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Are the Equatorial Highlands on Venus Formed by Mantle Plume Diapirs?

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Several origins have been proposed for the Equatorial Highlands on Venus, including (i) ***spreading centers***, analogous to mid-ocean ridges on Earth (Head and Crumpler, 1987), and (ii) ***plume-related uplift***, analogous to hotspots on Earth (Phillips and Malin, 1984; Stofan and Saunders, 1990). Recently, the spreading center hypothesis has been shown to be incompatible with the measured geoid and topography variations over the Highlands (Kiefer, 1990). It is also difficult to reconcile the range of geoid anomalies over the Highlands with a steady-state plume model. There is a large variation in admittance values (geoid/topography ratios) among Highland regions (see table 1). This variation suggests different uplifted regions represent distinct stages in a time-dependent process. Herrick and Phillips (1990) have proposed that the Highland regions listed in table 1 are formed by large mantle diapirs. According to this model, topography and geoid height decrease with increasing age of the highland, as the diapir spreads out beneath the lithosphere. A similar dynamical process has been proposed for continental flood basalt and ocean plateau volcanism on Earth (Richards et al, 1989). On Earth, rapid uplift and massive volcanism are hypothesized to accompany formation of a new hotspot, when a large mantle plume diapir rises toward the lithosphere and undergoes decompression partial melting.

In order to determine if the diapir model is compatible with the sequence of tectonic and volcanic events recorded in the surface geology of the Highlands, a series of finite difference calculations have been made of the ascent and partial melting of a spherical thermal diapir in an incompressible, infinite Prandtl number, isoviscous fluid. The upper surface of the fluid is a rigid lid, representing the crust. The initial conditions include a conductive thermal boundary layer at the upper surface, representing the thermal lithosphere, and a buoyant spherical diapir with initial temperature T_D, located near the base of the fluid. The diapir is released at the beginning of the calculation, and allowed to rise. The diapir shown in Figure 1 began with an excess temperature $\Delta T = T_D - T_\infty$=400K. Appropriate thermodynamic and transport parameters were chosen for the mantle of Venus. Partial melting is calculated using a simplified pressure-dependent melting law. The dynamical behavior of the melt phase is represented as a bimodal process. Where the porosity ϕ is below a critical value, ϕ_c, percolation is ignored, and melt is advected along with the unmelted matrix. Where $\phi \geq \phi_c$, the excess melt is assumed to be infinitely mobile, and is added immediately to the overlying crust.

Figure 1 shows the main stages in the evolution of the diapir, and the corresponding stages in surface volcanism and tectonics. Figure 1a illustrates the first stage, as the diapir approaches the lithosphere from below. During this stage, broad-scale, dynamically supported uplift and the first phase of volcanism occur. Most of the new crustal material is derived from partial melting *ahead* of the diapir. The peak geoid anomaly is approximately 100 m, and the admittance is large. In the second stage (Figures 1b-c) the diapir spreads out at the base of the lithosphere. The main phase of volcanism occurs at this stage, with melt derived from the diapir at 100-150 km depth. The dynamically supported topography subsides, the component of topography due to crustal thickening develops, and the peak geoid anomaly drops to about 25 m. In the final stage (Figure 1d), melt production has ceased, and a ring-shaped instability develops in the thermal boundary layer around the collapsed diapir. Topography at this stage consists of a low plateau surrounded by a broad, depressed plain, and a central highland region elevated by thick crust. The ring instability generates extensional stress in the central highlands, and compressional stress along plateau margin.

The time scale for evolution is quite short: the dynamic topography subsides in about 10 Myr, and volcanism is essentially finished within 15 Myr. These timescales are consistent with the rapid extrusion of flood basalts and ocean plateau on Earth. They also place an important constraint on models of Highland formation on Venus. According to the mantle diapir model, Beta Regio represents stage 1, while Thetis and Ovda and the Artemis Plateau in Aphrodite Terra represent stages 2 and 3. If this interpretation is correct, then Beta, Thetis and Ovda must all be rather young, probably 50 Ma or less. Preliminary age estimates derived from crater statistics indicates substantially older ages for the uplifted areas in Aphrodite Terra (Phillips et al, 1991).

References .

Head, J.W. and L.S. Crumpler, *Science 238*, 1380-1385, 1987.

Herrick, R.R. and R.J. Phillips, *Geophys. Res. Lett. 17*, 1373-1376, 1990.

Kiefer, W.S., *Geophys. Res. Lett. 17*, 1373-1376, 1990.

Phillips, R.J. et al, *XXII Lunar Planet. Sci. Conf.*, 1991.

Phillips, R.J. and M.C. Malin, *Ann. Rev. Earth Planet. Sci. 12*, 411-413, 1984.

Stofan, E.R. and R.S. Saunders, *Geophys. Res. Lett. 17*, 1377-1380, 1990.

Richards, M.A., R.A. Duncan and V.E. Courtillot, *Science 246*, 103-107, 1989.

Table 1: Equatorial Highlands

Dome	Diameter (km)	Elevation (km)	Geoid (m)
Beta Regio	2800	4.5	90
Thetis Regio	3000	4	70
Ovda Regio	3400	4.8	35
Artemis Plateau	2500	1.5	<20

Table 2: Diapir tectonics

Stage	Time (Myr)	Tectonic Style	Volcanic Style
1	0-5	Rapid Uplift + Extension	Rift Volcanism
2	5-20	Rapid Subsidence	Flood Volcanism
3	>20	Slow Subsidence + Marginal Compression	none

Figure 1: A numerical calculation of the evolution of a rising thermal diapir. Upper panels: Profiles of geoid height (solid) topography (dotted) and dynamical topography (dashed). Lower panels: Contours of the temperature field. Shaded regions show partial melt concentration.