STRUCTURAL ANALYSIS OF CENTRAL AND EASTERN OVDA REGIO, VENUS. R.R. Ghent[1] and V.L. Hansen[2], [1,2] Department of Geological Sciences, Southern Methodist University, Dallas, TX 75275
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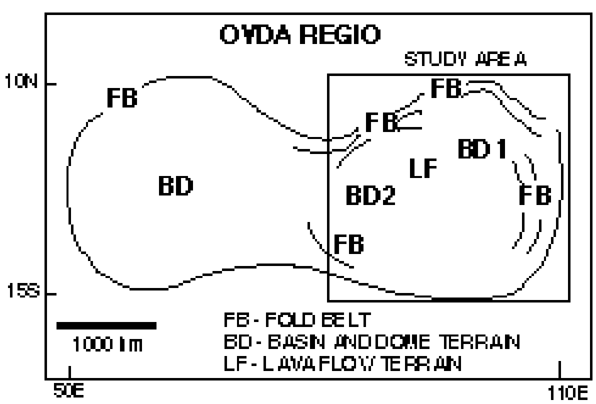
Introduction. Ovda Regio is the largest of the Venusian crustal plateaus and lies in Western Aphrodite Terra, Venus. Understanding the strain history of this region will provide a key to understanding the processes involved in the formation of Ovda Regio and of crustal plateaus in general. Here we report on detailed structural mapping and analysis of Ovda and implications for the tectonic evolution of Ovda and other crustal plateaus.

Observations. We mapped tectonic features of Ovda Regio using Magellan SAR images. We used photographic and computer enhanced digital images; where available, both left- and right-look radar data were used. Ovda is divisible into several provinces (Fig. 1). The margins are defined by fold belts (FB). The interior is characterized by two basin and dome regions (BD1 and BD2) and a region of anastomosing folds called "lava flow terrain" (LF). We first describe the tectonic features of each of these provinces, and then outline the temporal relations between them. Finally, we discuss implications for the history of Ovda Regio and for crustal plateau formation.

Fig. 1. Regional sketch map of Ovda Regio showing study area and tectonic provinces.



Folds: The eastern boundary of Ovda is defined by broad folds (λ up to 25 km) parallel to the margin. These folds range in length up to several hundred km. Parallel folds (λ = 100 m to 5 km) occur both between crests and along crests of larger folds.

In the region labeled BD1, margin-parallel folds are cross-cut at high angles by at least one suite of folds. The result is a series of short folds whose axes trend in two general directions: NE and NW. The average wavelengths of these folds is approximately 5 km, but this is often difficult to determine due to the highly tectonized character of the structures and extreme radar brightness of the region.

In the region labeled LF, folds take on an anastomosing character, with λ ranging from the limit of SAR resolution up to 10 km. This terrain has been called "lava flow terrain" [1] because of its resemblance to the surface of a pahoehoe lava flow. Fold axis trends gradually rotate from NW to NE from west to east across LF. South of LF, the basin-and dome character of folds from BD1 is preserved; the dominant fold axis trend is NW. North of LF, folds parallel the plateau margin, which here forms a "neck" between central and western Ovda.

In BD2 the character of the folds is different from those in BD1. The folds in BD2 are more continuous than in BD1, and have long sinuous radar-dark troughs, some of which are filled with lava. Fold axes generally trend NE with some fold axes trending N to NW. West of BD2, folds trend E-W and begin to disappear into the plain between central and western Ovda.

Ribbons: These structures are steep-sided, flat-floored troughs with shallow depths (<500 m), spaced from 1-5 km apart. Trough widths are 1-3 km, and can extend for several hundreds of km. Detailed morphology of these structures is described by Hansen et al. [1,2]. In Ovda Regio, ribbons are best preserved in the eastern fold belt, but they are present everywhere except in LF. Their trend is generally radial throughout the study area. In the eastern fold belt and south of LF, two sets of ribbons intersect at an angle of 30-45°. In BD1 and BD2, ribbons are disrupted, partially obscured, and locally reactivated as graben. Individual ribbon troughs in these regions are difficult to follow; some are flooded, some have been reactivated as graben, and some are obscured by features at the limit of SAR resolution.

