GEOLOGIC ANALYSIS OF SIR-B DATA FOR KILAUEA VOLCANO, HI: IMPLICATIONS FOR INTERPRETATION OF VENERA 15/16 AND MAGELLAN DATA OF VOLCANIC CENTERS ON VENUS ***Lisa Gaddis,*** *Department of Geology, Arizona State University, Tempe, AZ 85287*

Geologic analyses of imaging radar data of volcanic terrains on Earth and Venus have illustrated a need for understanding how such data can be used to interpret eruptive styles and to characterize the geologic history of volcanic centers. This report outlines results of a geologic analysis of Shuttle Imaging Radar (SIR-B) data of Kilauea Volcano[1] and discusses some of the implications of these results for interpretation of Venera 15/16 and Magellan radar data for volcanic centers on Venus. SIR-B obtained two digital radar images (25 m resolution, 23 cm wavelength, 28° and 48° incidence angles) over southeastern Hawaii in October, 1984; the target area of these data takes was the summit and Southwest Rift Zone of Kilauea Volcano[2]. Geologic analyses of these data indicated that while large-scale landforms (e.g., the summit caldera, pit craters, and fault scarps) and deposits with extremely smooth (e.g., the 1790 tephra deposit) or extremely rough (e.g., aa lava flows) surfaces are readily distinguished on the SIR-B data, many additional landforms (e.g., pahoehoe lava flows, cinder cones, and small fissures) are difficult if not impossible to detect, particularly if the adjacent or underlying substrate has comparable radar signatures.

To understand some of the advantages and limitations of using SAR data for geologic analysis of a volcanic terrain, the eruptive history of the summit and Southwest Rift Zone of Kilauea as it is currently understood and as it can be interpreted on the basis of the SIR-B data alone were compared[1]. From the SIR-B data, Kilauea is accurately interpreted to be a volcanic shield, with a well-developed summit caldera which suggests multiple episodes of collapse; evidence of radial and concentric rifting is also observed in the form of faults, traces of fissures, and lava flows from small-scale eruptive centers. The extensive low-return unit observed near Kilauea Caldera correctly suggests that explosive volcanism has played a major role in the development of the summit caldera. Effusive volcanism, observed in the form of radar-bright lava flows, is inferred to have played a more important role away from the summit along the radial rift zone of the Southwest Rift. Variable backscatter intensity from these rough-surfaced lava flows suggests that eruptive centers with associated bright (young?) lava flows evolved from earlier, more randomly distributed volcanism along the rifts.

Although this SIR-B-based interpretation of volcanism is generally correct, misinterpretation of several aspects of the volcanic history of Kilauea would result from reliance upon the SIR-B data alone. Pyroclastic volcanism, as evidenced by the extensive low-return units near the summit (inferred to be ash deposits) and the apparent absence of pahoehoe lava flows, appears to be the dominant style of volcanism at the Kilauea summit. In reality, pyroclastic eruptions comprise only a small percentage of Kilauea eruptions; explosive volcanism has occurred primarily at the summit, covering less than 2% of the present subaerial surface of Kilauea[3]. The apparent lack of pahoehoe lava flows on the SIR-B data erroneously suggests that effusive eruption of these very fluid lavas was not a common phenomenon at Kilauea. In addition, since pahoehoe lavas often comprise the near-vent portions of longer flows, both the number of flows and the dimension, especially the lengths, of many lava flows would be greatly underestimated. The apparent prevalence of aa lavas along the rift zones also suggests that Kilauea lavas had higher average viscosities than they do, and that the average eruption rates of Kilauea lavas were higher than they are. Finally, the inability to distinguish features such as cinder cones, low-relief lava shields, and small fissure systems falsely indicates that effusive or strombolian activity was a less important style of volcanism than large-scale pyroclastic eruptions.

These complexities in the use of SIR-B data for characterization of volcanic landforms and interpretation of the eruptive history of Kilauea resulted from the combined influence of system, data acquisition, and terrain parameters. The directional nature of the SIR-B radar beam (NW to

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SE) served to enhance large-scale topographic features such as the summit caldera and a radial system of normal faults oriented approximately perpendicular to the radar antenna. Also, the sensitivity of the 23-cm wavelength of SIR-B to the roughness of the surface at a comparable scale permitted mapping of the location and distribution of rough-surfaced aa lava flows along the Southwest Rift Zone of Kilauea. Limitations of the SIR-B data for geologic analyses of Kilauea included an inability to resolve small-scale topographic features such as cinder cones and fissures, and insensitivity to variations in small-scale roughness, resulting in an inability to distinguish pahoehoe lava flows from other low-return volcanic units.

The similarity in expected flow morphologies and eruptive styles on Venus and Earth[4] suggests that the results of this radargeologic analysis of Kilauea can be extended to the interpretation of eruptive styles of volcanic centers on the basis of Venera 15/16 (resolution from 1 to 3 km, 8 cm wavelength, 10° incidence angle) and future Magellan (resolution about 300 m, 12.6 cm wavelength, about 15° to 50° incidence angles) SAR images of Venus. In particular, these results permit an estimate of the influence of radar imaging parameters (such as resolution, wavelength, and incidence angle) on the geologic characterization of volcanic units on Venus. For example, at the 1 to 3 km resolution of the Venera 15/16 images, only large-scale volcanic landforms such as calderas, rift systems, lava shields or domes, lava flows, and possible pyroclastic deposits should be identifiable. Smaller-scale features such as cinder cones, pit craters, fissures, vents, lava channels, levees, and flow lobes would generally remain undetected, inhibiting the recognition of smaller volcanic centers on the Venera 15/16 data. In addition, at the 8-cm effective surface roughness defined by the wavelength of the Venera 15/16 system, many volcanic landforms might be expected to be radar-rough and thus to have bright or high returns. Certainly most lava flows should appear as high-return or bright units on the Venera 15/16 data, and the distinction between flow types such as aa and pahoehoe should not be possible. Because pyroclastic deposits may vary greatly in average surface roughness, such deposits on Venus could have either bright (e.g., radar-rough) or dark (radar-smooth) radar image signatures. Due to the steepness of the slope of the curve describing the radar scattering law for Venus[5] (where specular reflections from facets oriented perpendicular to the radar antenna dominate radar return), smooth (less than a few cm in average roughness) units (e.g., ash deposits, sand sheets) should have higher radar returns than rough units (e.g., lava flows) at the Venera 15/16 wavelength. For geologic interpretation of volcanic centers with the Magellan data, the significant improvement in resolution (about 300 m) may result in identification of smaller-scale (<100 m) volcanic landforms such as cones, domes, small eruptive centers, vents, and pit craters. Details of flow morphologies and vent structures are likely to remain unresolved with the Magellan data. At the 12.6 cm Magellan wavelength, lava flows should still exhibit radar-bright returns, and separation between aa and pahoehoe should not be observable. Due to the 15° to 50° range of incidence angles of the Magellan data, units of comparable surface morphology in areas imaged at different incidence angles should have variable return intensities.

Presentation of this radargeologic analysis of SIR-B data for Kilauea[1] is intended to facilitate an understanding of both the interactions between radar energy and volcanic target properties, and how those interactions will influence delineation and interpretation of major volcanic landforms on Venus. It is hoped that the continued study of terrestrial volcanoes with imaging radar data will promote efficient and effective use of imaging SAR data for geologic analyses of volcanic centers on other planetary surfaces.

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