GEOPHYSICAL RESEARCH LETTERS, VOL. 14, NO. 6, PAGES 607-610, JUNE 1987

# REGIONAL LINEAR CROSS-STRIKE DISCONTINUITIES IN WESTERN APHRODITE TERRA, VENUS

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*Abstract.* Western Aphrodite Terra, Venus, is characterized by a series of parallel linear structural discontinuities 2000–4000 km in length and 100–200 km wide, which strike at high angles to the general topographic trend of the highlands. The detailed characteristics of these features are similar to terrestrial oceanic fracture zones and strike–slip fault zones. Either interpretation implies the presence of large–scale horizontal tectonic movement on Venus.

## Introduction

The highlands of Venus have attracted attention because of their topographic and morphologic distinctiveness (Masursky et al., 1980) and for the clues that their characteristics and origin might provide in understanding the style of tectonics (Phillips and Malin, 1983) and the major mechanisms of lithospheric heat transfer on Venus (Kaula and Phillips, 1981; Morgan and Phillips, 1983; Solomon and Head, 1982). Pioneer–Venus near–global altimetry data (average horizontal resolution of about 100 km) and equatorial radar images (average horizontal resolution 30 km) showed that Aphrodite Terra was the largest contiguous highland region on Venus, extending over 17,000 km along the equator (Pettengill et al., 1980). These data also revealed the major topographic and radar brightness features associated with this region (Schaber, 1982; McGill et al., 1983; Ehmann and Head, 1983; Kaula and Phillips, 1981; Sharpton and Head, 1985). Recent altimetry profiling along the equator (−3° to +6°) by Arecibo Earth–based radar (Campbell et al., 1984) has provided local high–resolution data that help to characterize topographic trends detected in the lower–resolution Pioneer–Venus data. The purpose of this paper is to analyze the regional structure of the western Aphrodite highlands using these two complementary data sets, and to characterize the nature of a series of regional linear discontinuities cutting across the topographic trend of Aphrodite Terra (Crumpler et al., 1987).

## Data and Methods

Pioneer–Venus radar experiment data sets (altimetry, surface roughness, reflectivity, and imaging; Pettengill et al., 1980; Head et al., 1985) were used to study a topographically distinctive portion of western Aphrodite Terra (Ovda Regio and Thetis Regio) between longitudes 60°E and 150°E (Figure 1). Major linear trends in the topography and imaging data were identified and mapped in PV altimetry maps and PV SAR images. Criteria for the identification of linear features included: 1) aligned individual topographic features, 2) long linear ridges and troughs, 3) linear discontinuities in elevation (scarps), 4) steep linear radar backscatter gradients in images, and 5) linear boundaries in maps of radar properties of surface materials (RMS slope and reflectivity; Head et al., 1985). Figure 1 shows the location of the major linear features detected and the criteria for identification of each is listed in Table 1. These features cut across the topographic strike of the Aphrodite highlands at large angles and are thus designated "cross–strike discontinuities" after Wheeler (1980). For example, CSD 1 is defined on the basis of truncated topographic trends, linear topographic slopes, and displaced contour lines, as well as linear shapes in radar images. Arecibo altimetry profiles were then assembled from several equatorial range–Doppler radar traverses (Figure 1). In general, the sampling interval along the Arecibo profiles is approximately 10 km, and the lateral (off–profile) sampling includes radar returns from about 50 km north and south of the east–west profiles. The actual resolution varies depending on the details of the surface slope distribution and the number of integrated observations for a given point on the surface, but a good average value for the horizontal resolution is 10 km (approximately a factor of 10 higher than the average Pioneer–Venus altimetry data) and for the vertical resolution, 100–150 m. We then used the high–resolution Arecibo altimetry profiles (Figure 1) to characterize the detailed topographic nature of the cross–strike discontinuities detected in the Pioneer–Venus data, and to determine the continuity of their characteristics between altimetry profiles (Table 1).

