#2782 – Morphometry of Mid-Sized Venusian Shield Volcanoes

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Introduction

Comparing simple morphometric values between Venusian shield volcanoes and their terrestrial and Martian counterparts can provide insight into the eruptive conditions and lithospheric state when the volcano formed. Previous efforts have focused primarily on large volcanoes (>300 km diameter flows) because the gridded Magellan altimetry data has a resolution of 10-20 km. Here we examine the shape of small (<300 km) volcanoes using stereo-derived topography from the Magellan SAR imagery and compare their morphometry to terrestrial, Martian, and larger Venusian shield volcanoes.

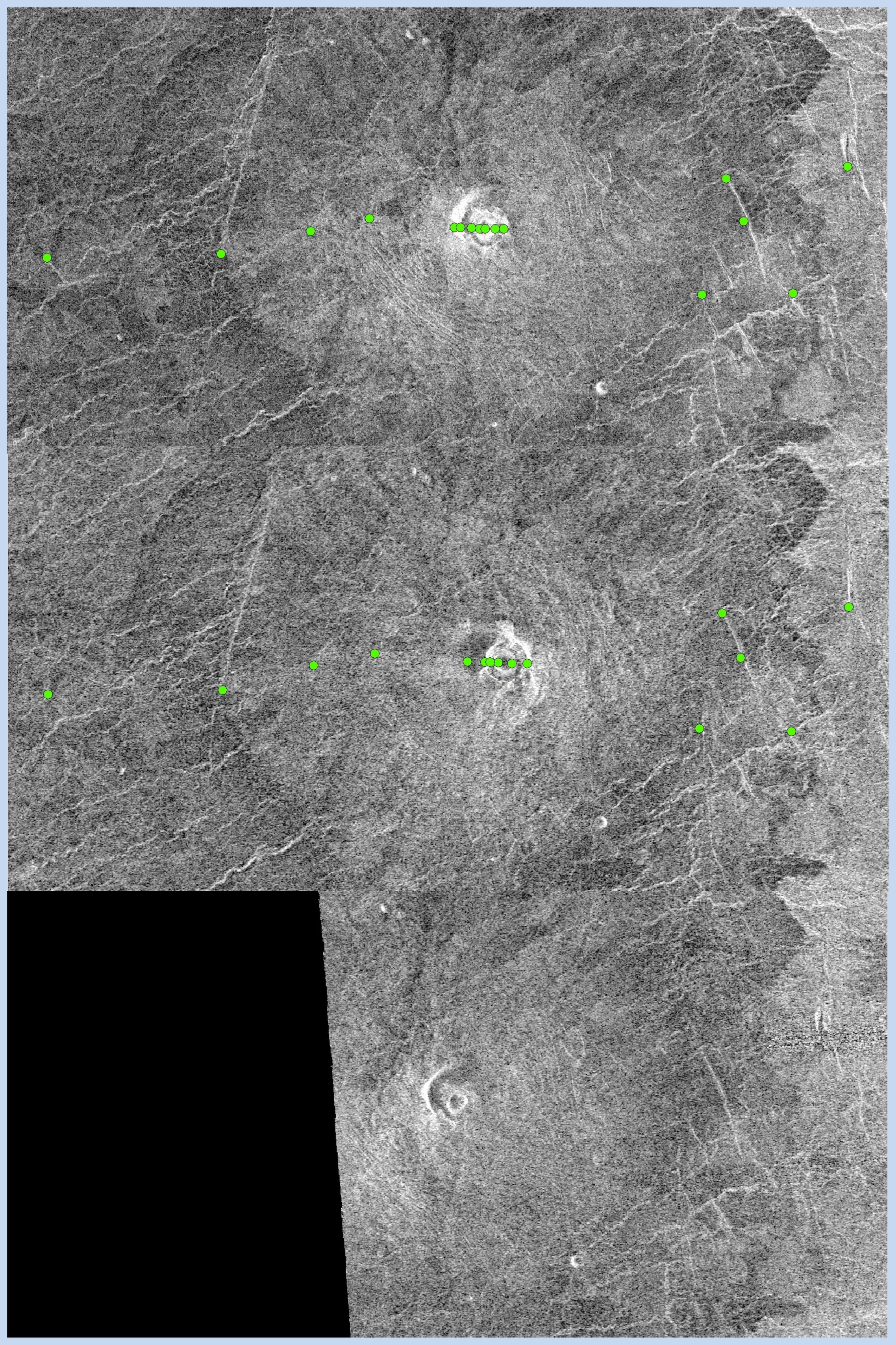


Figure 1. Cycle1 left-look (top), Cycle2 right-look (middle), and Cycle3 left-look (bottom) radar images of the volcano at 13.5°N 78°E. Green dots represent match points used to create an elevation profile from the left/right image pairs. A narrow profile could not be maintained for all volcanoes. For volcanoes that appeared radially symmetric, distances were calculated from a reference point near or within the summit caldera. For those without radial symmetry, distances are calculated between successive points. The black patch in the Cycle3 image is a data gap.

Profile Creation

Topographic profiles were derived from two sources. The first source is stereo-derived topography from the Magellan Cycle1-Cycle3 stereo imaging, processed through automated methods and estimated to have a horizontal resolution of 1-2 km and a vertical resolution of 50-80 m [1]. These data only cover ~20% of the planet in areas that are relatively volcano-poor. West/East and North/South profiles were extracted where possible. The second source is manually generated profiles extracted from Cycle1 left-look and Cycle2 right-look image pairs. This "opposite-look" stereo data covers much more of the planet (~40%) but is not well-suited to automated matching and thus much more tedious to work with. Matching points were manually selected along approximately West/East profiles to obtain relative height and distance.