Graben: We distinguish true graben from the ribbons described above as lens-shaped features bounded by normal faults and with length:width aspect ratios of 1 to 4. Some graben have been filled by lava, giving their floors a smooth appearance; others have distinctly visible scarps bounding their edges, imparting a terraced appearance. In contrast with ribbons, graben are not present everywhere on the plateau, but are restricted in large part to the crests of folds in the eastern fold belt and in BD1 and BD2. Graben are wellpreserved in the northeast margin fold belt (see for example [3], figure 12) where they are present together with folds and ribbons, and the three structures can be distinguished.

Lava flows: Lava flows in Ovda appear both as intratesseral plains and as flows which partially obscure folds and other structures in the most complex regions of the plateau. The sources of these lava flows are not readily apparent. Lava from intratesseral plains fills some low-lying fold troughs and graben in BD2 and at the eastern margin.

Temporal Relations. The three major structures in Ovda Regio are folds, ribbons, and graben. The folds are interpreted to be contractional, and graben and ribbons extensional. Binschadler et al. [3] have proposed that Ovda records early contractional strain (fold formation) and later extension (graben and "steep trough" formation). Extension following fold formation is supported by the fact that the graben are generally limited to the crests of folds, indicating that their formation is influenced by the presence of the folds. The ribbon structures, however, are structurally quite different from the graben, and therefore their origins should be considered separately. The flat-bottomed, steep-sided ribbons have extreme aspect ratios, they track across folds of all wavelengths with no change in width or orientation, and they form a penetrative fabric throughout Ovda Regio.

We propose that ribbon formation predates, rather than postdates, fold formation. Details of ribbon structure are most easily accomplished by the opening of tension fractures in a thin brittle layer above a ductile substrate, *before* folding [1,2]. Ribbon distribution and orientation support this chronology. Whereas folds and graben have several different orientations, ribbons are uniformly radially oriented throughout central and eastern Ovda. This broad coherent penetrative fabric would not be likely to form over such vast regions if the folds were already present. If ribbons postdated folds, we would expect to see local patterns of extension, influenced by fold wavelengths and orientations, rather than a single continuous fabric over all the different fold terrains present in Ovda.

Formation of ribbons before folds indicates that the earliest recorded strain in Ovda Regio is extensional, rather than compressional. Furthermore, the broadly radial pattern and penetrative nature of the ribbons throughout central and eastern Ovda is evidence of radial membrane extension of the entire region. This broad radial membrane extension is consistent with the idea that Ovda Regio formed above a mantle upwelling, or plume [4,5]. The presence of a sublithospheric plume could cause the brittle-ductile transition to become very shallow, and would initiate doming of the lithosphere, allowing for the formation of ribbons. The patterns of folds and graben in Ovda Regio are also consistent with this theory. Margin-parallel folds could result from gravitational slumping along the margins of the upwarp. Subsequent plume degradation would lead to slumping in the interior of the plateau, overprinting ribbon terrain with a seemingly polyphase basin-and-dome pattern of folds. Crustal thickening due to underplating would cause late gravity-driven extension, resulting in graben formation [4,5].

In summary, the structural characteristics of Ovda Regio have significant implications for its history and evolution. The strain history recorded in Ovda involves early extension, followed by contraction, then later extension. This strain history is consistent with formation of Ovda Regio by mantle upwelling. Many of the same tectonic features present in Ovda have also been observed in Alpha Regio [6], and it is therefore possible that Alpha also records early extension. This would have important implications for the formation of crustal plateaus in general.

References [1] V.L. Hansen and J. J. Willis (1996) Icarus **123**, 296; [2] V.L. Hansen and J.J Willis (1997) LPSC XXVIII, this volume; [3] Binschadler et al. (1992a) JGR **97**, 13495; [4] R.J Phillips and V.L. Hansen (1994) Ann. Rev. Earth Planet. Sci. **22**, 597; [5] R.J. Phillips et al. (1991) Science **252**, 651; [6] Binschadler et al., (1992b) JGR **97**, 13563