

MOLA TOPOGRAPHY OF SMALL VOLCANOES IN TEMPE TERRA AND CERAUNIUS FOSSAE, MARS: IMPLICATIONS FOR ERUPTIVE STYLE. M.P. Wong¹, S.E.H. Sakimoto², and J.B. Garvin³, ¹Department of Geological Sciences, University of California, Santa Barbara, CA, 93106; wong@geol.ucsb.edu, ²UMBC/GEST at NASA's GSFC, Geodynamics Branch, Code 921, Greenbelt, MD 20771; sakimoto@core2.gsfc.nasa.gov, ³NASA HQ, Office of Space Science, Code SR, Washington DC 20546-0001

Introduction: Numerous small volcanic edifices have been previously identified in the Tempe Terra [1] and Ceraunius Fossae regions of Mars [2, 3]. Low shield volcanoes dominate Ceraunius Fossae, while Tempe Terra has both low shields and steeper, possibly explosively erupted cones [1]. These features are an interesting example of plains volcanism, and several comparisons have been made with terrestrial volcanic features. From Viking images, Hodges and Moore [3] used crater diameter/basal diameter (C/b) ratios for the Tempe volcanoes [C/b of 0.06-0.17] to suggest they may be similar to Mauna Ulu shield, Hawaii and low shields in the Snake River Plain, Idaho. Additional photoclinometric measurements made by Davis and Tanaka [4] of five volcanoes in Tempe Terra indicated morphological similarities to terrestrial cratered basaltic lava shields and tuff rings. Volcanoes in Ceraunius Fossae are less well studied, but previous work suggested they are similar to shields in Tempe Terra [3].

This study uses new Mars Orbiter Laser Altimeter (MOLA) topographic data to more accurately measure the geometry of the Tempe Terra and Ceraunius Fossae volcanic edifices. We determine the geometric properties, locations and populations of these edifices to help constrain eruptive style and test theoretical predictions of eruptive processes on Mars [5].

Methods: We produce digital elevation models (DEMs) for each study area in order to assess which previously identified volcanic edifices were sampled by MOLA, and what additional, previously undetected, edifices might be present. We then select near center MOLA orbital tracks for each edifice and measure basic geometric parameters from the profiles including basal diameter, height and flank slope. We also calculate approximate volume assuming a conical volcano shape and using only the most symmetrical profiles for the calculations.

Results: We measure 11 shields in Ceraunius Fossae and 10 shields and 2 steep cones in Tempe Terra. A total of 6 shields in both areas had not been previously identified, probably because of a lack of high resolution Viking images. Our MOLA measurements of low shields in both Tempe Terra and Ceraunius Fossae reveal typical basal diameters of 30-50 km (range of 7-80 km). This is significantly larger than the diameters measured by Hodges and Moore [3], who estimated Tempe Terra basal shield diameters of 2-10 km. Typically, we find that these smaller prior estimates of basal diameters characterize only the steeper summit regions of the shields and not the entire edifice. In Viking images, the lower slopes often blend smoothly into the surrounding

plains (Fig. 1), which explains the photoclinometry measurement difficulties.

For both regions, typical heights of the low shields are 100-400 m and average flank slopes are 0.25°-1°, although some shields show a bimodal slope with a steeper summit region of 1°-2°, but sometimes up to 4° (Fig. 1). The two Tempe Terra cones are generally smaller and steeper than the shield volcanoes, with basal diameters of 5-5.5 km, average flank slopes of 3°-5.5°, and heights of 50-180 m.

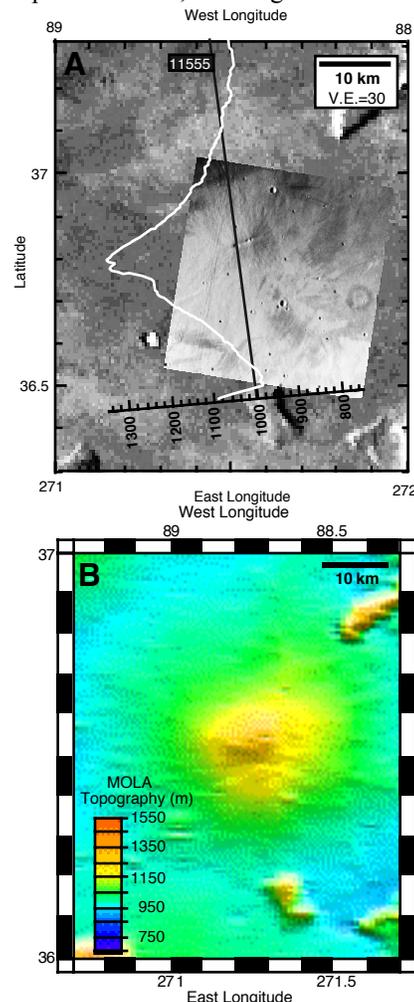


Figure 1. A) Typical Tempe Terra shield volcano with a summit slope of ~2° and lower flank slope of 0.5°-1°. Black line is ground track, white is topography, 57 m/pixel VO image over 234m/pixel MDIM. B) 64 pixel/deg. longitude x 256 pixel/deg. latitude DEM

Interpretations: Edifice parameters can help constrain volcano eruptive style. Pike [6] characterized terrestrial small shield volcanoes with the dimensional ratios of crater diameter/basal diameter (C/b) and height/basal diameter (h/b) and

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Wood [7] measured these ratios for fresh terrestrial cinder cones. We find that, in contrast to prior photogrammetric results, the MOLA determined C/b and h/b ratios are much lower than any of the typical terrestrial values (Fig. 2), clearly a consequence of the larger basal diameters apparent in the new topography.

