A NEW SURVEY OF INTERMEDIATE VOLCANOES ON VENUS. O.L. White[1], E.R. Stofan[2], and J.E. Guest[1]. [1]Dept. of Earth Sciences, University College London, Gower St., London, WC1E 6BT, UK (o.white@ucl.ac.uk). [2]Proxemy Research, Laytonsville, Maryland 20882, USA.

Introduction: The Magellan mission to Venus succeeded in providing the first high-resolution radar images and altimetric maps of the surface, covering most of the globe [1, 2]. The combination of these datasets has allowed characterization of surface features in great detail; an observation of particular importance is the very wide range in morphologies and sizes of volcanic edifices. The appearances, distributions and associations of shield fields, intermediate and large volcanoes, calderas, coronae, 'arachnoids', 'novae', and lava flows have been broadly classified [3]. The prevalence of all these features across the globe means that a very large dataset of volcanoes of all morphologies is available from which to investigate how the distribution of different volcano classes corresponds to altimetry and geological environment.

Previous studies have concentrated on the altitude dependence of morphologically distinctive intermediate volcanoes (steep-sided domes, 'ticks' and 'anemones' of basal diameter 20-100 km), large volcanoes (basal diameter >100 km) and radiating dyke swarms to explain their distribution [3, 4, 5]. A model for the distribution of magma reservoirs and neutral buoyancy zones (NBZs) in the crust based on the distribution of volcanic landforms has been formulated [4]. The results of subsequent studies have in some cases supported NBZ theory predictions [6, 7, 8] while others have disagreed or are inconclusive [5, 9]. The latter study noted that, in addition to NBZ formation, factors such as edifice morphology must be considered to a greater degree in order to build up a full picture of the process of edifice formation and growth on Venus.

It is with these previous studies in mind that a comprehensive global survey of intermediate-sized volcanoes has been compiled, using high-resolution F-maps, stereoscopic images (C1-MIDR scale), and GTDR altimetry data. This has allowed a database to be compiled that catalogues the diameters of any flows, edifices and calderas/craters present in each structure considered, basal heights and altitudes, as well as qualitative descriptions of the edifice morphologies and characteristics of flows and fractures intrinsic to the volcanoes.

Results: The catalogue incorporates five main morphology categories: cones, domes, modified domes, shields and calderas. Each class is defined as follows:

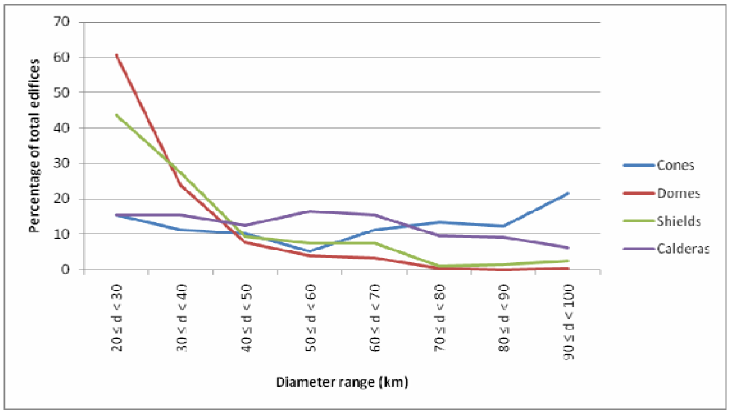

Figure 1. Size distribution of Venusian intermediate volcanoes.

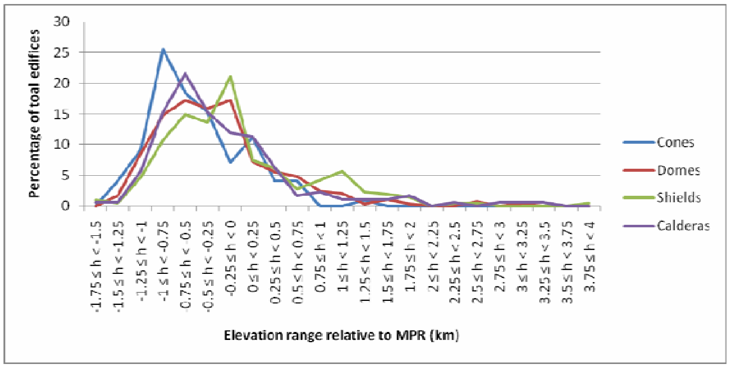

Figure 2. Altitude distribution of Venusian intermediate volcanoes.

Cones: Conical edifices with or without a summit caldera, and which display steep slopes and significant vertical relief manifested in topography data and/or radar backscatter. Edifices are often surrounded by relatively flat apron flows and sometimes display a summit dome.

Domes: Steep-sided, flat-topped edifices, often with a circular planform. Display radar-bright foreslopes. Edifices may or may not have a central caldera. Edifices sometimes display radial fracturing. Summit region is sometimes downwarped.

