechanism.

Two end-member models for volcanic resurfacing have emerged from interpretations of Magellan data. The 'catastrophic' model proposes Venus underwent an abrupt and rapid global resurfacing event [*e.g.,*3-4] 300-600 Ma and has been more or less inactive since. Alternatively, the 'steady-state' model [*e.g.,* 5-6] calls for continual, patchwork volcanism, possibly aided by enhanced heat flow at sites such as coronae [7] where delamination of the lower lithosphere may have occurred.

Even after two decades of analysis, the catastrophic v. steady-state debate persists. While various positions have incrementally shifted [*e.g.,* 8-9], resolution of this keystone planetary issue remains elusive, indicating that no resolution may be possible with current data limitations. It is mystifying, therefore, that NASA and its international counterparts have shown so little interest in returning to Venus to collect better surface observations that are needed to resolve the issue and lay the controversy to rest.

Current Effort: Here I rely on nominal 2-m resolution RADARSAT-2 images of Kileaua volcano's

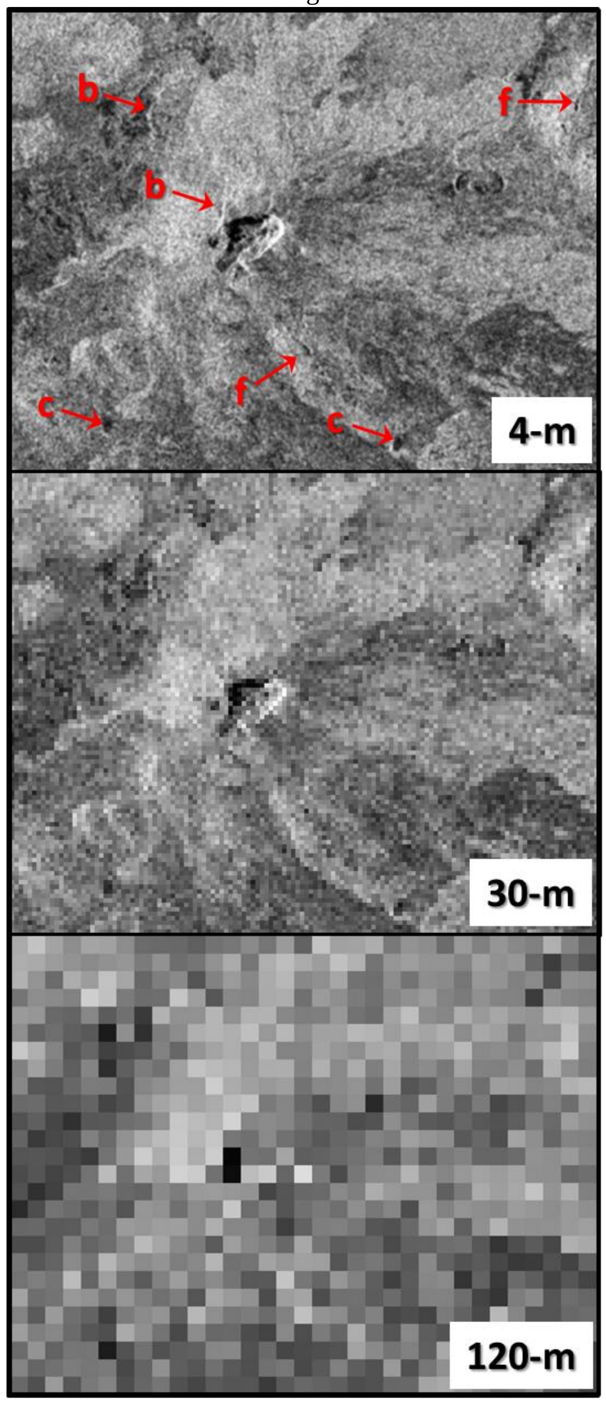

Figure 1 (right). Synthetic images of a 4-km wide region on Kileaua's East Rift Zone, showing Pu'u O'o crater and associated volcanic features. Look direction is from the left; incidence angle is ~44 degrees. Bottom frame approximates Magellan quality data, although the technique used to reduce resolution dramatically dampens noise and, in effect, improves the NESZ compared to Magellan data.

active East Rift Zone to (1) constrain backscatter image resolutions required to detect and characterize volcanic activity, and (2) explore the limitations of Magellan images for identifying diagnostic volcanic features such as fissures, vents, and lava flow boundaries.

