COMPARATIVE HYPSOMETRIC ANALYSIS OF EARTH, VENUS AND MARS: EVIDENCE FOR EXTRATERRESTRIAL PLATE TECTONICS? W. Luo[1] and P. R. Stoddard[2], [1]Department of Geography, Northern Illinois University, DeKalb, IL 60115, luo@geog.niu.edu, [2]Department of Geology and Environmental Geosciences, prs@geol.niu.edu.

Introduction: Recent studies with MGS magnetic and topographic data have suggested of possible plate tectonics and a martian ocean. [1,2]. Hypsometric analysis has been used in [3] to reveal planet scale internal activity from topography data. Global comparative hypsometric analysis of Earth and Venus showed that there exists a domain of elevation on Venus for which the relationship between the elevation and square root of cumulative area percentage is linear, similar to that of Earth, suggesting the existence of a similar thermal isostasy acting at the planetary scale [3]. This paper attempts to conduct the same exercise for Mars, and to extend the analysis for Venus.

Data source and analysis: Earth topographic data are from NOAA National Geophysical Data Center 5-Minute Gridded Elevation Data (TerrainBase CDROM, http://www.ngdc.noaa.gov/). Mars topographic data are from the 1/32 degree/pixel MOLA Experiment Gridded Data Record (EGDR) data (http://wufs.wustl.edu/). Venus topographic data are from Magellan Spherical Harmonic Models and Digital Maps Archive (1°x1° grid). All data sets were projected to a cylindrical equal area projection. Earth topography was isostatically adjusted by unloading ocean water, assuming a mantle density of 3300 kg/m^3. The differential hypsometric curves are constructed using 300 m bin size. Slopes were calculated using nine-point elevation data sets (a-i) as follows:

$$(dz/dx) = ((a + 2d + g) - (c + 2f + i)) / (8 * x \text{ mesh spacing})$$

$$(dz/dy) = ((a + 2b + c) - (g + 2h + i)) / (8 * y \text{ mesh spacing})$$

$$\text{Rise run} = \text{sqrt}((dz/dx)^2 + (dz/dy)^2)$$

$$\text{slope} = \tan^{-1}(\text{Rise run})$$

Results and Discussion: On earth, the linear domain of the differential hypsometric curve represents the ocean floor created by sea floor spreading and there is a linear relationship between the cumulative area of sea floor and the square root of its age [4]. The upper bound of the linear domain (-1950m) is the unloaded mean elevation for the mid-ocean ridge, where the thermal lithospheric thickness is equal to zero [3]. For Mars, a similar linear domain exists. The upper bound of this linear domain is at +600 m (see Figure 1 and Table 1) and the linear domain covers about 60% of the surface area. Unlike the Earth, however, the topographic signature of the upper bound more closely aligns with the ocean margins. Most of the Mars linear-domain topography is in the planet's northern hemisphere, long known to be topographically lower than the south. In addition, the northern hemisphere is less heavily cratered than the south, consistent with more recent thermal rejuvenation of the northern lithosphere. Such thermal activity, dating to a recently as several hundreds of millions of years [5], may indeed leave a topographic signature still visible today. The higher slope of the martian linear fit, however, argues either for different material properties or a much steeper geothermal gradient on Mars, neither of which seems likely. (By comparison, the difference in the slopes between Earth and Venus is at least partially accounted for by Venus' higher surface temperature decreasing the thermal gradient.) In addition, part of the low-topography end of the hypsographic curve, corresponds to Argyre and Hellas basins, and presumably would not contribute to a thermal cooling signature. These data should be removed from the topographic set for this analysis. Another difference is that the extension of the Martian trend goes above most of the rest of the hypsometric curve, reflecting a lack of true "continental" regions.

To further test for Earth-style tectonics on Venus, we compare topographic slope maps (Figure 2) of Earth and Venus. A quick look at the slope map for Earth reveals a substantial difference in the slopes of the slow-spreading mid-Atlantic ridge and the fast-spreading East Pacific Rise (EPR). The faster spreading of the EPR spreads the topographic relief over a larger region, thus decreasing its slope. On Venus, several rift regions have been identified [6]. The highest concentration of these is in the Beta-Atla-Themis (BAT) region. It has been noted that the three major rift provinces in the BAT region display different characteristics, including the number of associated coronae [7]. The rift that extends from Atla southeastwards towards Themis contains many coronae, and it has been suggested that this is therefore an active rift, whereas the rift trending north/south between Beta and Themis contains no coronae, and may therefore be less active or completely inactive[7]. Slope analysis of this region shows pronounced slopes for the Beta/Themis rift, and much more subdued slopes for the Atla/Themis rift, consistent with the earlier suggestions for their relative activity.