Modified domes: Identical to the edifices in the dome class, although these domes display considerable flank collapse, and are often surrounded by debris aprons. Some appear to have undergone extensive fragmentation throughout their body.

Shields: Gently-sloped, low-relief edifices that display a range of planform morphologies. Do not display radar-bright foreslopes. May or may not display a summit caldera. Some display prominent high-backscatter radial digitate flows. Some comprise flows emanating from an elongate fissure vent rather than a point source.

Calderas: Circular or elliptical collapse features with zero or negative relief, whose rims are defined either by an annulus of concentric fracturing (which is sometimes raised above the caldera interior) or by a sharply-defined cliff-face. Calderas often have low-backscatter flows on their floors.

Domes and modified domes can be considered as different evolutionary stages of a single class. The frequencies, mean basal planetary radii (i.e. elevations), mean diameters (inclusive of any flows originating from the feature), and mean latitudes of each class are shown in Table 1. The total areal coverage of each class is also shown as a proxy for the total magma contribution of each; volumes of individual edifices have yet to be calculated, yet these would themselves be minimum values for the magma contribution as the sizes of any intrusive bodies associated with the edifices cannot be constrained. For the caldera class, the areal coverage is a proxy for the size of the subsurface magma chamber. Figures 1 and 2 present the size and altitude distribution of each class respectively. Some observations are noted below:

- Domes are the most prevalent class, occur at intermediate elevations, and cluster at intermediate latitudes, although they are relatively evenly spread across the planet (they do not cluster in the BAT region as much as other categories). Despite their prevalence, their small sizes mean they occupy the least areal coverage of any class.
- Cones by contrast are the least prevalent class, yet their large sizes mean that they occupy almost 45% more areal coverage than the domes. They occur at the lowest elevations and are the most latitudinally restricted class, clustering around the equatorial regions and particularly the BAT region.
- Shields occur at the highest elevations, cluster at low latitudes (particularly in the BAT region), and are generally larger than domes but smaller than cones: they occupy almost 10% more areal coverage than domes and almost 25% less areal coverage than cones.
- Calderas occupy the most areal coverage (>25% more than cones). They cluster at low latitudes (particularly in the BAT region) and occur at intermediate elevations.

Figure 1 shows that both domes and shields tend towards the 20-40 km diameter range – very few larger than 70 km exist. In contrast, the diameters of cones and calderas are more evenly distributed – there is even a slight increase in the frequency of cones from small to large diameters. This distribution would suggest that the majority of large volcanoes (basal diameter of >100 km) are larger versions of the cone class identified in this study, rather than larger domes or shields. This inference is supported by an initial morphological comparison of intermediate cone volcanoes and large volcanoes, yet a more thorough survey of slope values is necessary in order to verify the continuation of cone morphology through both intermediate and large size ranges.

All of the volcano classes display mean elevations that are less than the mean planetary radius (MPR) of Venus (6052 km) – almost 75% of all features occur below this elevation. This apparently contradicts the NBZ theory prediction that, for a range of common terrestrial magma volatile contents, shallow magma chambers will infrequently form beneath terrain existing near or below MPR [4]. If this were the case, the majority of these features should exist above MPR.

Analysis is ongoing and will incorporate more comprehensive distributional statistical analysis, including identification of any correlations existing between volcano type and geological environment. The variation in summit morphology of cone volcanoes with increasing edifice diameter will also be characterized.

References: [1] Pettengill, G.H. et al. (1991) *Science*, *252*, 260-265. [2] Saunders, R.S. et al. (1991) *Science*, *252*, 249-251. [3] Head, J.W. et al. (1992) *J. Geophys. Res.*, *97*, 13,153-13,197. [4] Head, J.W. and L. Wilson (1992) *J. Geophys. Res.*, *97*, 3877-3903. [5] Krause, M.O. and E.B. Grosfils (1999) *LPS XXX*, Abstract #1685. [6] Keddie, S.T. and J.W. Head (1994) *Planet. Space Sci.*, *42*, no. 6, 455-462. [7] Grosfils, E. and J.W. Head (1995) *Planet. Space Sci.*, *43*, no. 12, 1555-1560. [8] Ristau, S. et al. (1998) *LPS XXIX*, Abstract #1100 (CD-ROM). [9] Stofan, E.R. et al. (2001) *Icarus*, *152*, 75-95.

Table 1. Statistics relating to each morphological class in the catalogue.

Volcano class	**Frequency**	**Mean diameter (km)**	**Mean basal planetary radius (m)**	**Mean latitude (°)**	**Total areal cover ($\times 10^5$ km^2)**
Cone	98	62.5	6051508	21.2	3.45
Dome	168	30	6051669	32.1	1.36
Modified dome	131	30	6051792	30.8	1.04
(All domes)	(299)	(30)	(6051723)	(31.5)	(2.40)
Shield	215	36.5	6051942	25.7	2.63
Caldera	176	54.5	6051797	26.7	4.42
All classes	**788**	**41.5**	**6051772**	**27.6**	**12.89**