## Discussion and Interpretation

The western Aphrodite highlands (Ovda and Thetis Regiones) are characterized by seven major regional linear discontinuities that cut across the approximately equatorial strike of Aphrodite Terra at a high angle (Figure 1). The discontinuities are in excess of 2000–4000 km in length, are parallel to each other, trend in a N18–22°W direction, and are separated by distances ranging from 200 to 800 km. These discontinuities segment western Aphrodite into long, several–



Paper Number 7L7139.
0094-8276/87/007L-7139$03.00

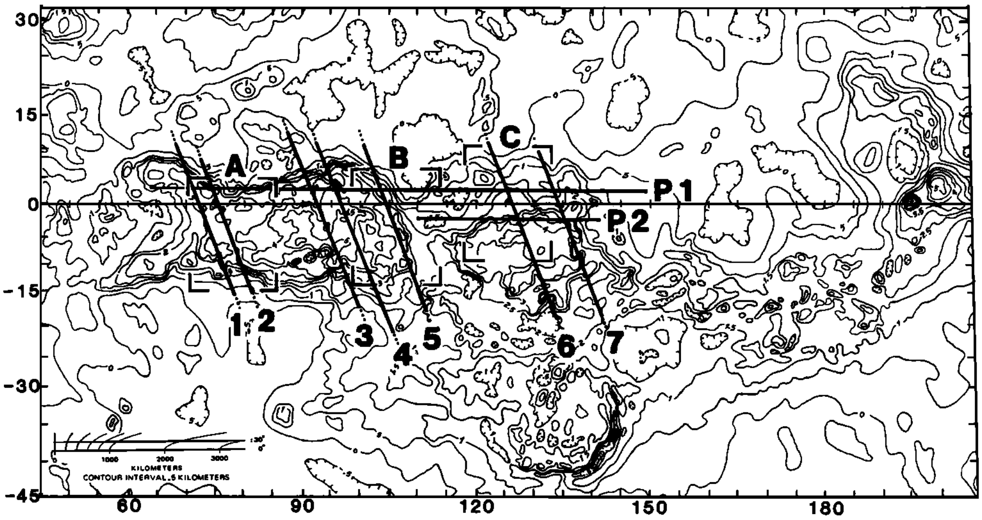


Figure 1. Location of topographic discontinuities (numbered lines) in western Aphrodite Terra. Only those discontinuities detected in three different data sources are mapped. Ovda Regio extends from 70° W to 110° W and Thetis Regio extends from 110° W to 150° W. Boxes A, B, and C refer to areas shown in Figure 2. P1 and P2 indicate Arecibo altimetry ground tracks.

hundred-km-wide plateau-like domains whose long axes are parallel to the discontinuities. This configuration is responsible for the general rhombic or orthogonal shape of Aphrodite as a whole. The predominant topographic character of the linear discontinuities varies along strike. In the lowlands adjacent to Ovda and Thetis Regiones, the discontinuities are often characterized by regional changes in topography of 200–400 m from one side of the discontinuity to another (e.g., CSD 4). These topographic changes are generally less distinct away from Aphrodite (distally) as the linear features traverse the lowlands and then disappear, and most distinct toward the highlands. At the edge of the highland plateau, the discontinuities are often marked by a linear offset of the topographic edge of the plateau of 100 to 1000 km in a direction parallel to the linear feature (e.g., CSD 5, 6), producing a sinuous or zig-zag pattern to the plateau boundary. High-resolution PV radar images of the near-equatorial latitudes(20 to 30 km resolution) further illustrate the character of the discontinuities in Aphrodite Terra (Figure 2). The main characteristics of the cross-strike discontinuities are distinct linear gradients or abrupt changes in radar brightness across linear zones from 100 to 200 km wide.

High-resolution Arecibo profiles (Figure 2), which generally parallel the topographic strike of western Aphrodite and are at high angles to the linear discontinuities (Figure 1), show that the discontinuities are characterized in detail by: 1) major consistent changes in topography across the discontinuity of several hundred meters to two kilometers, over a lateral distance of less than 200 km, 2) a narrow trough (less than 100–200 km wide and several hundred meters deep), commonly marking the location of the discontinuity, 3) narrow peaks along the edge of the trough often rising several hundred meters above the adjacent datum, and 4) a generally systematic rise or fall of topography between discontinuities (Figure 2). Comparison of detailed characteristics along the strike of linear features where they intersect two adjacent and parallel profiles (Figure 2C) shows that: 1) the central trough is a basic part of the linear feature, 2) the localized highs at the edge of the troughs are common, and 3) a common topographic trend in domains between cross-strike discontinuities is one of increasing