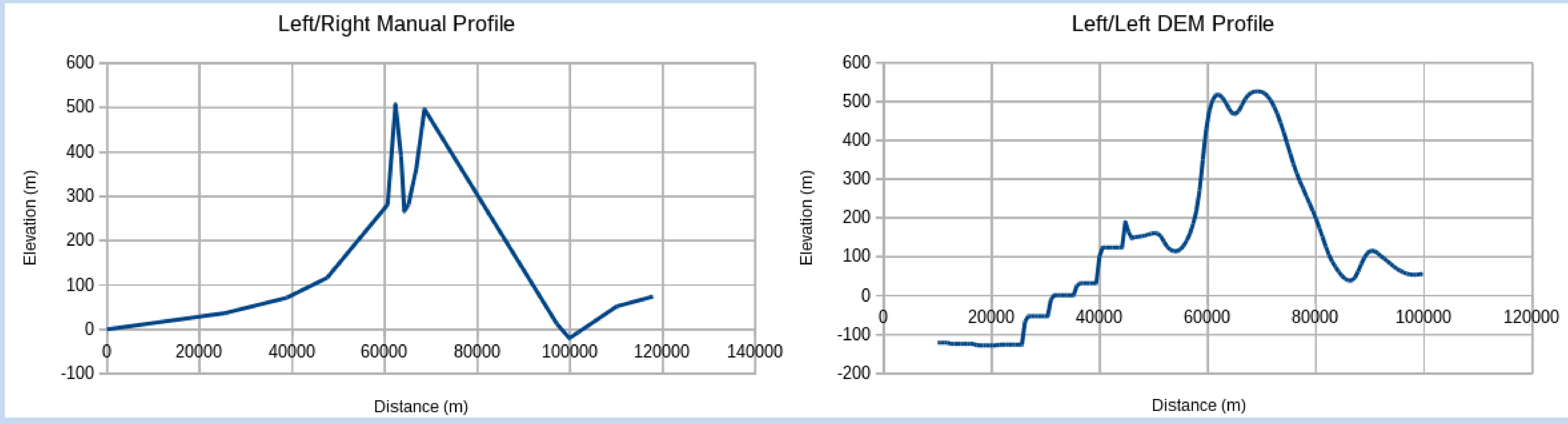
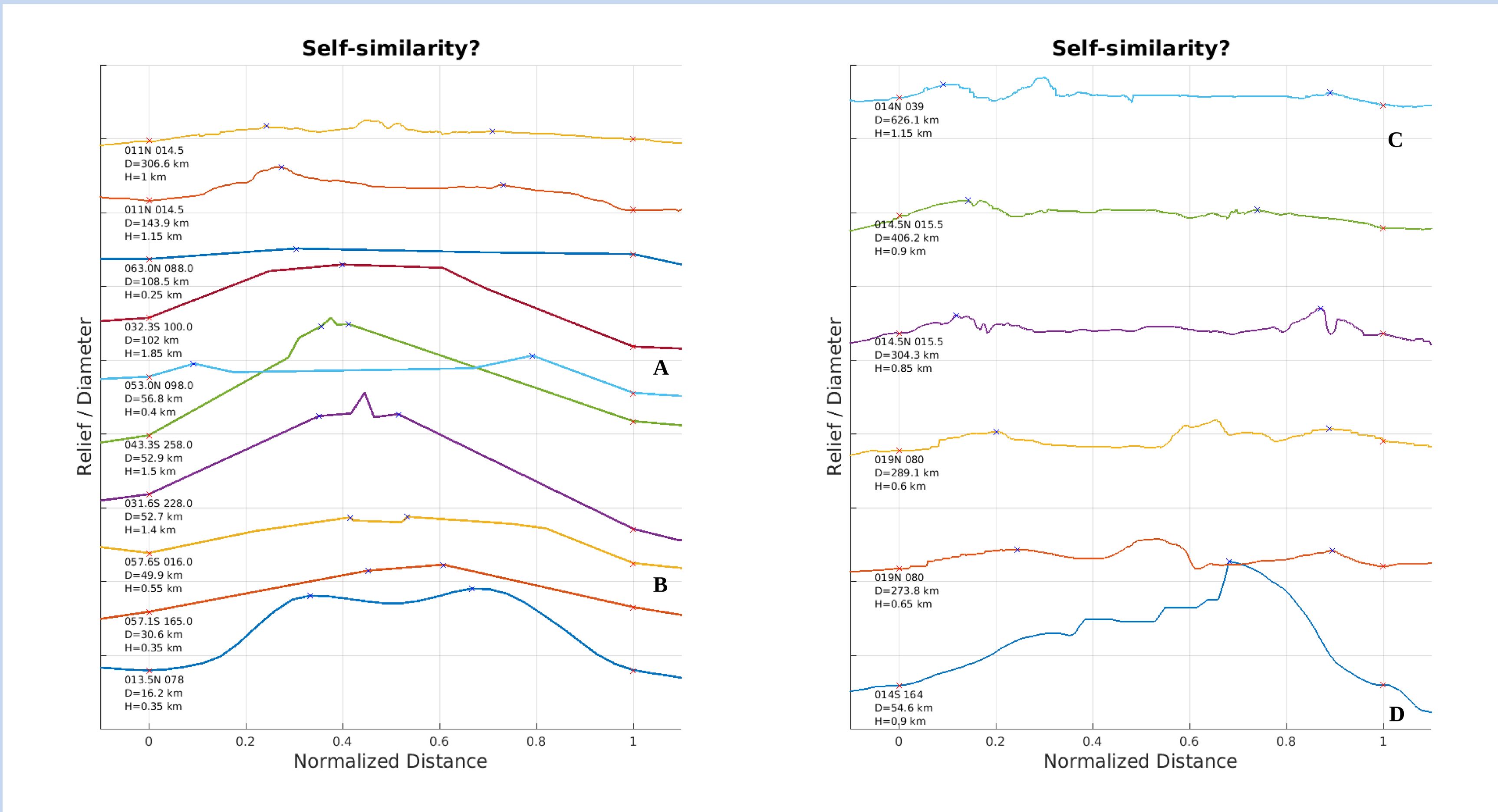


Figure 2. Manually (left) and stereo-derived (right) profiles of the volcano at 13.5°N 78°E. Horizontal and vertical distances are considered accurate up to 0.1 km and 0.05 km respectively. Profiles from left/right image pairs are comparable in quality to those from left/left image pairs from the automated process. The stair-step in the stereo-derived DEM profile results from a gap in the Cycle3 imagery which was filled using the altimetry.

