VENUS HYPSOMETRIC CURVE: AN ASSESSMENT OF ITS COMPONENTS AND COMPARISON TO EARTH; James W. Head, Dept. of Geo. Scis., Brown Univ., Providence, R.I. 02912.

Pioneer Venus analyses showed that the unimodal global altitude-frequency distribution of Venus is distinctly different from that of the bimodal Earth[1] (Fig. 1). Early investigators assessed the influence of oceanic load and the different thermal structure[2] and showed that although accounting for these factors brings the two terrestrial peaks closer together, it does not erase the bimodality. In this study, various factors that influence the structure of the hypsometric curve are identified and these are assessed relative to contributions to the Venus curve and its relation to the terrestrial curve:

1) Oceanic Load: The load of the oceans on Earth depresses the topography of the ocean basins as a function of water depth (removed in Fig 1b); removing the load decreases the difference between the two terrestrial peaks and decreases the range of oceanic elevations, increasing the amplitude of the terrestrial ocean peak and making the curve more leptokurtic.

2) Oceanic Thermal Structure in the Venus Environment: The differences in the outer thermal structure of Earth and Venus caused by the enhanced Venus surface temperature[2] are a factor; when Earth oceanic crust is corrected for Venus surface temperatures, this decreases the elevation of the rises and decreases the range of oceanic elevations, increasing the amplitude of the terrestrial ocean peak and making the curve more leptokurtic.

3) Continental Crust Area: The larger percentage of continental crust on the Earth (41%) relative to highland crust on Venus (<10%); this increases the amplitude of the continental peak relative to Venus highlands.

4) Continental Crust Thickness: The greater average thickness of Earth's continental crust (about 40 km) relative to Venus uplands and highlands (about 25-35 km)[3]; this increases the average elevation of the continental peak relative to Venus highlands and thus increases the distance between the oceanic and continental peak.

5) Venus Basaltic Crust Average Thickness: The greater average thickness of the Venus basaltic[4] lowland/rolling upland crust (about 15 km)[5] relative to the Earth's basaltic oceanic crust (5-6 km); this elevates the Venus lowland terrain average elevation relative to Earth oceanic crust and decreases the range of elevation differences between lowlands and highlands terrain on Venus, decreasing the total range of elevations and making the Venus curve more leptokurtic relative to Earth.

6) Venus Non-highland Crust Area: The greater percentage of lowland/rolling upland crust on Venus (> 80%) relative to oceanic crust on Earth (59%); this increases the amplitude of the Venus peak relative to Earth ocean basin peak.

7) Terrain Relative Crustal Thickness Contrast: The greater contrast in average thickness difference between the crusts of the two terrains on Earth (5/40 = 35 km) and Venus (about 15/30 = 15 km) is about 20 km between Venus and Earth; this causes the fundamental separation of the two peaks on Earth relative to Venus (adding 20 km of basaltic crustal thickness to the average thickness of the Venus highlands is about equal to adding 2 km in additional topographic elevation, or equivalent to 2 km additional separation between the Earth provinces and peaks relative to Venus).

8) Composition Contrast Between Continental and Oceanic Crust: The average compositional difference between the continental crust and the oceanic crust on the Earth contributes only about 20% of the separation of peaks on Earth, but is not as important a factor as the crustal thickness differences between continents and ocean basins which contributes about 80% of the separation.

9) Compositional Similarity Between Venus Highlands and Lowlands: Although no direct measurements are available on the highlands of Venus, photogeologic studies are consistent with basaltic volcanism for the deposits observed in the highlands.[6] Thus the apparently similar composition of the lowlands/rolling uplands[4] and highlands on Venus contributes to the narrowness of the Venus peak. Any additional less-dense crust added to the highlands would increase its skewness toward higher elevations.

10) Relative Importance of Erosion and Sedimentation on Venus and Earth: The enhanced influence of erosion and sedimentation (primarily due to water) on Earth, relative to Venus[7] provides erosional and depositional planation on Earth and decreases maximum and minimum elevations due to erosion and deposition respectively. For Earth, this factor increases the area of low elevations near sea level on the continental curve, steepening that portion of the curve. This factor also decreases the elevation of deeper parts of the ocean basin making the peak less broad. Erosion and sedimentation act to decrease or limit the total range of elevations on Earth. Although erosion and deposition operate on Venus[7], they are clearly not as volumetrically or globally significant as on Earth.

11) Lithospheric Thickness Variations: Regional variations in heat loss and thermal structure between terrain types and between planets are very important contributors to the frequency distribution of elevations on a planet. For example, Morgan and Phillips[8] showed that 93% of Venus topography could be plausibly explained by

variations in lithospheric thickness. Of course, crustal thickness differences could also account for the vast majority of Venus topography as well[3], but clearly both must contribute to topography. The major contribution on Earth is the influence of the oceanic rises, which would decrease the amplitude and broadening the base of a oceanic crustal peak without spreading centers. Similar thermal variations in the Venus Equatorial Highlands (possibly associated with mantle plumes and crustal spreading) contribute to the breadth and observed amplitude of the Venus peak[8,3]. Obviously, variations in thermal structure map directly into topography, but a comprehensive delineation of the contribution of this factor to the hypsometry requires knowledge of the local geology and geophysics in order to assess the cumulative regional contributions to the global hypsometric curve. Such analyses for Venus will be made more possible by the Magellan global data set.

It is clear that the most significant factors in accounting for the differences in the hypsometric curves are related to crustal thickness variations and their distribution (factors 3-7 above) between Venus and Earth. One of the most significant factors in creating the bimodal character of the Earth curve is the relative crustal thickness contrast between the two terrains on Venus and Earth (factor 7). The approximately 20 km difference is suffficient to separate the terrains by about 2 km, enough elevation to create a bimodal distribution if it were added to Venus and a much more unimodal distribution on Earth if it were removed. This is in contrast to the commonly held assumption that it is compositional differences between continents and ocean basins (sialic versus simatic) that produce density differences that account for the topographic variations between continental and oceanic crust.

The major differences between the long-baseline slope distributions for Venus and Earth (Sharpton and Head, 1985, 1986)[2] also appear to be linked to the difference in contrast in crustal thickness variations (causing less distinctive slope changes at boundaries between two terrain types on Venus than Earth), the smaller abundance of highland terrain on Venus, and the larger number of highland regions on Earth causing an increased total length of continental boundaries with high slopes.

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Figure 1. Hypsographic curves for three cases, Earth, Earth with the load of the oceans removed, and Venus. All three data sets are of equivalent spatial and vertical resolution. Each plot illustrates the frequency of occurrence of surface elevations grouped in 100-m elevation increments. For both the terrestrial cases 0.0 elevation refers to sea level; for Venus elevations are referenced to a planetary radius of 6051.0. From Sharpton and Head (1985).[2]