A pixel averaging technique is employed to synthesize images at resolutions ranging from 4m to 120m. While Magellan's basic image products are sampled at 75m/pixel uniformly across the planet, its resolution is considerably coarser and varies with latitude: Along-track (N-S) resolution is 120m; cross-track (E-W) varies between 120m at periapsis (~10ºN) to ~280m near the poles. Consequently, 120-m resolution cells represent the best quality data the Magellan mission offered.

Results: Figure 1 shows representative samples of synthetic images covering a 4-km-wide area surrounding Pu'u O'o crater, the most active site on Kileaua's East Rift Zone and one of the most active volcanic craters on Earth. In addition to the conspicuous lava flows that eminate from the crater (center of the top image), small features such as cones (c), fissures and channels (f) and flow boundaries (b) that are diagnostic of the rates and styles of activity are clearly discernible in the 4-m data. Hummocky deposits within Pu'u O'o crater itself record slumping lava lake surfaces formed as the crater drained immediately prior to the image acquisition in July, 2009.

In 30-m images, some cones and flow boundaries are detected but their slopes cannot be measured reliably. However, the crater and the flows surrounding it are clearly identifiable.

In planetary missions, a tradeoff between resolution and coverage typically results from various engineering constraints. If, therefore, the mission goal is to identify and inventory recent or potentially active sites of basaltic volcanism over broad regions of Venus, then 30-m images may suffice. If, on the other hand, the mission requires quantitatively describing features that would lead to a fuller understanding of the rheological properties (e.g., rates and styles) of volcanism on Venus, higher resolutions should be considered.

As the bottom frame of Figure 1 illustrates, at Magellan resolution, all indications of Pu'u O'o crater and its associated feathres are obscured. It stands to reason, therefore, that if volcanic centers on Venus are similar to those of Kileaua's East Rift Zone, those features would go undetected in Magellan data. Based on their dimensions alone, the lava flows eminating from such centers should be detectable in Magellan data. However, their detection depends strongly on backscatter contrasts between and within flows, which in turn are dependent on poorly constrained rheological properties of the volcanic sequence. High surface temperatures and preservation of extensive volcanic channels, some 1000s of km in length [10], suggest that some lavas are extremely low viscosity and would have very low backscatter cross sections. Such lavas could go largely undetected in Magellan data.

Table 1 provides resolution constraints needed to detect and characterize Venusian volcanic features if they are similar to those of Kileaua's East Rift Zone.

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Table 1: Resolution requirements for surveying and characterizing volcanic centers on Venus

Feature	**Maximum resolution cell dimensions**	
	Detection	*Characterization*
Fissures, channels, collapsed lava tubes	36 m	Complete: 12 m Acceptable: 18 m
Flow boundaries, lobes, toes, levees, etc. (< 20 m wide scarps)		Complete: 6 m Acceptable: 12 m
Vents, craters, collapse features (10 – 80 m wide)		Complete: 3 m Acceptable: 6 m
Spattercones, rootless cones, shields (20-200 m wide)		Complete: 3 m Acceptable: 18 m
Small flows, tephra, lava pools (typically < 500 m wide)	72 m	Complete: 6 m Acceptable: 24 m

Note: Detection and characterization are strongly affected by backscatter contrasts. This imposed additional constraints on instrument/acquisition design (SAR frequency, NESZ, look angle, swath width, etc.). **Complete**: ≥80% features detected in 2-m data are resolved; **Acceptable**: ≥60% resolved.