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Tessera Terrain: Characteristics and Models of Origin.

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Tessera terrain consists of complexly deformed regions characterized by sets of ridges and valleys that intersect at angles ranging from orthogonal to oblique [1], and were first viewed in Venera 15/16 SAR data. Tesserae cover more area (~15% of the area north of 30°N) than any of the other tectonic units mapped from the Venera data [2,3] and are strongly concentrated in the region between longitudes 0° E and 150° E. Tessera terrain is concentrated between a proposed center of crustal extension and divergence in Aphrodite [4,5] and a region of intense deformation [6], crustal convergence, and orogenesis in western Ishtar Terra [7,8]. Thus, the tectonic processes responsible for tesserae are an important part of Venus tectonics. As part of an effort to understand the formation and evolution of this unusual terrain type, we have compared the basic characteristics of the tesserae to the predictions made by a number of tectonic models. Here we describe the basic characteristics of tessera terrain and then briefly discuss the models and some of their basic predictions.

Observational Data

Altimetry and Surface Roughness: Pioneer Venus data show that the regions tessera lie at higher elevations than surrounding plains, are typically plateau-like in topographic cross section, and are characterized by high values of rms slope [3] (a measure of roughness at a scale of ~0.5 m to 10's of m) [9,10]. Tesserae are also characterized by greater cm–scale roughness than the plains which we interpret to be due to erosion linked to extensive deformation and possibly to greater relative age [11]. Craters are sufficiently sparse to make determination of the relative age of the tesserae unreliable [12].

Gravity Anomalies: For the largest regions of tessera, line of sight (LOS) gravity data may be used to infer depths of compensation. Of the three largest regions of tessera (Tellus Regio, Laima Tessera and Fortuna Tessera) LOS gravity data extend far enough north for Tellus, partly cover Laima Tessera, and do not cover Fortuna Tessera. Anomalies associated with the ~2.5 km of topography in Tellus are < 5 mgal, leading Sjogren et al. [13] to suggest that the region is compensated at shallower depths than most large-scale uplands in the equatorial region. Anomaly values over Laima Tessera are also < 5 mgal [13].

Morphology: Examination of Venera data for the large regions of tessera reveals three morphologic subtypes for the terrain. These are the sub–parallel ridged terrain (T_{sr}), trough and ridge terrain (T_{tr}), and disrupted terrain (T_{ds}).

The sub–parallel ridged terrain (T_{sr}) is similar to ridge belts in that it consists of sub–parallel ridges. However, T_{sr} ridges are less sinuous and do not intertwine. Ridges tend to be disrupted along linear zones of consistent orientation and often form en echelon groups, perhaps indicating strike–slip offset. The three structural orientations are consistent with compression (ridges) and conjugate strike-slip or shear motion (lineations). Type locale: Fortuna Tessera, east of Maxwell Montes.

Structures in the trough and ridge terrain (T_{tr}) are expressed as troughs in one direction and as ridges and/or valleys with approximately orthogonal orientations. Troughs appear both as broad (~50km) and narrow (< 20 km) structures. Ridges occasionally show en echelon offset and tend to be spaced approximately 5 to 10 km apart. Troughs are spaced at least 10–20 km). Type locale: Eastern Laima Tessera

The disrupted terrain (T_{ds}) is characterized by a general lack of continuous ridges or valleys longer than ~50 km. The terrain is often blocky to chaotic in appearance, depending upon the consistency of ridge orientations. Even if ridge orientations are chaotic, lineations defined by short troughs, ridges and by discontinuities in ridges preserve consistent orientations over the region of tessera. Disrupted terrain is usually transitional with the T_{tr} or T_{sr}. Type locale: Central Tellus Regio.

Contacts between tessera and plains are characterized by two types of boundaries. In Type I boundaries, the contact is highly irregular at the 100 km scale, consisting of numerous ovoidal to polygonal plains regions that often separate small regions of tessera from the main body of a block. Structures within the tessera take on a subdued appearance near the boundary and show little relation to the shape of the tessera–plains boundary. Type I boundaries thus appear to be an expression of embayment of the tessera by plains–forming materials. Type II boundaries are much more regular at the 100 km scale and typically characterized by the presence of the T_{sr} subtype of tessera as well as steep topography and the presence of small ridges or ridge belts within the adjacent plains. These boundaries appear to be places where the tesserae have formed at the expense of the plains.

Models

A number of models have been suggested for the formation of tessera terrain [2,14,15]. From these and other tectonic models, we set forth working hypotheses for the formation of tessera, which are divided into three formational models (those which produce the high topography of the tessera) and two modificational models (those in which deformation results from high topography).

Horizontal convergence and crustal thickening may be driven by in-plane lithospheric stresses (as on Earth) or by flow within the mantle of Venus [16,17]. In general, convergent motion is expected to result in high topography, steep topographic slopes, and fold-and-thrust deformation at the surface. Crustal compensation of topography should result in a relatively small LOS anomaly over regions of tessera, given predicted crustal thicknesses for Venus of ≤30 km [18]. In addition, both strike-slip and extensional deformation are observed in terrestrial orogens such as the India-Asia collision and the Andean orogen, and might also be expected to occur on Venus

Mantle upwelling may be manifested as the upwelling limb of a convection cell, a long-lived hotspot, or a diapir-like body. Such an upwelling will result in the formation of a dome-shaped region of high topography, characterized by extensional deformation, and possibly by volcanism [19]. Relatively large LOS gravity anomalies are anticipated, unless the characteristic depth of the source is quite shallow. Numerous workers have identified Beta, Bell, and Atla Regiones as likely surface manifestations of mantle upwelling. Such regions are thus likely to represent some part of the evolution of any tessera formed due to upwelling.

Seafloor spreading or an analogous process is suggested to occur within Aphrodite Terra [5] and to be responsible for the structural fabric of Laima Tessera [20]. On Earth, seafloor spreading results in the formation of an approximately orthogonal structural fabric consisting of transform faults and fracture zones in one direction, and abyssal hill topography in the other. Tessera formed near Aphrodite and transported north is predicted to be old compared to the undeformed plains that surround it. High topography is explained as being due to a relatively thick crust, suggesting that topography at plains-tessera contacts should be gently sloping. Steep topography might be expected to occur at transforms due to juxtaposition of lithosphere of different ages and to thermal stress-supported bending of plate segments [21]. Finally, a common feature of the terrestrial ocean floor are volcanic seamounts, which may be observable as small domes on the surfaces produced by a spreading process.

Gravity sliding is defined here as a thin-skinned, predominantly brittle process involving the downslope movement and deformation of a wedge of material above a decollement. This process is expected to produce extensional features (e.g. a detachment fault) at or near local topographic highs, with structures becoming increasingly compressional toward local topographic lows. If topographic slopes are approximately radial about the highest topography, radial graben would also be expected to form, as observed in the aureole surrounding Olympus Mons on Mars [22].

Gravitational relaxation of compensated topography is distinguished from gravity sliding as a predominantly ductile process driven by gradients in vertical normal stress due to surface and/or crust-mantle boundary topography. In the case of crustally compensated topography, calculations predict extension of high topography and increasingly compressional deformation toward the edges of a topographic high. Highest rates of extension occur at the highest elevations, but extension may occur even in relative lows if they lie above the level of the surrounding plains. If the high topography of the tessera is due to uplift rather than crustal thickness variations, a somewhat different scenario is predicted, see [19].

References

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