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MORPHOMETRIC COMPARISON OF ICELANDIC LAVA SHIELD VOLCANOES VERSUS SELECTED VENUSIAN EDIFICES; James B. Garvin[1] and Richard S. Williams Jr.[2]; [1]NASA/Goddard, Geodynamics, Code 921, Greenbelt, MD 20771, and [2]U. S. Geological Survey, Branch of Atlantic Marine Geology, Quissett Campus, Woods Hole, MA 02543.

INTRODUCTION: Shield volcanoes are common landforms on the silicate planets of the inner Solar System [1], and a wide variety have recently been documented on Venus by means of *Magellan* observations [2-5]. Head and colleagues [2] have compiled a comprehensive global census of discrete volcanoes on Venus, with a diameter cut-off for equidimensional, shield-like varieties of ~ 25 km. Aubele and colleagues [4] have documented the distribution of clusters of small shield-like volcanoes on Venus ("shield fields"). Most of the apparently conical landforms which define the shield fields are less than 25 km in diameter, and Garvin and Williams [5,7] have argued that many of these volcanoes (so-called "domes" in [4]) are analogous to Icelandic lava shield volcanoes on the basis of their inferred morphology. In this report, we emphasize our recently completed morphometric analysis of three representative Icelandic lava shields: the classic *Skjaldbreidur* edifice, the low-relief *Lambahraun* feature, and the monogenetic *Sandfellshaed* shield [6,8], as a basis for comparison with representative venusian edifices (> 60 km in diameter). Our detailed morphometric measurements of a representative and well-studied set of Icelandic volcanoes **(Table 1)** permits us to make comparisons with our measurements of a reasonable subset of shield-like edifices on Venus on the basis of Magellan global radar altimetry (i.e., GxDR). Our study has been restricted to venusian features larger than ~ 60 km in basal diameter, on the basis of the minimum intrinsic spatial resolution (8 km) of the Magellan radar altimetry data [9]. Finally, in order to examine the implications of landform scaling from terrestrial simple and composite shields to larger venusian varieties, we have considered the morphometry of the subaerial component of *Mauna Loa*, a type-locality for a composite shield edifice on Earth [1,11] (see Table 1).

THE DATA: As part of our ongoing research concerning subaerial mid-ocean ridge volcanism, we assembled 80 m spatial resolution DEM's for *Skjaldbreidur, Lambahraun, and Sandfellshaed*, as well as for *Mauna Loa* in Hawaii. These data are similar in effective resolution to the typical Magellan radar imaging resolution, but they provide quantitative topographic information at length scales inaccessible to the Magellan altimeter. From our DEM's, we have been able to objectively and systematically measure a set of morphometric parameters suggested by Pike and Clow [11], including average basal diameter D, maximum height H, mean landform volume V, average flank slope, as well as a set of ratio parameters (Table 1). For example, we have been investigating the ratio V/D, a "volume productivity per unit length of edifice" parameter or what we have called "pseudo area" in Table 1. Other ratios include V/SA, the volume to surface area index which can be related to mean landform thickness Te, "coverage" which is simple diameter-normalized thickness, and topographic "skewness" which relates the thickness to maximum volcano height. Both topographic skewness and coverage are dimensionless parameters (Table 1) which can be used to intercompare the morphometries of planetary volcanoes independent of scale. We have computed the series of morphometric statistics listed in Table 1 on the basis of two-dimensional DEM format data. However, for the three Icelandic volcanoes, we have also computed the complete set of parameters on the basis of geodetic aircraft laser altimetry profiles acquired in 1989 and 1991 with meter-scale horizontal resolution and ~ 15 cm vertical control [6]. Because our aircraft laser altimeter topographic profiles are geodetically referenced, we have been able to compare results at meter-scales with those at 100-m scales. The results differ by at most 10-15%. Thus, the values listed in Table 1 for the Icelandic features are derived by calibrating our 80 m resolution DEM data with the 1 m resolution geodetic laser altimeter topographic profiles.