TABLE 1 Characteristics of Major Cross-Strike Discontinuities in Western Aphrodite Terra

| CSD | Long. | Strike | Length | PV/Altimetry | | PV/SAR | | Arecibo/Altimetry | |
|---|---|---|---|---|---|---|---|---|---|
| | (at eq.) | (N W) | (km) | (loc.) | (type) | (loc.) | (type) | (loc.) | (type) |
| 1 | 72 | 21.9 | 2500 | -9/75 | D | 4.71 | L | 3.7/71 | t |
| | | | | -11/76 | L | 7/70 | L | | |
| | | | | 2/72 | R | | | | |
| 2 | 76 | 21 9 | 2200 | -13/80 | D | -19/77 | L | 3.1/74.5 | L |
| | | | | 13/81 | L | -10/80 | L | | |
| | | | | -8/78 | R | | | | |
| | | | | 0/75 | R | | | | |
| | | | | 3/74 | R | | | | |
| 3 | 92 | 21.3 | 3200 | 3/91 | D | -5/95 | L | 2.7/91.5 | t |
| | | | | -8/95 | D | | | | |
| | | | | -10/97 | T | | | | |
| | | | | 0/92 | T | | | | |
| 4 | 97 | 21.4 | 4000 | 1/97 | D | -2/100 | L | 2.3/95.5 | T |
| | | | | -6/99 | L | 5/96 | L | | |
| | | | | 15/90 | L | | | | |
| | | | | 21/106 | T | | | | |
| | | | | 5/95 | T | | | | |
| 5 | 105 | 20.4 | 2500 | 5/103 | D | -12/100 | L | 2/104 | t |
| | | | | -15/110 | L | -3/106 | L | | |
| | | | | 3/104 | L | | | | |
| | | | | -6/107 | L | | | | |
| | | | | -20/113 | L | | | | |
| | | | | -3/105 | T | | | | |
| | | | | -6/107 | T | | | | |
| 6 | 126 | 20.4 | 2500 | 5/124 | D | 0/126 | L | 1.9/125 | T |
| | | | | -19/132 | L | | | -3/127 | T |
| | | | | -9/128 | R | | | | |
| | | | | -13/129 | T | | | | |
| | | | | -3/127 | T | | | | |
| 7 | 134 | 20.7 | 2500 | 0/134 | D | -5/138 | L | 1 5/134 5 | t |
| | | | | 3/134 | L | | | -3.1/137.5 | t |
| | | | | 15/130 | L | | | | |
| | | | | -9/139 | R | | | | |
| | | | | -5/138 | R | | | | |

Note: Loc = location; D = displaced contour line; L = linear slope or linear boundary, T = trough >1 km deep; t = trough <1 km deep, R = truncated trend or truncated ridge

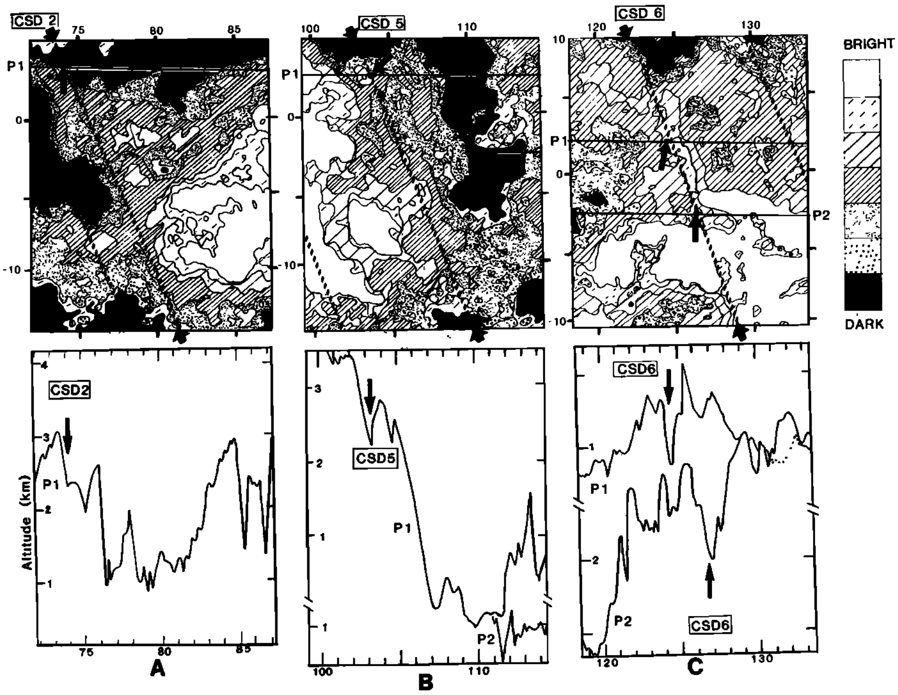

Figure 2. PV SAR images and Arecibo altimetry profiles across three discontinuities. Only those discontinuities detected in three different data sources are mapped. Blunt arrows on margins of SAR images indicate trend of CSD. Long arrows in SAR images and on Arecibo profiles indicate the intersection of a CSD and an altimetry track. Note trough-like aspect of CSD 6.

elevation from west to east and abrupt decreases at the discontinuity at the eastern edge of the domain. A summary of the distribution and basic characteristics of the major linear cross-strike discontinuities in Arecibo profiles is presented in Table 1.

