Venus Small Volcano Classification and Description

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Introduction. The high resolution and global coverage of the Magellan radar image data set allows detailed study of the smallest volcanoes on the planet. A modified classification scheme for volcanoes less than 20 km in diameter is shown in Fig.1 and described. It is based on observations of all members of the 556 significant clusters or fields of small volcanoes located and described by this author during data collection for the Magellan Volcanic and Magmatic Feature Catalog [1]. This global study of approximately 10^4 volcanoes provides new information for refining small volcano classification based on individual characteristics. Total number of these volcanoes was estimated to be 10^5 to 10^6 planetwide based on pre-Magellan analysis of Venera 15/16 [2], and during preparation of the global catalog, small volcanoes were identified individually or in clusters in every C1-MIDR mosaic of the Magellan data set [3]. Basal diameter (based on 1000 measured edifices) generally ranges from 2 to 12 km with a mode of 3-4 km, and follows an exponential distribution similar to the size frequency distribution of seamounts as measured from GLORIA sonar images [2,3]. This is a typical distribution for most size-limited natural phenomena unlike impact craters which follow a power law distribution and continue to infinitely increase in number with decreasing size. Using an exponential distribution calculated from measured small volcanoes selected globally at random, we can calculate total number possible given a minimum size. The paucity of edifice diameters less than 2 km may be due to inability to identify very small volcanic edifices in this data set; however summit pits are recognizable at smaller diameters, and 2 km may represent a significant minimum diameter related to style of volcanic eruption. Guest, et al, [3] discussed four general types of small volcanic edifices on Venus: (1) small lava shields; (2) small volcanic cones; (3) small volcanic domes; (4) and scalloped margin domes ("ticks"). Steep-sided domes or "pancake domes" [4], larger than 20 km in diameter, were included with the small volcanic domes. For the purposes of this study, only volcanic edifices less than 20 km in diameter will be discussed. This forms a convenient cutoff since *most* of the steep-sided domes ("pancake domes") and scalloped margin domes ("ticks") are 20 to 100 km in diameter, are much less numerous globally than are the smaller diameter volcanic edifices (2 to 3 orders of magnitude lower in total global number [1]), and do not commonly occur in *large* clusters or fields of large numbers of edifices.

Defined by Apparent Topography . Topography is interpreted from the image and confirmed by a small number of radarclinometric profiles from Venera 15/16 and Magellan data (2,5) and stereo analysis [6] and edifices can be sub-divided into four types: (1) "shield-shaped" (the most common type of small volcano on Venus []); (2) domical-shaped; (3) cone-shaped; and (4) flat-topped or mesa-shaped edifices. Although edifice slopes vary between these types, there is no difference in size frequency distribution of their diameters or the planimetric circularity which delineates them on the radar images. Summit pit size for all types is 0.2 to 1.8 km. Summit pit diameter (or occurrence) does not have a direct relationship to basal edifice diameter; however, pits large in relation to the diameter of the edifice occur more commonly in dome-shaped or cone-shaped edifices. Although individual flow units cannot be identified on edifice flanks at Magellan resolution, the volcanoes can be modeled by multiple centralized small-volume lava flows with a contribution by localized phreatic deposition. Steeper edifice slopes imply a greater contribution by phreatic material or a variation in geochemical evolution or eruption rate. The mesa-like or "flat-top" edifices are distinctive and similar to some seafloor volcanoes imaged by GLORIA[7]. The Venus flat-tops are characterized by a radar-dark flat summit and small central crater. One or two of this type commonly occur in fields of dominantly shield-shaped edifices. The flat-top profile is difficult to model by construction due to multiple centralized small-volume lava flows; but such a profile can be created by a perched and flooded lava pond [3]. A few of the flattops show a radar bright, striated apron of narrow width encircling the edifice base which may represent flows originating at the summit and overflowing the edge or a debris apron. Some of the topographic edifice type small volcanoes are very similar to larger and less common Venus volcanic landforms, implying a continuum of similar volcanic processes, materials or eruption rates/conditions operating at different scales. The small domical-shaped edifices frequently show the flat and patterned summit common to the larger steep-sided domes, and the flat-top type may be produced or modified in ways similar to those suggested for the larger and much less common scalloped margin domes [3].

Defined by Radar Backscatter Pattern. Many small volcanoes are visible only as variations in radar backscatter and are interpreted to have extremely low topographic slopes. They are defined separately from the topographic edifice types because their differences in characteristics imply differences in material, volume of material, or eruption rate/conditions. Sub-divisions are: (1) Radial flow pattern; (2) halo (aureole); (3) bright or dark "spot"; and (4) defined solely on the basis of the presence of a pit or crater or by disruption of local structural trends. The radial flow pattern type is similar in diameter to the shield-shaped type but individual flows are clearly visible and well-defined. They are similar to the "anemone-type" intermediate-sized (30-40 km diameter) volcanoes first described early in the Magellan mission [8]. They occur individually within fields of dominantly shield-shaped edifices or, in a few areas, in entire fields of the radial flow pattern type. These volcanoes appear to be produced by long linear flows extruded from a circular to elongate fissure-type vent and are frequently aligned along local structural trends. Radar bright (or less commonly dark) aureoles or haloes [2,9] are sometimes associated with small but otherwise typical topographically defined edifices and may be evidence that the total volume of extrusive material associated with each vent is larger than the edifice alone. Although haloed edifices are somewhat rare, when they do occur, they commonly occur in fields rather than as a single example. This implies that the origin of the halo effect may be a regional phenomenon. The halo is either constructional and emplaced on pre-existing plains in association with the volcanic edifice or it may represent the exposed radar bright lower slopes or surrounding apron of flows of the edifice encircled by later plains material at a constant contour level. Circular radar

bright (commonly without central pits) or irregularly shaped radar dark "spots" represent very low slope shield volcanoes or extrusion of a much less viscous material than commonly occurs in the typical shield-shaped edifices. The dark irregular patches frequently occur associated with graben and may represent individual flows erupted from a point source on a fissure, similar to small localized Hawaiian rift eruptions, rather than a true constructional shield-type edifice.

Future Work. There are three fundamental questions regarding the small volcanic edifices on Venus: (1) what type of volcanic activity is represented by these edifices? (2) what is the volume contribution of these numerous but small volcanic source vents? and (3) what does the presence of abundant volcanoes, frequently occurring in concentrated "fields" imply for the heat flow and resurfacing history of Venus? There is now a complete data set of small volcanoes identified and located on the surface of Venus. Detailed observation has resulted in a classification of these features and preliminary interpretations of the type of volcanic activity that they represent. Detailed mapping of the geologic relationships of these small volcanoes to the plains and larger volcanic features is essential to continue to explore these questions.

References: [1] Head, et al, 1992, JGR 97, 13,153; Crumpler, et al, 1992, this volume; Crumpler, et al, 1992 GSA Sp Pap, in prep [2] Aubele and Slyuta, 1990, EMP 50/51, 493 [3] Guest, et al, 1992, JGR 97, 15,949 [4] Pavri, et al, 1992, JGR 97, 13,445; Mckenzie, et al, 1992, 15,977 [5] C. Weitz, unpub. data, 1991 [6] Moore,et al, 1992, Int. Ven Colloq.(abst), 71 [7] USGS MIsc. Invest. Series I-1792, 1986 [8] Head, et al, 1991, Science 252, 276 [9] Klose, 1990, LPSC 21 (abst) 639.

Figure 1