THE DISTRIBUTION OF HOT SPOTS AND ITS RELATION TO GLOBAL GEOLOGY: VENUS, EARTH, AND MARS;

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INTRODUCTION. Completion of the Magellan spacecraft mapping of Venus [1] enables comparison of the global geologic characteristics of the three larger terrestrial planets. In this study it is shown that, despite the known dissimilarities in global geology and tectonic style, Venus, Earth, and Mars appear to share some large-scale similarities in the arrangement of fundamental geologic characteristics and the distribution of large magmatic centers.

CHARACTERISTICS AND SPATIAL DISTRIBUTION OF VOLCANISM. The distribution [2,3] of large volcanoes [4] and coronae [5] on Venus is non-uniform and is concentrated in the hemisphere between the highlands of Beta, Atla, and Themis Regiones. Reconnaissance geologic mapping [4], and preliminary mission science reports [1] were used to establish the relationship between all major volcanic and magmatic centers larger than 100 km in diameter and global geologic characteristics. Similar maps of the distribution of volcanic and geologic characteristics were prepared from existing data for Earth and Mars. As plate boundaries associated with mobile tectonics are not present on Venus or Mars, only the intraplate hot spots are considered on Earth. Active intraplate volcanism on Earth is non-random and occurs in two hemispheric groups [6,7]. Volcanic centers on Mars occur in three settings, the Tharsis region, the Elysium region, and the Hellas basin region, the latter two occurring in the hemisphere opposite from the Tharsis region.

Inspection of the global maps shows that the distribution of volcanic centers on each planet, although non-uniform, is geometrically similar. To test this, the total number of magmatic centers was determined as a function of hemispheric caps of increasing area about a point on the surface on each planet [Figure 1), a method used previously [7] in describing the global abundance of hot spots on Earth. Steep changes in slope of the observed cumulative number-versus-area curve from the diagonal, which represents the distribution as it would appear if the existing population of hot spots were uniformly distributed, represent significant departures from a uniform distribution. A similar bipolar arrangement of volcanic centers occurs on each planet with three common characteristics: (i) a *primary group*, or a concentration of volcanic centers in which more than one-half of the global population occurs within less than 30% of the global area; (ii) a peripheral region where the density is less than or close to that expected for a uniformly distributed population, and (iii) a *secondary group*, occupying about 30% of the global area where the density is essentially similar to the uniform case.

GEOLOGIC CHARACTERISTICS OF MAJOR CONCENTRATIONS. The primary groups (*region i*) are areas of major thermal perturbations on all three planets. Concentration of thermal and magmatic processes of this dimension might be accompanied by distinctive boundary layer characteristics and styles and rates of tectonic deformation, resurfacing, crustal formation, and crustal modification. This association was checked by comparing the area of the primary group on each planet with corresponding global geologic maps using the appropriate circle (of area defined by the prominent breaks in slope of Figure 1) superimposed on the center of mass of each concentration (Figure 2). Based on these maps, hemispheric regions of anomalously concentrated volcanoes and magmatic activity are shown to occur in association with geologically distinctive global geologic characteristics.

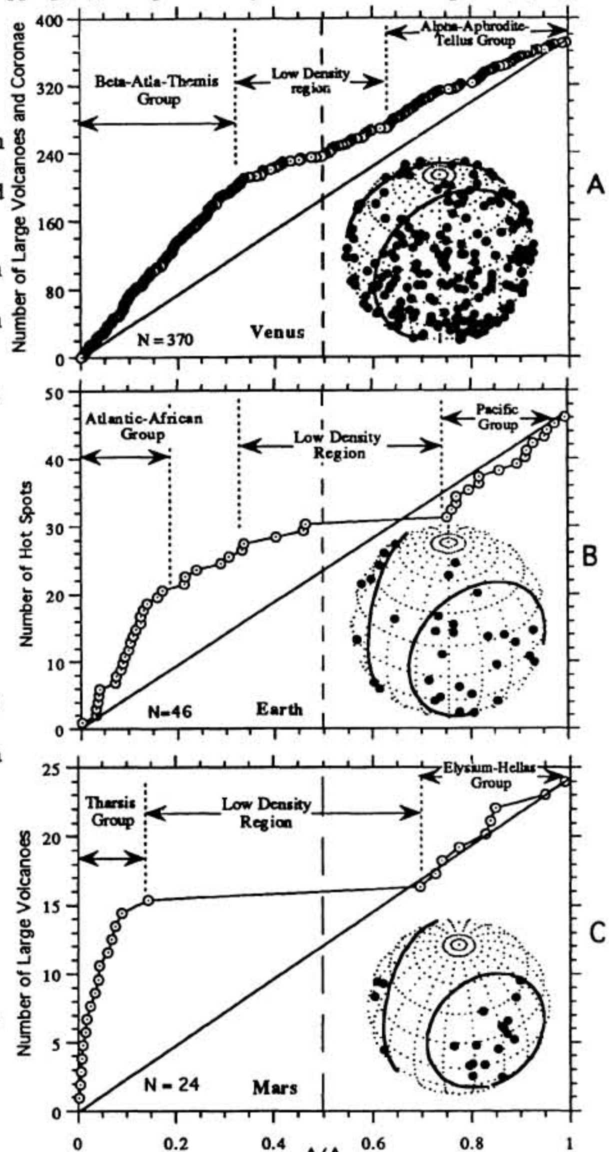

Figure 1. Cumulative distribution of volcanic centers about the centroid of the major concentrations on each planet. Insets are orthographic representations of the distribution centered at (A) 35N/240E(Venus), (B) 35N/20W (Earth), and (C)45N/130W (Mars). Facing circles identify the boundary of the primary concentration anomalies.

