Morphology and Distribution of Hotspots on Venus. Ellen R. Stofan[1] and Suzanne E Smrekar[2]. [1]Proxemy Research, 20528 Farcroft Lane, Laytonsville, MD 20882, [2]Jet Propulsion Laboratory, California Institute of Technology, Pasadena CA 91109.

Magellan spacecraft data have revealed that the surface of Venus is dominated by features of volcanic origin, many of them likely to be related to upwelling (e.g., Solomon et al., 1992). Patterns of tectonic and volcanic features failed to support pre-mission models of plate tectonics (e.g., Head and Crumpler, 1987), and the average surface age of 300-750 my [Schaber et al., 1992; McKinnon et al., 1997] hinted at a possible history of global-scale resurfacing (e.g., Strom et al., 1992). Thermal evolution models of the planet range from periodic plate tectonics [Turcotte, 1993] to stagnant lid convection [Solomatov and Moresi, 1996]. We have been investigating the characteristics of possible hotspot features on Venus, which include topographic rises (~1500 km across, 1.5-5 km high), coronae (100-2400 km across, 0.8-2 km high), and large volcanic provinces (up to 6000 km across). The morphology, evolutionary history and distribution of these features can provide insights into the behaviour of mantle upwelling on the terrestrial planets. We interpret the variations in styles of surface volcanism, surface deformation, topography and gravity signatures to indicate differences in the nature of the underlying thermal upwellings.

Topographic rises on Venus have diameters of at least 1000 km and have large associated volcanic edifices (e.g., Senske et al. 1992; McGill, 1994; Stofan et al. 1995). Stofan et al. [1995] classified rises into three categories: volcano-dominated, rift-dominated and corona-dominated. Of the ten rises identified to date, five are volcano-dominated, two are rift-dominated and three are corona-dominated. Topographic rises appear to be randomly located on Venus. Minimum melt volumes, calculated from edifice volumes are estimated to be at least 10^4-10^6 km^3. Some of the volume of the topographic rise may include early-stage flood basalts, but we have seen no clear evidence of this. The different categories of topographic rises do not appear to indicate an age progression, but instead reflect the variations in lithospheric structure, plume characteristics and regional tectonic environment [Stofan et al., 1995; Smrekar et al., 1997]. In particular, analysis of the geologic histories and gravity signatures of corona-dominated rises indicates that they might form from thermal anomalies originating from a relatively shallow interface, possibly the upper-lower mantle boundary [Smrekar and Stofan, 1999]. The characteristics of volcano and rift-dominated rises are most consistent with formation by ‘primary plumes’ (e.g., Courtillot et al., 2003).

Coronae are volcano-tectonic features believed to form over small-scale mantle upwellings [Basilevsky et al., 1986; Stofan et al., 1991; Janes et al., 1992]. Our updated corona database contains 513 features [Stofan et al., 2001; Glaze et al., 2002], an increase from the 326 coronae of the previous survey [Stofan et al., 1992]. Coronae occur in three distinct geologic settings: along chasmata (rifts), in the plains, and at volcanic rises [Stofan et al., 1997]. Coronae overlap in size and association with large amounts of volcanism with large volcanic edifices (e.g., Herrick and McGovern, 2000). While some large volcanoes are located at topographic rises, other features appear to be randomly located in the plains or along chasmata, similar to coronae. We are in the process of assessing the relationship between large volcanoes and coronae, in particular comparing their histories and gravity signatures.

We have identified ten characteristic topographic signatures for coronae, and compared them to model predictions [Smrekar and Stofan, 1997]. About half of coronae are depressions, some are plateaus up to 3 km high, and others consist of rimmed plateaus or rims surrounding flat interiors. The wide range in topography at coronae has led us to conclude that models involving thermal upwelling accompanied by delamination best fit corona characteristics [Smrekar and Stofan, 1997; Smrekar and Stofan, 2003]. Contrary to other models (e.g., McGovern and Solomon, 1998), we do not find that elastic lithospheric thickness appears to be a controlling factor in corona morphology [Smrekar and Stofan, 1999; 2003]. The relationship between corona topographic shape and size is consistent with the model predictions of Smrekar and Stofan [1997], in which later-stage coronae (depressions and rimmed depressions) are smaller due to the inward migration of the delaminating ring [Glaze et al., 2003]. Coronae are likely to be products of secondary plumes (e.g., Courtillot et al., 2003).

A number of large igneous provinces, or major concentrations of volcanic and volcano-tectonic features have been identified on Venus, most notably the Beta-Atla-Themis (B-A-T) region (~10^6 km^2) [Crumpler et al., 1997]. The provinces range from the B-A-T region with its distinct concentrations of large flow fields, coronae, and small to intermediate-size volcanoes, to groups of arachnoids (volcanic depressions surrounded by 'webs' of fractures), to large flow fields. Over 200 large flow fields have been identified and classified on Venus [Lancaster et al., 1995; Magee and Head, 2001]. Mylitta Fluctus is one of the larger fields, with an area of 300,000 km^2 and estimated thickness of 250-400 m [Roberts et al., 1992]. Most of the venusian flow fields are areally more extensive and less thick than terrestrial large flow provinces [Roberts et al., 1992; Lancaster et al., 1995]. The regions appear to be more common in the equatorial region of the planet. Although all of these regions have been suggested to be associated with thermal upwellings, little detailed analyses of these regions or their gravity signatures have been done. Magee and Head [2001] did note a strong association between rift zones and flow fields, suggesting that lithospheric extension may be critical to their formation. On Venus, the lack of plate motion might cause flow fields to be superposed by ongoing volcanic activity associated with the plume tail. The venusian large volcanic provinces must have plumes that have sufficient buoyancy fluxes to result in large amounts of melting, but either lack sufficient tails to create more numerous topographic rises or are in an early stage of development.

Our analyses of the geologic and geophysical characteristics of hotspots on Venus suggest that the features vary in stage of evolution, and likely originated at different times over the visible history (~750 my) of the planet (e.g., Guest and Stofan, 1999). Our work to date on topographic rises and coronae suggests that the variations in size, morphology and distribution of features related to thermal upwellings primarily reflect fundamental differences in the characteristics of the plume/thermal upwelling. Most topographic rises are likely to be formed by primary plumes, while coronae and corona-dominated rises result from shallower upwellings. Extension clearly plays a critical role in the formation of large flow fields [Magee and Head, 2001], coronae [Stofan et al., 1992; Stofan et al., 1997] and possibly the rift-dominated volcanic rises.

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