FORMATION AND EVOLUTION OF PLUME PLATEAUS ON VENUS; L. S. Crumpler and James W. Head, Department of Geological Sciences, Brown University, Providence, RI 02912

Introduction: Plateau-like areas with dimensions in the range of several hundreds to several thousands of kilometers are relatively common on Venus and are characterized by several of the following features: broad regional rises, linear boundaries, locally relatively steep sides, associated volcanic edifices and deposits, rifting, complex surface structure and texture (often tessera-like), and tectonic junctions (1-4). Plateaus can be classified into several types, some associated with the Equatorial Highlands (Beta, Atla, the sites of tectonic junctions; Western Eisila, the site of localized volcanism; Ovda and Thetis, the site of rifting and apparent crustal spreading), and others at mid to high latitudes and not obviously associated with rifting at present (Tellus, Alpha, Eastern Fortuna, Laima) (3,4). Here we examine the origin of the plateaus at Ovda and Thetis, and propose a model for their evolution and how they may be linked to the characteristics and evolution of plateaus elsewhere on Venus.

Crustal Spreading, Mantle Plumes, and the Formation of 'Plume Plateaus': Crustal spreading in Western Aphrodite Terra is interpreted from linear cross-strike discontinuities (CSDs) thought to represent fracture zones, which segment Aphrodite into domains characterized by bilateral symmetry parallel to the linear discontinuities. The centers of symmetry of the domains have central depressions and form linear rises that are oriented normal to the CSD's, terminate against them, and are offset at them in an en echelon manner (5), in patterns comparable to spreading centers in the Earth's ocean basins. On the basis of these data and analysis of topographic profiles, Aphrodite Terra appears to be the site of spreading at the present time at rates of the order of 1.5-3 cm/yr (5,6). Analysis of the nature of the process of crustal spreading in the Venus environment indicates that the enhanced upper mantle temperature (about 1500°C) caused by high surface temperature should result in a crustal thickness of about 15 km, a factor of 2-3 greater than that for the Earth (6). Material formed at the rise crest and moved laterally would become lower topographically as it cooled and would be modified by subsequent volcanism and tectonism. Localized plateaus along the Equatorial Highlands, such as Ovda and Thetis Regiones, are interpreted to be the site of elevated upper mantle temperatures, enhanced melting, and greater crustal thicknesses (5,6). Specifically, these Iceland-like pleateus could be formed by increased upper mantle temperatures of about 100°C, which would produce a 30 km thick crust characterized by an increase in isostatically supported elevations of about 1.5 km (6). Models of Ovda Regio that are consistent with both topography and gravity data suggest that such a process is plausible, with upper mantle temperatures of about 1600°C and spreading rates of about 1 cm/yr (6). The most likely mechanism for the enhanced upper mantle temperature is a localized upwelling of the mantle, and the geometry of the plateaus suggests that it may be a mantle plume or 'hot spot' similar to the one thought to underlie the Icelandic plateau (7). The size of Ovda Regio (2000 km wide) and the interpreted spreading rates suggest that this mantle plume has been active for the past 200 million years (6).

Evolution of 'Plume Plateaus': Cessation of the enhancement of upper mantle temperature at the site of a mantle upwelling or hot-spot would return the spreading environment to a more normal condition of spreading (if nominal, to a crustal thickness of about 15 km, and isostatically compensated topography of 1-1.5 km less than previously). In this case continued spreading would split the 'plume plateau', separate it, and move it laterally off the thermal rise into the adjacent lowlands at rates comparable to the spreading rates (8,9). Although the split and separated plateau would become topographically lower as it evolved thermally, its enhanced crustal thickness and its correspondingly increased isostatic topography, would result in the plateau remaining elevated above the adjacent surrounding plains by an amount related to crustal thickness variations. There are several possible modifications that might be expected as plateaus split, separate, and are moved laterally. The following predictions from the model are compared to some observations of Venus plateaus: 1) Presence of plateaus with predicted characteristics: about 10-15% of the area covered by Venera 15/16 data show the presence of plateaus which have at least some of the characteristics outlined above, and other areas of the surface have plateaus which are characterized by tessera-like fabrics (10); 2) Marginal deformation of plateaus caused by localization of deformation along

EVOLUTION OF PLUME PLATEAUS: Crumpler, L.S. and Head, J.W.

potential zones of weakness at edges of plateaus (e.g., crustal thickness differences, fracture zone boundaries of plateaus); possibly initiated by changes in tectonic geometry. Marginal deformation is observed along the borders of western Tellus and Alpha. 3) Accretion with other plateaus may occur when two plateaus converge; if underthrusting and crustal loss occur (11), then when zones of thicker crust converge, they may resist further underthrusting and coalesce to form a larger plateau. Such a situation has been porposed for the Clotho Tessera/Danu Montes region of Ishtar Terra (12). 4) Collage accretion would occur when plume plateaus with thick crust become the locus of accretion and continue to grow by collection of plume plateaus and associated deformation. Such collages of plume plateaus might be viewed as 'protocontinents'. This situation may be occurring in Ishtar Terra, where various segments of thickened crust appear to be converging and accreting into a larger upland plateau with associated orogenic belts and suture zones (13). 5) Volcanic flooding and embayment would be expected and low elevation plateaus (relatively thin crust) might be partially to wholly buried depending on the off-rise volcanic contribution. Many of the topographically low regions of tessera are distinctly embayed and partially buried, and almos all show embayment relationships by surrounding plains.

Predictions: Are the plateaus in middle to high latitudes remnants of thick crust originally created at rise crests ('plume plateaus') and transported laterally to their present positions? This hypothesis makes several predictions that can be tested: 1) shallowly compensated evolved plume plateaus (depths related to crustal thickness); 2) textures and structures that can be linked to plateau origin at rise crests (e.g., analogs to fracture zones and abyssal hills on Earth's seafloor); 3) symmetry of plateaus about their point of origin should be observed if they are split and rifted; 4) internal structures should be observed consistent with their mode of formation and direction of splitting and spreading; 5) plateau size frequency distribution and shapes consistent with plume production. Many of these predicitons can be tested with observations from the upcoming Magellan mission.

Possible relationships to the Earth: Oceanic plateaus are a well-known phenomenon in the Earth's ocean basins (14) and Iceland is a clear example of the formation of a plateau at a rise crest (7). Some presently off-axis oceanic plateaus are thought to have formed at rise crests and been moved laterally (8). Oceanic plateaus have been proposed to be important in continental accretion because of crustal thickness differences and suturing during subduction (15). We are presently analyzing oceanic plateaus on Earth for clues as to basic processes of their formation and evolution which might aid in the understanding of plateaus formed on Venus.

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