On Venus the primary regional concentration of volcanic centers (*region i*) is characterized in Magellan SAR images by linear extensional deformation belts [3] whereas the geologic characteristics within the peripheral region, where volcanic

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center abundance is low (*region ii*), include extensive lowland plains with the characteristics of flood lavas [10], frequent long linear ridge belts [11] interpreted to represent substantial crustal shortening [12], active orogenic belts surrounding complexly deformed highlands [13;14], and areas of proposed subduction-like behavior of the lithosphere [15].

The two-fold, African-Pacific global arrangement of intraplate volcanism on Earth (*region i* and *iii* respectively) correlates with prominent residual geoid highs [6] and large regions of anomalously low-seismic velocity mantle [16]. The intervening region (*region ii*) between hot spot groups corresponds to the location of plate convergence (Figure 2B), most of the current subduction zones, high seismic velocity upper mantle [16], and the current position of most of the continents [17]. The regions where most of the hot spots occur on Earth (*region i* and *iii*) includes most of the occurrence of large-scale global extension, and region ii, most of the examples of convergence.

The primary regions of extension on Mars occur in the Tharsis volcanic region (*region i*), a hemisphere characterized by high elevations, relatively youthful volcanism, and prominent geoid highs [18]. With the exception of minor occurrences of extensional features in the area of the Elysium-Hellas volcanic region (*region iii*), extensional tectonic features are relatively infrequent elsewhere on Mars (Figure 2C). In contrast, ridges of probable compressional origin [19,20] occur throughout *region ii*. Crustal shortening on Mars has been attributed to effects of subsidence associated with impact basins, gravity stresses associated with the Tharsis topographic dome, lateral effects of dynamic plumes associated with Tharsis, global contraction, or a combination of these influences [18;19;20].

CONCLUSIONS. On Earth it is as yet unclear whether the primary control on global patterns of interior convection are plates [17] or whether interior convection patterns control the pattern of surface tectonics [16;21;22]. In either model, hot spot type volcanism is likely to be suppressed in areas of subduction or down welling, and either enhanced or near that occurring in association with normal background levels of convection and volcanism in areas distal from subduction. The similarity among Venus, Earth, and Mars of the correlation between tectonism and hot spot concentration, regardless of the reigning global tectonic style, implies that the concentrations of volcanic centers in all three planets are deep-seated in origin rather than an influence of a mobile boundary layer alone. Plate tectonics could be influential in organizing the patterns of intraplate volcanism on Earth, but that mechanism alone will not work on Venus or Mars. Plates may be secondary as an influence on the global arrangement of intraplate volcanism on Earth.

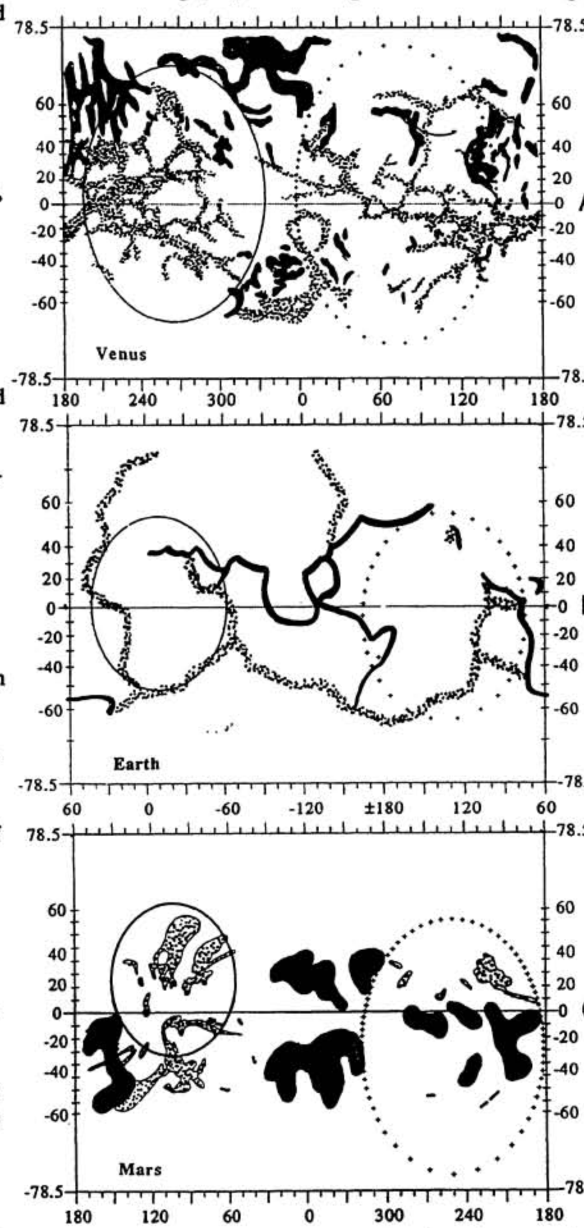

Figure 2. Arrangement of global volcanic and magmatic center concentrations (circles) relative to areas characterized by extension (stipple pattern) and significant contraction (black). Hemispheric organization occurs between concentrations of volcanic and tectonic features.

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