DIRECT OBSERVATION OF VOLCANIC ACTIVITY ON VENUS FROM REPEAT MAGELLAN IMAGING.

R. R. Herrick[1] and S. Hensley[2], [1]Geophysical Institute, University of Alaska Fairbanks, Fairbanks, AK 99775-7320 (rrherrick@alaska.edu), [2]Jet Propulsion Laboratory, CalTech, Pasadena, 91109 (shensley@jpl.nasa.gov).

Introduction: The Magellan mission imaged the surface of Venus over three sidereal days, or "cycles", using synthetic aperture radar (SAR) at a resolution of 100-300 m. Cycle 1 observed ~84% of the planet with east-looking SAR images. Cycle 2 was used to fill gaps from Cycle 1 and repeat-image ~35% of the planet using west-looking SAR, and ~15% of the planet was covered during Cycle 3 by a second east-looking image, generally at an incidence angle ~20° different from Cycle 1. Because ~8% of the planet was imaged in all three cycles, a total of ~42% of the global area was imaged two or more times.

We have been examining areas considered most likely to possess active volcanism [1-4] and that have been imaged multiple times. We are looking for new or altered volcanic constructs, e.g., cones or vents, or new flows. Table 1 summarizes the areas we have examined so far. Here we present results from examination of an area in Atla Regio, Venus that spans from 9° S, 190° E to 6.25° N, 209° E, an area of ~3.2M sq km. This area contains two of the planet's largest volcanoes, Ozza and Maat Mons, and has been hypothesized to be a location of active volcanism [5-7]. Magellan observed the area with east-looking images in Cycle 1 (inc. angle 45°) and west-looking images in Cycle 2 (inc. angle 25°).

Table 1. Areas searched for surface change.

Area name	NW lat °N	NW lon °E	SE lat °N	SE lon °E
C1-C3 same look angle	50.0	345.0	40.0	352.0
Sif Mons	27.5	344.4	19.0	356.0
Annapurna	-34.7	149.3	-36.7	153.0
Aramaiti	-23.9	79.5	-27.3	84.5
Bele-Ili	8.3	16.5	4.0	21.5
Idunn Mons	-43.6	211.0	-50.0	219.0
Atahensik	-16.3	167.3	-22.0	174.5
Nyx Mons	31.0	47.0	21.9	50.3
Boann	28.8	135.0	25.7	138.3
Colinjinsplaat	-30.1	147.9	-33.5	153.4
Toci Tholus	32.0	348.0	27.0	355.0
Gula Mons	26.0	356.0	19.0	3.6
Sappho	17.5	12.0	12.0	19.0
Didilia	20.0	36.0	17.5	39.0
Anala Mons	12.0	10.0	8.0	17.0
Ozza & Maat	6.3	190.0	-9.0	209.0

Results: We have identified a volcanic vent at 1.363° N, 194.641° E (Figure 1), that changed shape and expanded in the eight-month interval between Magellan imaging in Cycles 1 and 2. The vent is on the north side of a domical shield volcano that is part of the larger

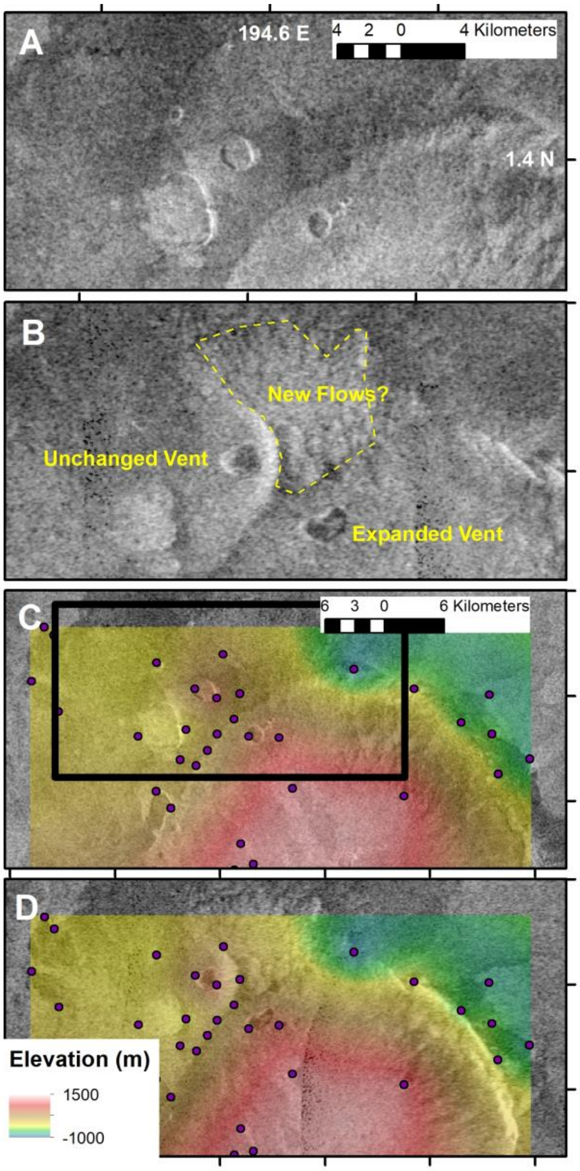

Figure 1. Change in vent shape and possible new volcanic flows. Top two panels show the east-looking Cycle 1 (**A**) and west-looking Cycle 2 (**B**) images of the vent. Bottom two panels show manually selected match points (dots) that were used to generate relative elevations (color) and orthorectify the Cycle 1 (**C**) and Cycle 2 (**D**) images. A black box in (**C**) outlines the extent of the unrectified images shown in (**A**) and (**B**). In the Cycle 1 image the vent appears to be nearly circular and deep with steep walls. In Cycle 2 the vent appears to have become larger in planform, irregular in outline, shallow and nearly filled. There may also be new, radar-bright flows in the Cycle 2 image. All images are in a sinusoidal projection, projection longitude 194.641°E; tick marks are 0.1°.