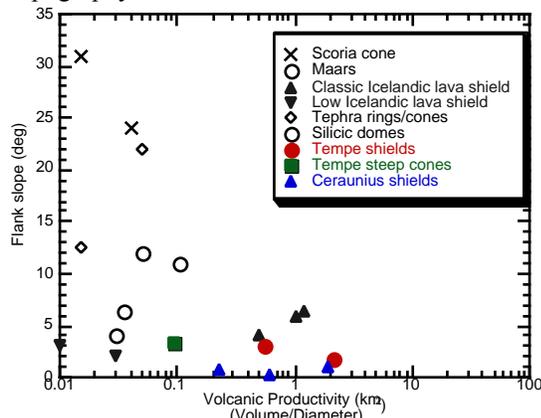


Fig. 2. Plot of C/b and h/b ratios for terrestrial shields and cinder cones (hollow symbols) and edifices from this study (color symbols). Martian values for effusive and explosive features do not plot with terrestrial values for analogous features.

While our mid-latitude effusive Martian edifices do have lower h/b versus C/b values than the apparent explosive features, their absolute values do not correlate with the corresponding effusive and explosive terrestrial fields. The steep (explosive) martian cones in this study plot near terrestrial low and steep shields. However, there is ample evidence that they are not effusive features. In high-resolution Viking and MOC images, the steep cones lack the radial flow pattern that is typical of many of the low shields and they resemble images of terrestrial cinder cones. We suggest that this newly discovered difference in terrestrial and Martian h/b vs C/b values is a result of Martian ambient condition effects on eruption mechanics. For example, Wilson and Head [5] predicted that Martian cinder cones should be 2 times wider and 4 times shorter than terrestrial cinder cones. Thus, a terrestrial cinder cone with a typical height/base (h/b) ratio of 0.18 [7] would form with a h/b ratio of only .02 on Mars. The two measured steep cones in Tempe Terra have h/b ratios of .02 to .035, which matches quite well with the theoretical predictions, and supports an explosive origin.

A second edifice type classification method that seems less dependent on ambient planetary conditions and more indicative of eruption process is the comparison of volcanic productivity (Volume/Basal Diameter) versus average edifice flank slope [see 8, 9, 10]. In Fig. 3, we compare our mid-latitude Tempe and Ceraunius shields to values for terrestrial volcanoes of different eruptive styles which have been well measured by laser altimetry. Our results suggest that while the low shield volcanoes in both Tempe Terra and Ceraunius Fossae have

somewhat lower slopes than Icelandic shields, they are considerably shallower in slope and higher in volcanic productivity than Terrestrial explosive features. In this parameter space, the Tempe and Ceraunius shields are most similar to Icelandic lava shields, and the effusive versus explosive fields are somewhat more distinct for each planet.

Conclusions: We conclude that the h/b vs C/b ratios are inaccurate and possibly misleading when measured from images alone, and are only a modestly good discriminator for different eruptive styles within the group of mid-latitude Mars edifices studied. In contrast to prior work, we do not find that h/b vs C/b ratios for Martian mid-latitude edifices are close to their terrestrial analogs. However, in volcanic productivity parameter space, we find additional evidence for Martian effusive and explosive eruptive styles consistent with their image interpretations of effusive or explosive origins. So, while their raw geometrical measurements differ from the low shields of the Snake River Plains [see 11] and Iceland, we suggest that the bulk of the edifices in Tempe Mareotis and Ceraunius Fossae are effusive shields, with several explosive features intermingled. Preliminary eruption models with new topography constraints appear to uphold this conclusion [12].

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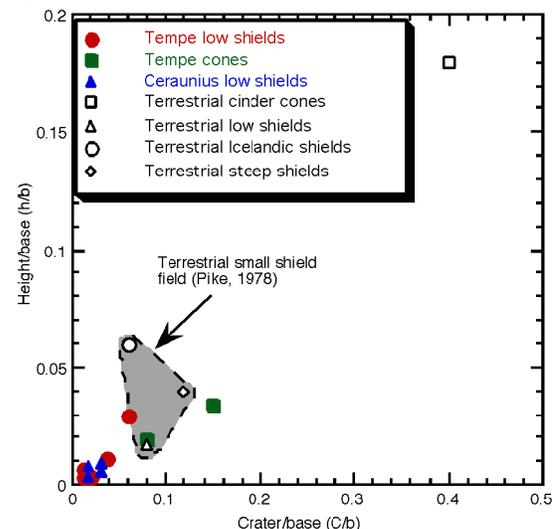


Figure 3. Plot of volcanic productivity and flank slope for this study (color symbols) with terrestrial examples. Here, Tempe and Ceraunius volcanoes most resemble classic Icelandic lava shields.