LAKSHMI PLANUM VOLCANISM: BASAL MELTING OF THICKENED CRUST?;
Kari M. Roberts and James W. Head, Dept. of Geological Sciences, Brown University, Providence, RI 02912

On the basis of an analysis of models for the origin of Lakshmi Planum in Western Ishtar Terra, Venus [1], we favor the hypothesis that Lakshmi is composed of a large block of tessera that has been subjected to compressional deformation about its perimeter and volcanically resurfaced within its interior. This "tessera/convergence model" for the origin and evolution of Lakshmi best explains its ~4 km elevation, its plateau-like nature and irregular polygonal outline, the surrounding compressional orogenic belts, the abundant volcanism and the presence of "ridged terrain" units [2]. We are now examining the hypothesis that volcanism on Lakshmi is linked to deformational processes in the surrounding orogenic belts, either as the result of ductile thickening of the plateau and basal melting of a thickened crustal root or melting of underthrusted slabs associated with activity at the peripheral orogenic belts. Here we test the first hypothesis in terms of the implications for melting and volcanism of the tessera/convergence model. We have examined crustal thicknesses predicted from the topography of the region (assuming Airy Isostasy) and possible depths to the solidus (given different theoretical conductive geotherms). Figure 1 is an isostatic cross section of Lakshmi Planum from north (Freyja Montes) to south (Danu Montes). We assume a basaltic crust with a density of 3.0 g/cc and a mantle density of 3.4 g/cc. A crustal thickness of 15 km is assumed to represent 0 km elevations. This is consistent with recent estimates of crustal thicknesses for regions of lowland plains based on observed deformation wavelengths (<20 km; [3]), geometry of tectonic features (5-15 km; [4]), and models of viscous relaxation of crater relief (10-20 km; [5]). The approximate locations of the solidus given theoretical conductive geotherms [6] of 25 and 15°C/km are shown by dashed lines. Using Figure 1 we will comment on the possible geometry of melting and location of surface volcanism on Lakshmi Planum.

In general, melting is expected in those regions of the crust which extend below the depth of the solidus. Thus, no crustal melting is predicted for Lakshmi given the 15°C/km geotherm but widespread melting is predicted for Lakshmi with the 25°C/km geotherm. At the surface, volcanism is observed to be concentrated within the plateau, away from the surrounding mountains. If the 25°C/km geotherm is appropriate, why doesn't melting appear to have been concentrated within the mountains, the regions of thickest crust? We know that volcanism on Lakshmi has occurred synchronously with the surrounding tectonism [2] so that the observed volcanic deposits are not significantly older than the orogenic belts. Perhaps "proto-Lakshmi" became thick enough to begin basal melting only after the initial phases of compressional deformation associated with the accretion of crustal blocks about its periphery [*e.g.*, 7] produced sufficient ductile crustal thickening. As the compression continued, the deformation was concentrated at the periphery of Lakshmi resulting in the orogenic belts now observed. In this scenario, melting would have begun first within the plateau, as its root crossed the solidus first. Later, as the mountain roots obtained greater thicknesses, melting would have begun there as well. Incipient melting within the mountain ranges is indicated by localized volcanic plains adjacent to Freyja Montes [7, 8]. This simple ductile thickening model does not consisder the possibility that volcanism is generated as a result of melting of an underthrusted or subducted lithospheric slab.

We have used the relationships illustrated in Figure 1 to attempt to constrain a possible geotherm beneath Lakshmi Planum. Assuming 50% of the crust between the solidus and liquidus melts and 100% of the crust below the liquidus melts, and that 10-20% of the melt reaches the surface [9], then the volume of resurfacing produced with a geotherm of 25°C/km is ~4.3-8.7 x 10^6 km^3. As this range exceeds the volume observed at the surface, which we estimate to be ~1 x 10^6 km^3, this geotherm is most likely too high. However, it is possible that fractional melting may reduce the amount of melt produced from the amount calculated here. The geotherm of 15°C/km is probably too low, as it predicts a solidus located at a depth greater than the thickness of the plateau. Of course, it is possible that melting of the mantle could produce volcanism, as it might anywhere on the planet. This simple analysis predicts that the true geotherm is intermediate to the 25 and 15°C/km geotherms evaluated here. The next stage in our analysis is to examine additional complexities which include the following: 1) the effect of self-compression on isostatically determined crustal thicknesses; 2) the role of shallow underthrusting and possible subduction in the generation of melt at depths beneath the plateau; and 3) changes in the crustal geotherm introduced as a result of various styles of structural deformation [*e.g.*, 10, 11].

Gravity data for Ishtar Terra obtained from the Pioneer Venus Orbiter have been interpreted to yield an apparent depth of compensation of ~150 km [12]. This is deeper than our estimates of crustal thickness for Lakshmi Planum but approximates the thickness of the crustal root determined for Maxwell Montes [13]. The groundtracks which were used to calculate the apparent depth of compensation [12] pass over the Maxwell region and perhaps the local influence of the thickened crust at Maxwell produced an apparent depth of compensation that is not typical of Lakshmi Planum as a whole. If not, then such a large apparent depth of compensation implies that there is at least some thermal component to the topography of Lakshmi Planum/Ishtar Terra. Such a

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thermal component may be related to a large region of partial melt, as we suspect is present beneath Lakshmi Planum. Further analysis of gravity data and geologic models is required to settle this question.

References: [1] Roberts and Head (1990) Models for the origin of Lakshmi Planum, Venus, LPSC XXI, this volume; [2] Magee and Head (1988) LPSC XIX, 713; [3] Zuber and Parmentier (1990) On the relationship between isostatic elevation and the wavelengths of tectonic surface features on Venus, **Icarus**, in press; [4] Banerdt and Golembeck (1988) **JGR**, 93, 4759; [5] Grimm and Solomon (1988) **JGR**, 93, 11911; [6] Hess and Head (1989) 28th IGC, 55; [7] Head (1990) The formation of mountain belts on Venus: evidence for large-scale convergence, underthrusting, and crustal imbrication in Freyja Montes, Ishtar Terra, **Geology**, in press; [8] Burt and Head (1989) **Bull. Am. Astron. Soc.**, 21, 920; [9] Crisp (1984) **J. Volc. and Geoth. Res.**, 20, 177; [10] England and Thompson (1986) in **Collision Tectonics**, Geol. Soc. Spec. Pub. No. 19, Coward and Ries (eds.), pp. 83-94; [11] Burt and Head (1990) Venus: tectonic and volcanic consequences of subduction and underthrusting, LPSC XXI, this volume; [12] Sjogren *et al.* (1984) **GRL**, 11, 489; [13] Vorder Bruegge and Head (1989) **GRL**, 16, 699.

Figure 1. Isostatic cross section of Lakshmi Planum trending north-south. Short dashed lines represent thickness of crust of zero km elevation; long dashed lines indicate approximate position of solidus and liquidus of given geotherm. Place names are as follows: a) Snegurochka Planitia; b) Itzpapalotl Tessera (300 km in width, 3.5 km in height); c) Freyja Montes (250 km in width, 7 km in height); d) Lakshmi Planum (1400 km in width, 4 km in height); e) Danu Montes (150 km in width, 6.5 km in height); f) Clotho Tessera (300 km in width, 3 km in height); g) Sedna Planitia. The vertical scale is exaggerated 20 times.