Modified lava domes on Venus; Bulmer MH, Guest JE (Univ. London Obs. NW7 2QS, UK)

During the early stages of the Magellan mission an edifice with scalloped margins was seen situated to the north of Alpha Regio (18.1^{0}S, 5.5^{0}E), whose origin was enigmatic and was thought to have no terrestrial analogue. As more data were examined other edifices with scalloped margins were identified. The radar characteristics and morphologies of many of these edifices were noted to be similar to volcanic domes and fell within a spectrum ranging from unmodified to remnant forms. Many modified domes had deposits associated with them that possessed a range of radar and morphologic characteristics indicative of landslide deposits. Large amphitheatres on the flanks of some domes indicated that large scale collapses had occurred. Other domes showed coalesced scallops giving a stellate plan form. Based on the characteristic margins, the edifices were termed scalloped margin domes[1].

An extensive database has been compiled from a global survey of volcanic domes on Venus. It incorporates information on morphologic and morphometric aspects of domes and large landslide phenomena associated with them. The survey identifies that volcanic domes are more common than suggested in a previous study[2]. Over 320 domes have been located of which over 80% had modified morphologies. A strictly descriptive classification scheme using the form of the upper surface, the planimetric form and the presence of associated deposits was devised, that allowed comparison between dome morphologies. Broadly the modified domes could be described by five groups with different characteristics that appeared to have evolved from three unmodified dome sub-categories (figure 1).

Dome diameters range from < 10 km to 120 km, the majority being between 10 km and 35 km. Domes with diameters greater than 70 km tend to be comprised of several superposed or coalesced domes whose margins are often indistinguishable. Modified domes have heights ranging from 0.4 km to 5.8 km. The mean height is 1.3 km which is 970 m higher than the mean for terrestrial subaerial domes. The distribution of domes as a function of altitude shows that they range from 6050.4 km to 6054.7 km mpr. The majority are located between 6051.0 km and 6052.0 km mpr very close to the mean planetary radius.

Volcanic domes are present over the majority of the surface of the planet though few domes are located in the highlands of Ishtar Terra, Aphrodite Terra and Lada Terra where a general absence of small volcanoes was noted. The lowest areas of the plains are also devoid of domes. An examination of the association of volcanic domes with other geological features revealed 50 % occur in plains. A total of 31 % of modified domes were recorded as associated with volcano-tectonic structures and 56 domes are situated in or on such structures. This association supports the suggestion that volcano-tectonic structures are the surface expressions of magma plumes or reservoirs[3,4]. Such large volumes of magma could have provided a source for differentiated or volatile enhanced material. The association of 17 % of domes with large volcanoes may be explained by the presence of high level magma reservoirs, the existence of which is supported by the observation of calderas on the summit of many large volcanoes. More evolved magmas could have been formed in such reservoirs. Of the domes associated with large volcanic centres 47% are situated on the summit region such as the domes on the 4.8 km high shield volcano Sapas Mons (9^{0}N, 188^{0}E). Those on the summit of large volcanoes possibly represent the youngest volcanic event. A total of 11 % of domes are situated in fracture zones and have been heavily modified. Only 3 % are associated with tessera, but they are often situated on plains at the margins of upland areas. The number of domes found on tessera and fracture belts coupled with their degree of modification indicates that in zones that had been tectonically deformed many small volcanoes may have been destroyed.

The majority of domes are found in isolation or in pairs. Often circumferential fractures surround one or sometimes two domes situated close together and may have been related to upwarping associated with dome emplacement or with downwarping at the end of an eruption. A total of 10 % of domes occur in clusters often formed of overlapping or coalesced domes. These dome complexes have large diameters ranging between 70 km to 120 km. Other clusters are made up of overlapping pairs of domes such as those to the east of Alpha Regio (30^0 S, 12^0 E).

Landslide deposits associated with volcanic domes may have originated from destructive geomorphic processes. On Earth such processes occur on volcanic dome during emplacement (explosive decomposition, directed blasts, pyroclastic flows and surges, lava flows, and rockfalls and rock avalanches) and after dormancy (rockfalls and rock avalanches), exhibiting a broad range of complexity, diversity and magnitude.