Maat Mons volcano. In the Cycle 1, east-looking image the vent appears near-circular (1.5 x 1.8 km, area 2.2 km^2) with steep interior slopes, and we speculate that it was a drained post-eruptive vent. In the Cycle 2 west-looking image the vent has become larger (4.0 km^2) and irregular in shape. In Cycle 2 the SAR expression of the wall slope is narrow (bright facing east, dark facing west) with sharp boundaries. We interpret this as indicating that it is nearly filled to its rim, and we speculate that a lava lake formed between images.

To aid in providing regional context, we identified match points in the Cycle 1 and 2 images and used them to generate relative elevations and orthorectify the images. Downhill, to the north, in the Cycle 2 image are a set of radar-bright flows that do not appear to have been present when the Cycle 1 image was taken. However, the topographic relief of the flows is not resolvable at Magellan resolution, and the different incidence angles of the two images means that we cannot rule out that the flows were present when the Cycle 1 image was taken, but the surface texture makes the flows more distinguishable at the lower incidence angle of Cycle 2. If the identified flows are new, their surface area is 69 km^2, a flow size consistent with typical terrestrial hot-spot volcanism.

As a check on our interpretation, we used a simple model of a vent as a circular, flat-floored rimless pit to model its appearance under Cycle 1 imaging conditions. We then compared how that pit would look under Cycle 2 observation conditions to the actual Cycle 2 image. We simulated the changed vent and what we interpret to be an unchanged vent of similar size just to the north (Figures 1,2). The models had rim radii r_b of 850 m and 1070 m, respectively, with varying depths and steepness of the walls. We used a simple analytic function to smoothly go from the pit rim to a floor radius r_f. We varied the depth D from 175 to 675 m in increments of 125 m for the changed vent, and from 175 to 875 m in increments of 175 m for the unchanged vent. We varied the steepness of the walls by varying the floor radii from 400 to 625 m (steepest interior slopes) in increments of 75 m on the changed vent and from 500 to 800 m in increments of 100 m on the unchanged vent. We also simulated overall cross-track terrain slopes of 0°, 5°, 10° and 25°. Our simulation modeled radar imaging effects due to radar speckle, thermal noise, layover, and shadow. The simulated radar images do a reasonable job of replicating the Cycle 1 and 2 images of the unchanged vent but we could not match the Cycle 2 image of the expanded vent either geometrically or radiometrically.

A sample size of one does not lend itself to a statistical treatise on Venusian volcanism. However, there is clearly a major distinction between identifying geologically recent volcanism on a planet (e.g., Mars) and demonstrating that it is currently volcanically active, as we have done here. Our limited survey of the Magellan data, combined with no easily observable changes over the multi-decadal k-scale observations by Arecibo for ~25% of Venus, means that Venus is not Io-like in its level of volcanism. The total area that we searched for changes is only ~1.5 % of the planet's total surface area, but the location where we found active volcanism is in a region where we most expected to find it. There are a wide range of possible resurfacing histories and associated geodynamic scenarios that are compatible with what we interpret as roughly Hawaiian-like levels of current volcanism in Atla Regio.

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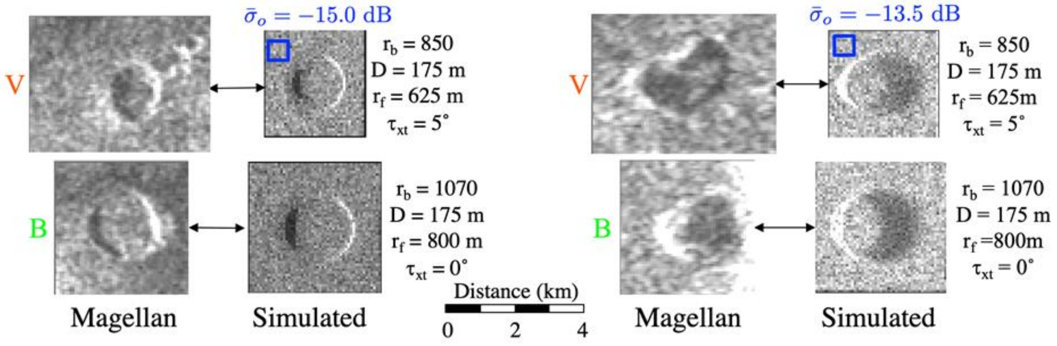

Figure 2. Comparison of radar images acquired in Cycle 1 and Cycle 2 of the changed vent (V) and nearby unchanged vent (B). We computed the mean backscatter in the blue rectangle next to the vent to constrain the cross-track slope. Shown are the best simulated vent geometries for the changed and unmodified vent along with the Magellan Cycle 1 and 2 images of these vents.