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CHARACTERISTICS, DISTRIBUTION AND GEOLOGIC/TERRAIN ASSOCIATIONS OF SMALL DOME-LIKE HILLS ON VENUS

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Introduction. Approximately 22,000 small dome-like hills have been recognized on the northern 20% of the surface of Venus imaged by Venera 15/16. These features have been described [1] as generally circular in planimetric outline, with a range in basal diameter from the effective resolution of the Venera images (1-2km) up to 20 km.

General Characteristics. The small hills have been called domes [1,2] following the lunar nomenclature, because of their broad apparent form. The nomenclature used here, "small dome-like hills", is preferred because of the strict volcanological definition of a dome and terrestrial lithologic connotations. The actual number of these features, and their true range of diameter and modal diameter is unknown; since there is undoubtedly a population, of unknown size, of dome-like hills $\lesssim$1 km that cannot be resolved in the Venera images. The maximum diameter of 20 km is, in a sense, an artificially imposed size range since similar features occur on Venus in the 20 to 100 km diameter range. However the 20 km cutoff reflects a significant change in the overall number of edifices, and in number versus basal diameter frequency distribution. Using diameter measurements in the along-range direction, best estimate modal diameter was determined for a typical cluster of small dome-like hills in Tethus Regio [3]. The 444 total ranged in basal diameter from 2-8 km, with a mode of 3-4 km. Based on constraints on the appearance of features imaged by this radar system, individual dome-like hill slopes are all less than 10°. Assuming these slopes, simple geometric models imply maximum height of approximately 1 km, and average height less than 1 km. Recent radarclinometric data confirms these estimates [4]; profiles of seven small dome-like hills, ranging in basal diameter from 7.2 to 19.2 km, show a slope that is slightly convex near the summit, relatively uniform (maximum slope 5°) on the flank, and slightly concave (minimum slope 1°) near the base. The maximum height ranges from 150 to 650 m; and increased height is generally related to increased basal diameter, with some variations. Most of the small dome-like hills show no individually associated features; however, a small number exhibit summit pits, low basal topographic rises or platforms, and radial or lobe-like bright features. Summit pits are infrequently observed in dome-like hills larger in basal diameter than 8 km, and more frequently in ones larger than 15 km. The total number with visible summit pits is less than 5%. Bright circular aureoles, without apparent topographic relief, appear to be associated with small dome-like hills northeast of Atalanta Planitia.

Dome Distribution. Slyuta, et al [2,5] have produced dome density contour maps and find that most dome-like hills occur in *groups* of several tens within areas of 10^3 km^2. Adjacent *groups* form *clusters* consisting of 10-20 *groups* within areas of 10^5 km^2. The greatest concentration of *clusters* of dome-like hills occurs in the general area of 60°N, 120°E. Major concentrations of *clusters* are located in Tethus Regio (65°N, 110°E), Atalanta Planitia (60°N, 155°E), Ananke Tessera (55°N, 138°E), and Akkruva Colles (from Niobe Planitia, 35°N, 130°E, to Allat Dorsa, 65°N, 70°E). In general, these major areas of cluster concentration are approximately equidimensional in areal extent, with the exception of Akkruva Colles which is elongated in the NW-SE directions. Akkruva is also associated with a linear positive gravity anomaly of 25 mgal in the Pioneer Venus data set. The cluster concentrations in Tethus, Ananke and Akkruva are associated with broad regional topographic highs. However, many small groups or clusters of groups occur on low plains or inside circular depressions and the cluster concentration in Atalanta occurs in the general area of the topographically lowest region of Venus. Within a specific cluster, the dome-like hills appear to occur in relatively evenly scattered groups. Counts in a representative cluster in the Tethus Regio region show that overall density of the dome-like hills, within a specific cluster, is ≈ 0.4/100 km^2 and maximum density is 1.0/100 km^2 [3]. A few dome-like hills appear to exhibit alignment due to minor local structural control, but there is no evidence of large-scale structural control or dominant trend directions.

