large thicknesses (~100 km), gravity anomalies are expected to be relatively small. Features on Venus thought to be due to convergence include Akna, Freyja, and Maxwell montes. These mountain belts are dominated by compressional features and also contain features interpreted as strike-slip faults or shear zones [*Crumpler et al.*, 1986; *Pronin*, 1986; *Basilevsky et al.*, 1986; *Head*, 1990*c*; *Vorder Bruegge et al.*, 1990].

Based on terrestrial examples, convergence can cause sufficient crustal thickening to explain the observed elevation of regions of tessera. On Earth, the Tibetan Plateau appears to be a region where the crust is approximately double the thickness of typical continental crust [*Chen and Molnar*, 1981]. Even if the density contrast between Venus crust and mantle is relatively small (e.g., $\rho_c = 3.0$ g cm^{-3} and $\rho_m = 3.3$ g cm^{-3}), and we assume a typical crustal thickness of 25 km [e.g., *Zuber*, 1987; *Grimm and Solomon*, 1988], doubling such a crust yields ~2.3 km of isostatically supported relief. Approximately 90% of tesserae lies within 2.3 km of the mean planetary radius [*Bindschadler and Head*, 1989]. If the density contrast between crustal and mantle materials is greater, lesser amounts of crustal thickening are required to produce high elevations. Observed LOS gravity anomalies over Alpha and Tellus regiones are relatively small, consistent with crustal thickening and Airy compensation.

Considered in terms of the examples of terrestrial orogenic belts and Venusian mountain belts, horizontal convergence and compressional deformation predict many of the features of subparallel ridged terrain (T_{sr}) and disrupted terrain (T_{ds}). There are no compressional structures in the trough and ridge terrain (T_{tr}) (unless the interpretation of ridge and valley structures as extensional features is incorrect), and thus the T_{tr} does not appear to be the result of convergence. Ridges and lineations within the T_{sr} and T_{ds} (Figures 3 and 5) are consistent with compressional and strike-slip deformation, respectively. Moreover, lineations are found in the T_{sr} in the orientation expected for conjugate strike-slip faults formed during compression. The transitional nature of boundaries between T_{ds} and T_{sr} may be explained if disrupted terrain is formed by progressive strike-slip faulting, and possibly block rotation, of subparallel ridged terrain. *Tapponnier and Molnar* [1976] suggest that compressional deformation involving significant thickening of the crust will lead to reorientation of principal stresses. Following Anderson's theory of faulting, compression initially results in thrust faulting, since the least compressive principal stress (σ_3) is vertical. As topography grows and crustal thickness increases, vertical normal stresses become increasingly compressional until σ_3 lies within the horizontal plane and strike-slip deformation occurs. On Earth, strike-slip features have been associated with orogenesis. In addition, extensional features are found within high plateaus formed at convergent plate boundaries [*Molnar and Tapponnier*, 1978; *Dalmayrac and Molnar*, 1981] and are thought by a number of workers to result from continued growth of topography and increasing vertical normal stresses. Extensional features are found within the disrupted terrain and are discussed further in the section on gravitational relaxation.

The relationship between the mountain ranges of western Ishtar Terra and tessera terrain is also consistent with a horizontal convergence model. The mountain ranges that border Lakshmi Planum (Akna, Freyja, Maxwell, and Danu montes) are themselves bordered by tessera terrain. These regions of tessera form a plateau outboard of Lakshmi Planum and appear to be a significant part of the architecture of mountain belts on Venus [*Head et al.*, 1990]. Moreover, boundaries between the mountain belts and the tesserae are transitional in nature and are characterized by a great deal of structural continuity. Type II boundaries (Figure 7) between plains units and tesserae are also consistent with convergence and crustal thickening and are most commonly associated with T_{sr}. These relationships suggest that the origin of the Lakshmi-surrounding regions of tessera are related to horizontal convergence [*Head*, 1990*c*], as are other regions of T_{sr} and T_{ds} associated with type II boundaries.

Mantle Upwelling

In the second model, a mantle hotspot or plume causes thermal and/or dynamic uplift of the surface (Figure 8). The primary candidates for such upwellings are regions such as Beta, Atla, and Bell regiones. These swell-like regions have been suggested to be related to hotspot activity within the mantle on the basis of pervasive volcanism, apparent depths of compensation of the order of 150-300 km, and correspondingly large gravity anomalies [*Esposito et al.*, 1982; *Janle et al.*, 1987; *Senske and Head*, 1989]. It would then be expected that tessera terrain is related to these domal uplifts [*Barsukov et al.*, 1986], with tessera terrain perhaps representing a later stage in the evolution of domal uplifts. Deformation due to uplift would include circumferential extensional features due to flexure [e.g., *Banerdt*, 1986] and might also include features due to shear tractions applied at the base of the lithosphere by mantle flow [*Phillips*, 1986, 1990] . If upwelling flow persists for sufficiently long times, significant crustal thinning and surface subsidence may result [*Bindschadler and Parmentier*, 1990]. Deformational features due to mantle upwelling are expected to be dominated by extensional structures.

Topography and LOS gravity strongly constrain the applicability of the upwelling hypothesis to the formation of tessera terrain. Where both are available, these data suggest that regions of tessera terrain are compensated at relatively shallow depths (less than 100 km) and are characterized by small ratios of geoid to topography compared to proposed hotspot features [*Smrekar and Phillips*, 1989, 1990]. This suggests that regions of tessera are not presently supported by deep-seated variations in mantle temperature.

Pronin [1986] suggests that Lakshmi Planum is a locus of mantle upwelling and that the mountain ranges there were created by shear along the base of the lithosphere due to flow of mantle material away from the upwelling. According to this model, regions of tessera outboard of Lakshmi could form as a result of upwelling. However, a quantitative model for mantle flow tectonics [*Bindschadler and Parmentier*, 1990] indicates that such a scenario is unlikely. If the mountain ranges are the result of crustal thickening due to mantle flow, then this study indicates that crustal thinning of equal or greater magnitude is expected to occur in Lakshmi Planum. Extensional features are largely absent on the Planum surface, aside from a few small (~10 km wide) graben or fractures [*Roberts and Head*, 1990]. In fact, the deformation and topography associated with western Ishtar Terra and Lakshmi Planum are better explained in terms of mantle downwelling [*Bindschadler and Parmentier*, 1990; *Bindschadler et al.*, 1990*b*].

Several morphologic characteristics of tessera terrain are also inconsistent with a mantle upwelling origin. Swells such as Beta and Bell regiones are characterized by dome-shaped