Extraction of Morphometric Parameters

Three measures of volcano shape are presented in this work: height (relief), diameter, and flank slope. These depend on the clear identification of the volcano summit and base. Delimitation of the base follows the methods of Plescia (2004) and Grosse et al (2014) which define the base of the volcano by the topographically lowest concave slope break [2, 4]. This excludes the outer apron in favor of the main edifice only. The summit is the highest point along the profile that displays a positive slope. Volcano profiles are displayed in Figure 3. The bases and summits are marked with red and blue 'x's respectively. Selection of these points was done manually resulting in some subjective bias. Presented height, slope, and diameter for an individual volcano are the averages from available profiles and sides. The extracted slope and scaled relief (height divided by diameter) versus diameter are shown in Figure 5.

Figure 3. Normalized diameter versus scaled relief. Volcanoes are ordered from largest to smallest, top to bottom, scaled to a diameter of 1 to evaluate overall shape change. Red and blue 'x's mark the base and summit of the volcanoes. The volcanoes were split into two groups: those without corona characteristics (left) and those with some corona characteristics (right). Below each profile, the location in latitude and longitude East, diameter (D), and height (H) are provided. Volcanic constructs generally become flatter with increasing diameter.



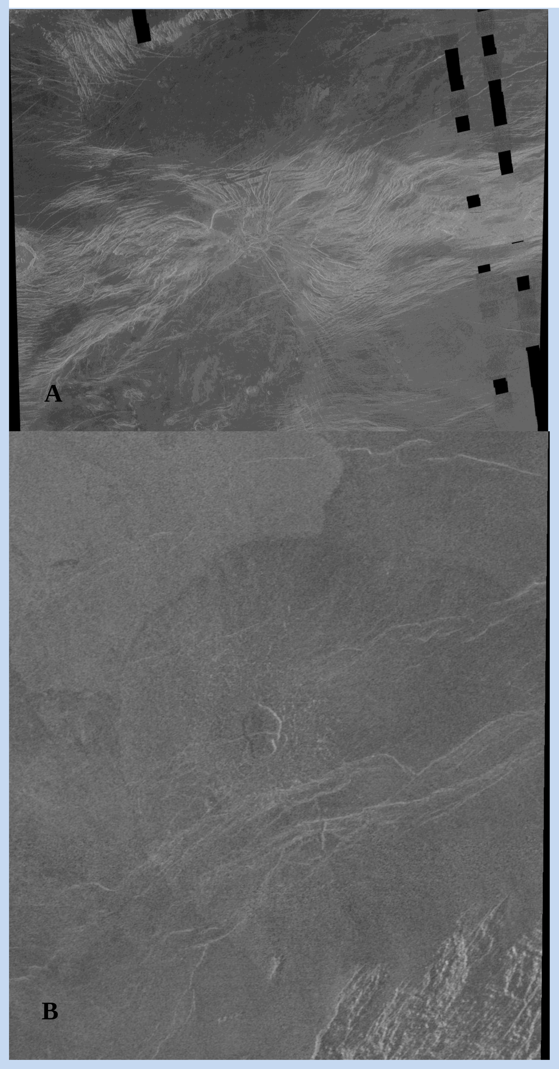
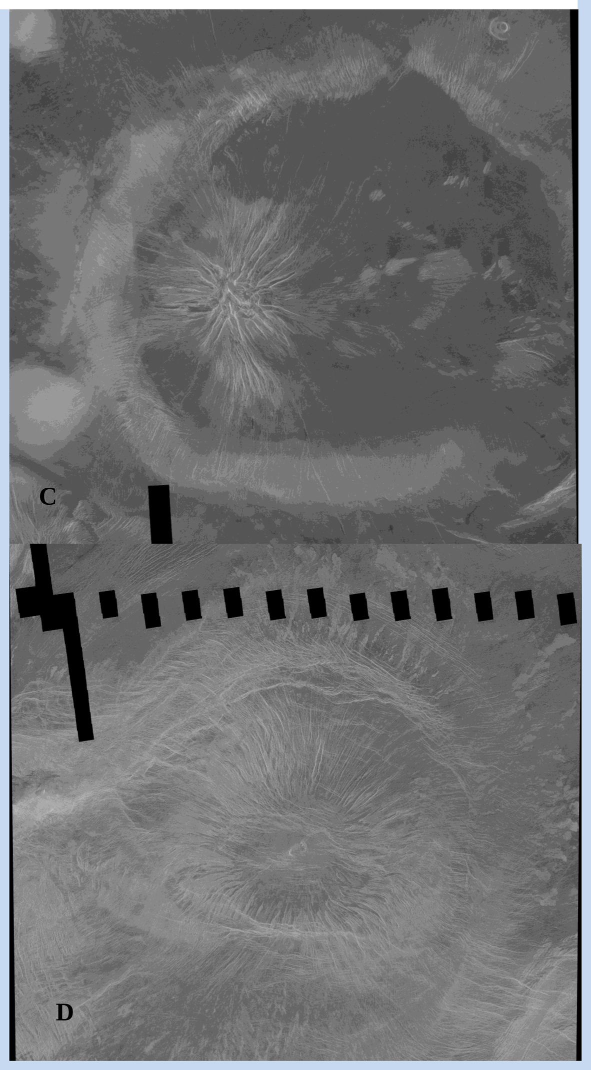