ANALYSIS: In order to calibrate our comparisons of venusian shields versus Icelandic ones, we have considered the average cross-sectional "shape" of each landform (the n parameter in Table 1) by means of a dimensionless polynomial shape factor. If we consider the maximum degree n of that polynomial which best matches the mean topographic cross-section of each edifice in question, then it can be shown that : $n = (8V)/(\pi HD^2 - 4V)$, where V, H, and D are measured parameters as described above. For example, for typical conical edifices, n is ~1.0 in value, but for more dome-like forms, n increases above 2.0 (paraboloidal). When n values are less than 1.0, the flanks of the volcano are typically *concave*, as is the case for major oceanic shields such as *Mauna Loa* (n = 0.7). A brief examination of the cross-sectional shapes of terrestrial shields (Table 1) demonstrates that the larger, polygenetic varieties (*Mauna Loa, Skjaldbreidur*) have concave flanks on the basis of eruptions which oversteepen the summit at the expense of the lower-gradient flanks. Low lava shields such as *Lambahraun* are more conical, and the most pristine, monogenetic varieties (*Sandfellshaed*) tend to be

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slightly paraboloidal. Of all of the *venusian edifices* we have measured (Table 1), only a few have n-values less than 1.0, and most are slightly dome-shaped like *Sandfellshaed*. Only the larger composite shield structures such as *Tepev Mons, Maat Mons, and Sapas Mons* are domical. Some of the un-named low shields (i.e., volcano at 9.4N, 29E) are sub-conical, and apparently resemble the lowest lava shields known in Iceland. In terms of the "pseudo-area" parameter (V/D), many of the sub-100-km scale Venus varieties appear to be statistically similar to *Mauna Loa,* although virtually all of the larger edifices such as *Maat Mons* are at least an order of magnitude larger. Indeed, if one were to use typical high volume eruption rate estimates [10] from terrestrial observations (i.e., from 100 m^3/s to ~ 1000 m^3/s) to investigate eruption lifetimes for the larger venusian edifices such as *Maat,* sustained eruptive activity for up to 0.1 Ma would be required. Typical Icelandic shield building volume eruption rates are probably in the 10-100 m^3/s range, suggesting that large venusian edifices such as *Maat* could be constructed over 0.1 to 1.0 Ma periods by means of essentially quiescent basaltic eruptions. Both *Maat* and *Tepev* resemble larger terrestrial shields such as *Skjaldbreidur* and *Mauna Loa* in terms of our "coverage" parameter, further suggesting that they may represent a reasonable venusian analogue to 10-100 km scale terrestrial basaltic shields. Why such large-scale venusian edifices appear more domical in cross-section than their apparent terrestrial counterparts remains to be explained, but it may be related to the long-term history of flank eruptions required to construct these features. Analysis of our preliminary morphometric results is ongoing, as is our measurement program for all identifiable venusian edifices larger than ~ 60 km in diameter.

REFERENCES: [1] BVSP (1981) *Basaltic Volcanism on the Terrestrial Planets,* Pergamon, NY, 1202 pp. [2] Head J. et al. (1992) *JGR 97,* 13153. [3] Schaber G. (1991) *Proc. LPSC XXI,* p. 3-11. [4] Aubele J. and L. Crumpler (1992) *Int'l Colloq. on Venus,* LPI Contrib. 789, p. 7-8. [5] Garvin J. and R. Williams (1990) *GRL 17,* 1381-1384. [6] Garvin J. and R. Williams (1992) *EOS Trans. AGU, Vol. 73 (43),* p. 130. [7] Garvin J. and Williams (1991) *LPSC XXII,* p. 431-432. [8] Garvin J. and R. Williams (1992) *EOS Trans. AGU, Vol. 73 (14),* p. 58-59. [9] Ford P. and G. Pettengill (1992) *JGR 97,* 13103. [10] Whitford-Stark J. (1982) *Earth Sci. Rev. 18,* 109-168. [11] Pike R. and G. Clow (1981) *USGS Open File Report 81-1039,* 40 pp.