Modified lava domes on Venus; Bulmer MH

A descriptive classification using headscarp-debris-apron relationship, surface texture and plan view, was used to compare different landslides around modified domes. Four morphologic groups are identified. Three have morphological and morphometric similarities to terrestrial flow deposits. The term flow is used to describe any fluidized transport or movement of fragmented solid rock, with or without interstitial fluid (e.g. atmospheric gases, magmatic gases, melted rock or fines). Two of the flow deposits are most comparable to terrestrial volcanic debris avalanches and the third, to pyroclastic flows. The fourth group of deposits are similar to deep-seated arcuate, planar, and translational slides on Earth.

The landslide deposits and backscarps indicate that volcanic domes on Venus have been modified primarily by slope failures. The stellate or arcuate margins of domes can be attributed to large scale landslides[5]. The absence of landslide deposits around some domes with scalloped margins can in particular geological settings be explained by younger material having been superposed on the deposits. Elsewhere the deposits may have formed only a thin unconsolidated mantle that was penetrated by the radar or has been reworked by secondary processes. It is also possible that some deposits possess similar radar backscatter coefficients to the surrounding plains.

References: (1) Guest et al (1992) J. Geophys. **Res.,** 15,949-15,966. (2) Pavri et al (1992) J. Geophys. **Res.,** 13,445-13,476. (3) Stofan et al (1992) J. Geophys. **Res.,** 13,347-13,378. (4) Squyres (1992) J. Geophys. **Res.,** 13,611-13,634. (5) Bulmer et al (1994) in press.

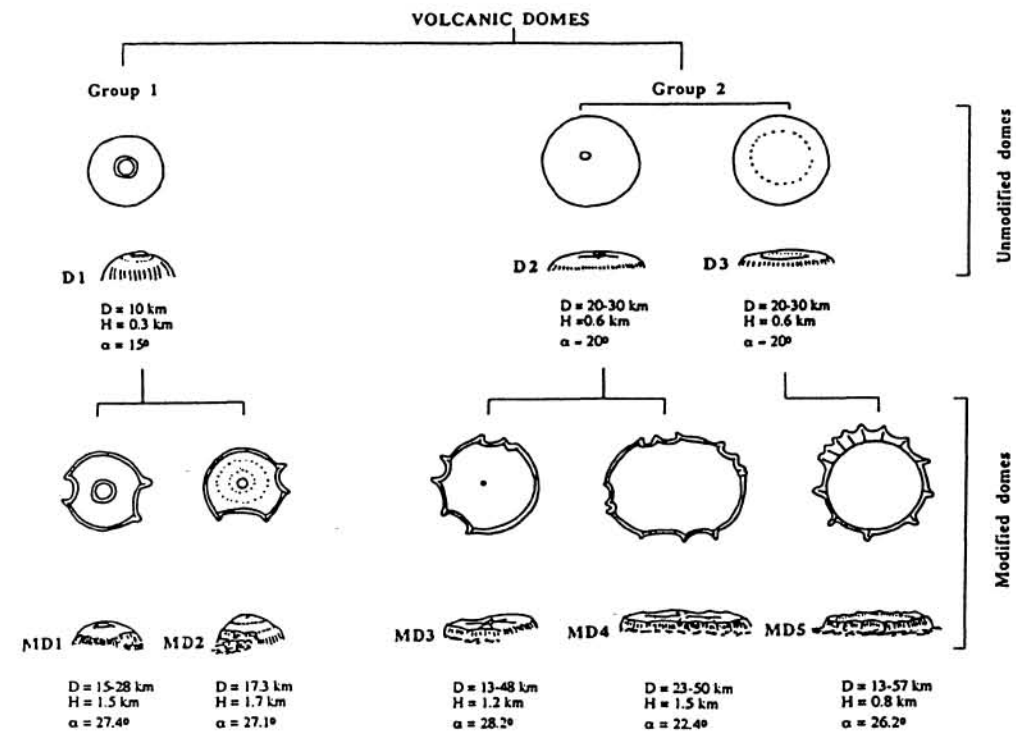

Figure 1 Schematic representation of the modification of volcanic domes. The first group of unmodified domes has one subcategory (D1) from which two subcategories of modified dome develop (MD1, MD2). The second group of unmodified domes has two subcategories (D2, D3). Two subcategories of modified domes (MD3, MD4) develop from D2, and one (MD5) from D3.