Summary: 1) This analysis is partially consistent with an early earth-like plate tectonics process on Mars that is responsible for the formation of the northern ocean. 2) Further analysis of Venus topographic trends reveals more similarities to such trends produced by plate rifting (sea-floor spreading) on Earth.

References: [1] Connemey, J. E. P. et al., (1999) *Science*, *284*: 794-798. [2] Head, J. W., III et al., (1999) *Science*, *286*: 2134-2137. [3] Rosenblatt, P. et al., (1994) *GRL*, *21*:465-468. [4] Parsons, B., (1982) *JGR*, *87*: 289-302. [5] Hartmann, W.K. (1999) *Meteoritics & Planetary Science*, *34*: 167-177. [6] Stofan, E.R., et al., (1992) *JGR*, *97:* 13,347-13,378. [7] Stoddard, P.R., and D.M. Jurdy (2001) *XXXII LPSC abstract volume.*

Table 1

Planet	Slope of linear fit	Upper threshold	Lower threshold	Linear domain area
Unloaded Earth	-580m ±20m	-1950m ±100m	-3950m ±100m	52.5% ±2.5%
Venus	-280m ±10m	6052.8km ±100m	6051km ±100m	75% ±5%
Mars	-1720m ±30m	600m ±100m	-5100m ±100m	59.9% ±3%

Note: Values for Earth and Venus are from [3].

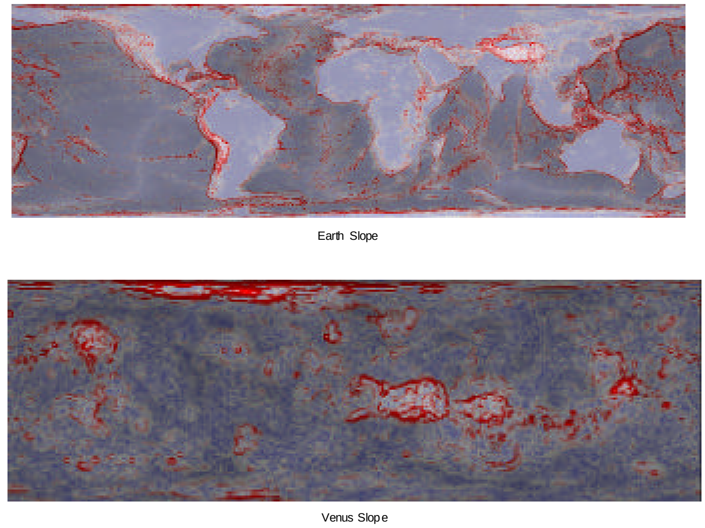

Figure 2: Slopes of Earth and Venus. Red indicates high slope and blue low slope. Gray color in the background shows original topography.

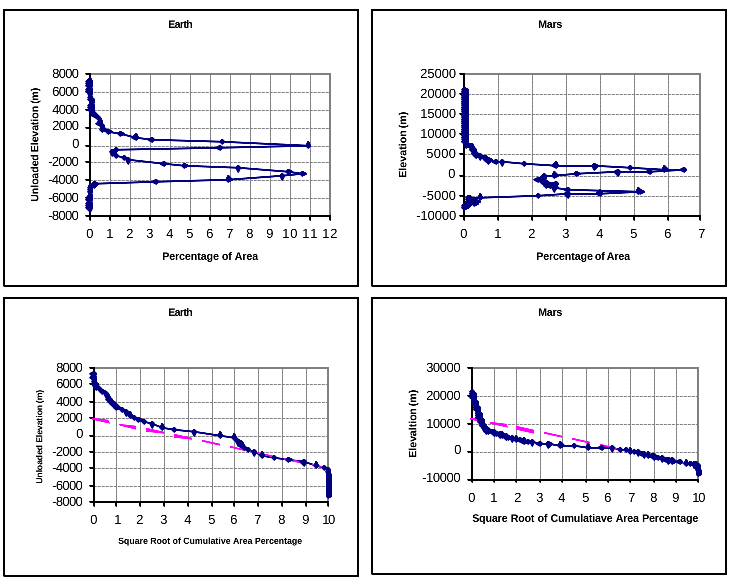

Figure 1: Differential hypsometric curves (top) and cumulative hypsometric curves (bottom) for unloaded Earth and Mars. Dashed lines on the cumulative hypsometric curves are the best fits for the linear portions.