Figure 4. Radar image examples of the volcanoes for which profiles were acquired. To the left are those without corona characteristics, to the right are those with corona characteristics. Black patches are missing data. Images have matching labels in Figure 3.
Top left: 32.3°S 100.0°E
Bottom left: 57.6°S 16.0°E
Top right: 14.0°N 39.0°E
Bottom right: 14.0°S 164.0°E



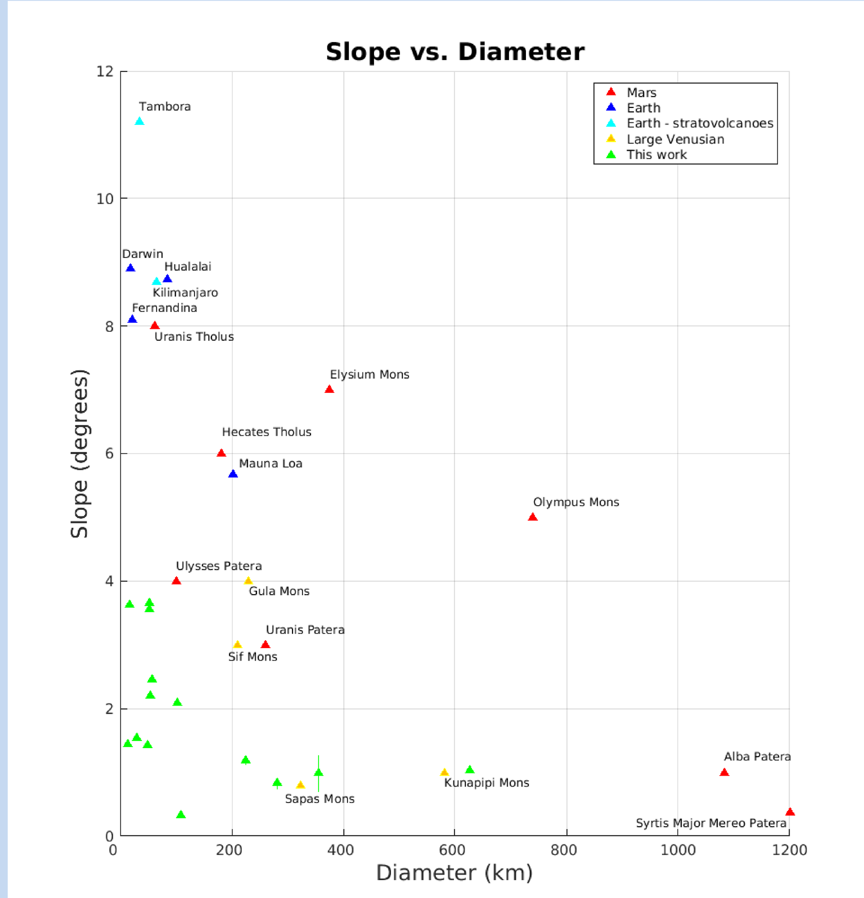
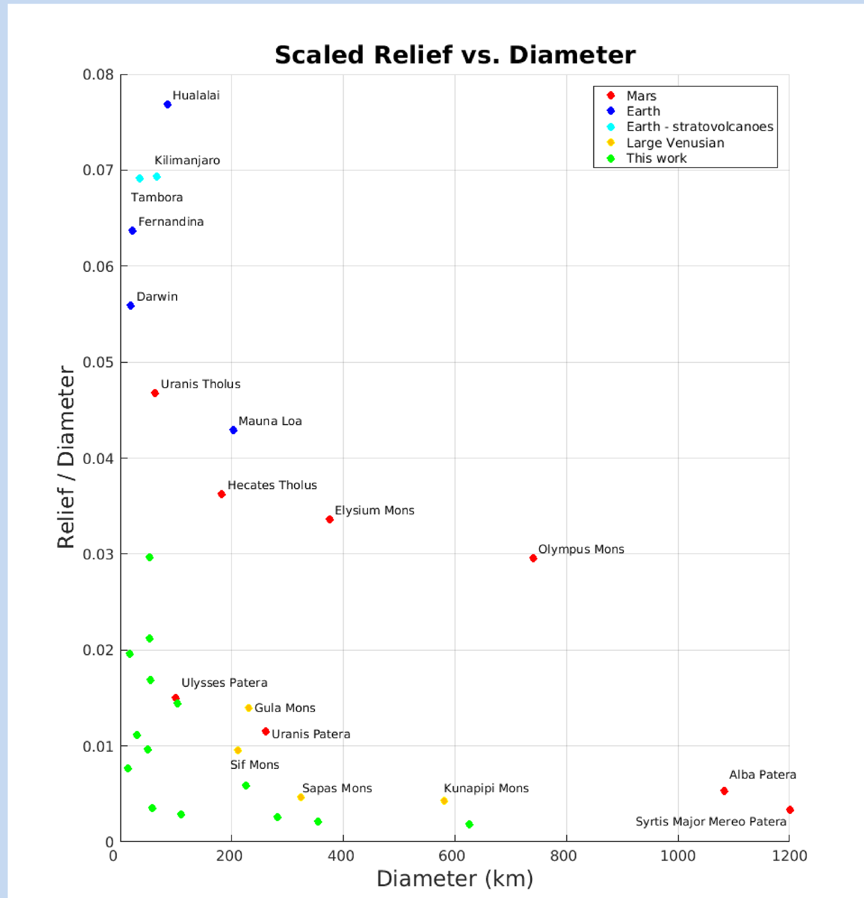