Terrain Unit and Geologic Feature Associations. Almost all of the areas of cluster concentration occur on mottled plains units designated as "rolling plains interpreted to be of volcanic origin" [6]. The outline of the major region of cluster concentration also generally corresponds to the Plains-Corona-Tessera Assemblage described by Head [7]. Major clusters frequently occur on plains units at the margins of areas of tessera, while very small groups occasionally occur in intra-tessera plains near the margins of large tessera units. Where it is possible to evaluate

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the evidence, it appears that the plains, on which the dome-like hills occur, post-date the formation of the tessera terrain. Smaller cluster concentrations occur in regions of predominant arachnoids, in the area between Sedna Planitia and Bell Regio and in the area south of the ridge belt province at 40°N, 215°E; and also occur at Beta Regio. Although domes occur on the plains to the north and south of Ishtar Terra, Lakshmi Planum and the horizontal compressional fold belts [8] of Akna and Freyja Montes exhibit one of the lowest densities of small dome-like hills on Venus. No major concentrations of dome-like hills occur in the major ridge belt areas, although small groups and isolated dome-like hills occur near the ends of a few ridge belts. Small groups of dome-like hills always appear to be associated [9] with the following specific geologic features: (1) coronae - dome-like hills occur predominantly inside the annular concentric ridges of coronae [10]; (2) arachnoids - dome-like hills occur predominantly in the areas of lineations on the plains surrounding and between adjacent arachnoids; (3) intermediate (20-100 km) sized hills interpreted to be volcanic constructs - these generally occur as isolated features on plains units near groups or clusters of small dome-like hills; (4) large volcanic centers ($\geq$100 km) - dome-like hills occur predominantly on the lower flanks, or beyond the distal edges, of the bright radial markings associated with these centers; (5) calderas - isolated dome-like hills generally occur on the rims and periphery [11]; and (6) large circular features of uncertain origin - dome-like hills occur predominantly within these features. The spatial association between these specific geologic features and groups of dome-like hills is ubiquitous, even when one of these geologic features occurs in an area with low overall density of small dome-like hills. Geologic mapping provides evidence that formation of the dome-like hills post-dated the development of tessera terrain; may have coincided with the emplacement of plains units interpreted to be volcanic; but may have pre-dated the final development of many large volcanic centers found spatially associated with the dome-like hills.

Discussion. Because they are so numerous, the origin and mechanism of formation of the small dome-like hills of Venus is a significant question that has implications for the geologic processes and evolution of the planet. Since many clusters of dome-like hills occur on plains units that are adjacent to, and appear to be younger than, tessera terrain, it is reasonable to question whether they merely represent partially buried and isolated topography. The large number of these features, their randomly scattered occurrence, their consistent circularity, the apparent lack of major structural alignments, and the frequent occurrence of summit pits suggest that the dome-like hills do not merely represent partially flooded pre-existing ridges. Large volcanic features have been previously recognized on Venus, such as the calderas in Laksmi Planum and the large volcanic edifices associated with Bell Regio. Smooth plains, frequently appearing to embay other terrain units, have been interpreted to be volcanic in origin. Circular features, such as corona or arachnoids, have also been interpreted to be associated in some way with volcanism [8]. In addition, detailed study of the Venera images has resulted in the recognition of approximately 1000 edifices, with diameter $\geq$20 km, that are interpreted to be volcanic. As the geologic associations described above have demonstrated, the small dome-like hills of Venus occur spatially associated with other features which are recognized as volcanic or interpreted to be volcanic by other researchers. The dome-like hills can, therefore, be reasonably interpreted to be small volcanic edifices themselves. Examples of small edifices, interpreted to represent predominantly effusive volcanism, occur on Earth in the form of low shield volcanoes and seamounts, and also occur on Mars and Earth's moon. The morphology of volcanic edifices is a complex function of fundamental volcanological properties and variables; however, the general appearance and characteristics of these dominantly effusive volcanic edifices appear to be similar to those of the Venus dome-like hills [3]. The existence of dome-like hills ($\leq$20 km), intermediate sized volcanic edifices (20-100 km), and large volcanic centers ($\geq$100 km) implies a continuum of volcanic edifices on Venus. There is a distinct distribution of number versus size range such that the number of edifices increases as the size decreases; this is similar to that observed for volcanic edifices on Earth.

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