Structural Deformation of Northern Ovda Regio, Venus: Implications for Venusian Tectonics.

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Overview: We analyze the history of structural deformation within a region of northern Ovda Regio, and then compare it to prevalent models for highland formation. Our mapping identifies a specific sequence of events for this portion of Ovda. The sequence begins with ridge formation in a compressive event that formed the highland; spatial analysis of these ridges indicates that they typically formed sub-parallel to the highland boundary. The ridges are embayed by younger lowland volcanic plains, and subsequent extensional deformation, preferentially oriented from N30W to N10E, crosscuts both the ridges and plains. When compared to the tectonic models, our sequence of events can best be correlated with the theory that Ovda Regio is the surface expression of mantle downwelling [1], perhaps initiated by a depleted mantle layer overturn event [2,3].

Introduction: Several tectonic models have been developed to explain the formation of plateau-shaped highlands on Venus. Each model predicts a different sequence of structural deformation which can be tested by direct comparison to the observed stratigraphic relationships. To evaluate these models for venusian tectonics, we have mapped a small area (3.2° to 6.3° north latitude, 93.3° to 96.8° east longitude) of northern Ovda Regio. By analyzing the regional structural deformation and its sequence of formation, we are then able to constrain the possible mode of origin for this plateau-shaped highland. Our area contains part of the arcuate margin between the highland and volcanic lowlands, so that the interaction of these units may be observed.

Methods: We have mapped our study area using Magellan Cycle 1 C1-MIDRs. Areas and features of primary importance to this study are the volcanic plains and tessera terrain, and the ridges, graben, and fractures contained within these areas. We have also inferred a sequence of events from the interactions of the features in this area.

We have also determined the relative density of number of ridges per kilometer of tessera/plains boundary. To differentiate between possible stress directions, we have divided the edge of the tessera in our map area into sections, each of which has a general strike. The number of ridges aligned with the strike of a particular section was then divided by the length in kilometers of the section. This unit of ridges/km gives us insight into whether there was a preferred direction of stress creating ridges, or if the number of ridges simply reflects the percentage of tessera/plains boundary with a given orientation.

In addition to our analysis of ridge orientation, we have analyzed the orientation of extensional lineaments. Our goal in this analysis is similar to that of our ridge analysis, in that our primary concern is to determine whether graben and fractures have formed in a preferred direction in this portion of Ovda Regio.

Results: We have inferred a sequence of events based upon our map of the region. The first event was the formation of a dense ridge system which constitutes the highland proper. These ridges are generally sub-parallel to the tessera/plains boundary and are not aligned preferentially with a specific azimuth. The development of the volcanic plains to the north follows this event. These plains extend to and embay the edges of the tessera, dating these plains as a younger unit. Extensional deformation, manifested as fractures and graben, has also occurred in the region. The interaction of the extensional features in the deformational fabric of the region makes the relative age of this deformation unclear. Similar fractures are both embayed by and cut across the volcanic plains, and in addition to this fractures are present that cross-cut other fractures. This seems to indicate the possibilities of one sequence of deformation over a long period of time or several, shorter events of extension.

The number of ridges per kilometer of tessera/plains boundary does not indicate a preferred direction of compressive stress for this area. The values for each section are roughly similar and range from 0.102 r/km to 0.146 r/km. The sub-parallel nature of the ridges and the similar values for ridges per kilometer suggests the possibility that the compressive stress responsible for creating the ridges in this region was radially oriented and relatively even in magnitude.

In contrast to the ridges in the region, the extensional features we have mapped preferentially form with a N30W-N10E alignment. Some of these features cut across the boundary from tessera to plains, and are not restricted to one type of unit. As these features are aligned in a general direction, and have formed in both highland and lowland terrains, it appears that there was an E-W stress operating in the region which created these features.

Discussion: We have considered three different models for the origin of a plateau-shaped highland such as Ovda Regio. The predictions and our observations are summarized in Table 1.

1) Spreading Center: This model suggests that many features present in Ovda Regio are similar to those found in terrestrial spreading centers. Specifically, these features include fracture zone-like lineaments, plus bilateral topographic and morphologic symmetry on either side of a postulated ridge crest [4]. This study was corroborated by another in which a strong correlation was found between the bilateral topography cited in [4] and Pioneer gravity data [5]. The predicted structures of this model, however, are not observed in our study area, and thus we conclude that this mechanism did not operate within our map area.

2) Hotspot/Mantle Plume: This model theorizes that hot, upwelling mantle creates the high topography and morphology of a plateau-shaped highland [6,7]. This sequence of events begins with uplift and radial fracturing, crustal thickening and flood-basalt volcanism, followed by subsidence of the dome and concentric compression due to an end of dynamic support [6]. This sequence of structure does not appear in our study area. Many of the components are reflected in the regional geology, but our order of events does not correlate well with this theory.

3) Mantle Downwelling: A plateau-shaped highland is produced in this model by crustal shortening over a region of mantle downwelling [1]. Here, ridges form sub-parallel to the highland boundary due to radial compression, which also causes an overall increase in elevation [1]. As this process eventually begins to slow and end, it is also predicted that extension and an overall decrease in elevation will occur as the highland begins to spread under its own weight [1]. *Parmentier and Hess* [2] and *Head et al.* [3] have proposed a depleted mantle layer overturn mechanism to begin such a downwelling event. The basic operating premise is that an accumulated depleted mantle layer from basaltic volcanism will eventually become negatively buoyant and founder, creating a mantle downwelling site [2,3]. There is good agreement between the structure predicted by this model and what we have observed in northern Ovda Regio. The prediction of sub-parallel ridges as the formative unit of the highland, and the subsequent sequence of structure, all agree with our observations, indicating that this region could have formed during such an event.

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Table 1: Comparison of Model Predictions to Observed Sequence of Structure.

Model	Predicted Sequence of Events	Observations
Spreading Center [4,5]	· NW-trending fracture zones · extensional rifting · crustal production	· no observed fracture zones · extensional structures similar to those at terrestrial spreading centers are not present
Hotspot/Mantle Plume [6,7]	· uplift and doming · radial fractures · flood-basalt volcanism · subsidence of dome	· radial extension is not oldest observed event · voluminous volcanic flows are absent
Mantle Downwelling [1,2,3]	· compression causes thickened crust and highland · extension and loss of elevation may begin when plateau spreads under its own weight	· observations agree with compressional origin · does not fully explain extensional features that we have also observed