TABLE 1: ICELANDIC VOLCANOES VERSUS VENUSIAN SHIELDS

VOLCANO NAME OR LOCATION	DIAMETER D (km)	MAX HEIGHT H (km)	ASPECT H/D	VOLUME V (km^3)	PSEUDO AREA V/D (km^2)	THICKNESS Te=V/SA (m)	SHAPE FACTOR n	SKEWNESS V/SA/H (x1000)	COVERAGE Te/D (x1000)	AVG FLANK SLOPE (degrees)
EARTH:										
MAUNA LOA*	51.2	2.9	0.06	1617	32	779	0.7	266	15.2	6.5
SKJALDBREIDUR	10.6	0.6	0.06	12.7	1.2	141	0.6	235	13.3	6.5
LAMBAHRAUN	7.5	0.14	0.02	2.0	0.3	44	0.9	319	5.9	2.1
SANDFELLSHAED	2.0	0.05	0.03	0.07	0.03	19	1.3	358	9.4	2.9
VENUS:										
TEPEV MONS	196.0	5.7	0.030	99618	508	2500	2.8	439	12.8	3.3
VOLC @ 2.4N, 272E	66.0	1.0	0.020	1771	27	387	2.0	376	5.9	1.7
VOLC @ 26S, 215E	77.0	1.7	0.020	3728	48	592	1.7	344	7.7	2.5
VOLC @ 36N, 21E	62.0	1.0	0.020	1400	23	533	1.6	513	8.6	1.9
VOLC @ 3.6N, 270E	87.0	3.1	0.040	4077	47	518	0.6	169	6.0	4.1
VOLC @ 21N, 91E	100.0	1.5	0.020	5077	51	494	1.6	340	4.9	1.7
VOLC @ 9.4N, 29E	320.0	2.4	0.010	59233	185	568	0.9	241	1.8	0.9
VOLC @ 11N, 174E	104.0	1.5	0.010	5542	53	496	1.5	330	4.8	1.7
VOLC @ 24N, 91E	119.0	2.1	0.020	8598	72	586	1.2	278	4.9	2.0
VOLC @ 14N, 162E	112.0	1.4	0.010	5022	45	384	1.1	272	3.4	1.4
MAAT MONS	312.0	7.5	0.024	354547	1136	3487	3.2	465	11.2	2.7
SAPAS MONS	231.0	2.3	0.010	61760	267	1128	3.6	490	4.9	1.1
SEKMET MONS	253.0	2.5	0.010	53450	211	829	1.5	332	3.3	1.1
ATIRA MONS	174.0	1.0	0.006	9326	54	307	1.3	307	1.8	0.7
VENILIA MONS	305.0	1.2	0.004	40545	133	436	1.6	352	1.4	0.5
RENPET MONS	297.0	2.2	0.007	71711	241	883	1.8	407	3.0	0.8
BACHUE	588.0	2.4	0.004	372289	633	1193	2.7	495	2.0	0.5
VOLC @ 5.7N, 269E	118.0	0.4	0.003	1647	14	116	1.2	290	1.0	0.4
VOLC @ 6.8N, 270E	64.0	0.4	0.006	565	9	135	1.9	375	2.1	0.6
VOLC @ 47S, 215E	186.0	2.4	0.013	29912	161	839	1.7	351	4.5	1.5
VOLC @ 4.6N, 274E	71.0	0.4	0.006	1164	16	227	3.8	504	3.2	0.7

NOTES:

*SUBAERIAL COMPONENT OF COMPOSITE HAWAIIAN SHIELD FROM DMA DTED DATA; ALL OTHER DATA FROM GEODETIC AIRCRAFT LASER ALTIMETER SURVEYS; VENUS DATA FROM MAGELLAN GXDR GLOBAL ALTIMETRY DATASET.