Figure 5. Results of this work are displayed compared to terrestrial, Martian, and large Venusian volcanoes acquired from [2], [3], and [4], excluding Sapas Mons, Mauna Loa, and Hualalai, which were extracted from DEM and bathymetry data from [5] and SRTM DEMs. Slope versus diameter (above) and scaled relief versus diameter (below) both show a similar trend of flatter volcanoes on Venus as compared to Earth and Mars. Scaled relief is calculated by dividing the relief of a volcano by its diameter. The names of several notable terrestrial, Martian, and Venusian volcanoes are displayed. Only the morphometry of the main edifice is considered, resulting in diameters of Sif, Gula, Kunapipi, and Sapas Mons that are smaller than those listed elsewhere.



Results

For volcanoes on all three planets, as diameter increases, slope and scaled relief decrease. This is readily apparent in Figure 5. The slopes of Venusian volcanoes cluster at values lower than terrestrial and Martian edifices, though there is some overlap between the steepest Venusian and flattest Martian volcanoes. A similar pattern is observed in the plot of scaled relief versus diameter. Venusian shield volcanoes are generally considered flatter than their terrestrial and Martian counterparts. The subset of volcanoes analyzed in this work supports this conclusion for volcanoes as small as 16 km in diameter. This could be a result of the relatively small sample size of Venusian shield volcanoes presented here, though this seems unlikely due to the consistency of their behavior. Future work will seek to automate DEM production for "opposite-look" pairs of radar images, and determine possible causes for the flatter Venusian volcanoes.

References

[1] R. R. H. et al. (2012) EOS, 93. [2] J. B. P. (2004). JGR, 109. [3] E. R. S. et al. (2001). Icarus. 152. [4] P. G. et al. (2014). BoV, 76. [5] NOAA NCEI, U.S. Coastal Relief Model.