Possible origins for large-scale linear cross-strike discontinuities include: 1) fractures or joint patterns representing a background structure or planetary-scale grid, 2) extensional fault troughs or graben, 3) radial structure associated with impact basins, 4) fracture zones analogous to those found in terrestrial ocean basins, and 5) strike-slip faults or shear zones. Large-scale topographic change across the discontinuities, the presence of central troughs, and the apparent lateral offset implied by the orthogonal nature of the plateau boundary where the discontinuities are encountered, all imply lateral and/or vertical movement along the linear zone, and thus seem to argue against a simple fracture or joint origin. The apparent linear offset of topography also argues against a simple extensional model for the discontinuities. The extreme parallelism of the discontinuities over several thousand kilometers argues against an origin related to radial structure surrounding an impact basin.

Many of the characteristics of cross-strike discontinuities are found in both regional strike-slip faults or shear zones, and oceanic fracture zones on Earth. The San Andreas (U.S.), Great Glen (U.K.), Anatolian (Turkey), and Alpine (New Zealand) fault systems are all predominantly strike-slip, and are up to about 200 km wide and several hundred to over 1000 km long. They frequently offset topographic features and have distinctive trough-like topography within the linear zone of deformation. Although zones of parallel strike-slip faults are known (Garfunkel and Ron, 1985), systematically parallel strike-slip faults of such great length, and separated by several hundreds of kilometers, have not been documented in the terrestrial record.

Oceanic fracture zones are characterized by long (100's to over 2000 km) linear to arcuate zones less than 100 km wide and often separating broad elevations of ocean floor in a step-down fashion. Topographic differences across the fracture zones are most distinctive in the central areas near the rises, and are less distinctive in the distal regions of the surrounding lows. Fracture zones die out distally, or terminate at the edges of continents, and commonly occur as a series of parallel structures separated by tens to hundreds of kilometers. Associated with the zones are linear troughs and small-scale rim topography (Collette, 1986; Macdonald et al., 1986). Topographic features such as rise crests and smaller linear ridges show apparent offset along the strike of the fracture zone.

On the basis of these comparisons, the cross-strike discontinuities in Aphrodite appear to share more characteristics with terrestrial oceanic fracture zones, than with strike-slip fault zones. However, insufficient data exist at present to confidently distinguish between these two possibilities.

## Conclusions

A series of parallel linear cross-strike structural discontinuities that subdivide terrain into large rectangular segments have been identified in the western Aphrodite highlands of Venus. These features are up to

2000–4000 km in length, 100–200 km in width, and show evidence of apparent offset of Aphrodite Terra. They are interpreted to be of tectonic origin, and they share many of the characteristics of terrestrial oceanic fracture zones (particularly length and parallelism), although an origin as strike–slip fault zones cannot be ruled out on the basis of presently available data. In either case, they represent evidence for large–scale lateral tectonic movement on Venus. If the linear discontinuities represent strike–slip movement, then there is evidence for a series of generally right–lateral en echelon offsets, each of several hundred kilometers. If the discontinuities represent fracture zones, and associated transform faults and crustal spreading, then the general distribution and characteristics (Figure 1) suggest terrestrial–like divergent plate boundary processes, and large–scale lateral movement. Either case differs from most present models for the tectonic style of Venus in which: 1) heat transfer processes are dominated by broad vertical movement linked to thermal anomalies and "hot spot" heat loss (Morgan and Phillips, 1983), 2) there are areal, belt, and circular deformational styles on Venus but no evidence for plate recycling processes (Basilevsky et al., 1986), and 3) divergence and crustal spreading are precluded by topographic and lithospheric stability considerations (Kaula and Phillips, 1981; Anderson, 1981). Further documentation of the nature of these areally significant structural features may provide additional evidence to distinguish their detailed origin and tectonic style.

*Acknowledgements.* Supported by NASA Grant NGR–40–002–088. The National Astronomy and Ionosphere Center is operated by Cornell University under contract with the National Science Foundation and with support from NASA.

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(Received February 24, 1987;
accepted March 17, 1987.)