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A Morphologic Study of Venus Ridge Belts: S.L. Frank and J.W. Head, Department of Geological Sciences, Brown University, Providence, RI, 02912

Ridge belts, first identified in the Venera 15/16 images [1,2] are distinguished as linear regions of concentrated, parallel to anastomosing ridges. They are tens to several hundreds of km wide, hundreds to over one thousand km long, and composed of individual ridges 5-20 km wide and up to 200 km long. The ridges appear symmetrical in the radar images and are either directly adjacent to each other or separated by mottled plains. Cross-strike lineaments, visible as dark or bright lines, are common within the ridge belts, and some truncate individual ridges. In places the ridge belt may be offset by these lineaments, but such offset is rarely consistent across the ridge belt. The angle between the lineaments and the ridge belts is usually 30° to 90°. Localized plains units from several km to 100's of km wide are bounded by arcuate ridges, forming elliptical-shaped plains regions within the ridge belts. Between 0°E and 90°E in the Tessera-Ridge Belt assemblage [3], the ridge belts form an orthogonal pattern surrounding large blocks of tesserae, while in the Plains-Ridge Belt assemblage, between 150°E and 250°E , the belts trend predominantly N-S, occasionally coalescing and dividing to form a fan pattern [3,4]. Ridge belts most often occur at elevations within 2 km of the planetary mean. Some ridge belts lie on broad highs up to 1.5 km high, many lie on topographic slopes, and a few occur in topographic depressions. The origin of these ridge belts is a matter of controversy, with both compressional origins [2,5] and extensional origins [6] proposed. Once the mode of formation of these ridge belts is understood, their distribution and orientation will help to constrain the homogeneity and orientation of the stresses over the period of ridge belt formation.

The look direction for the Venera system was to the west, so ridges appear as pairs of bright and dark lineaments, with the bright line to the east of the dark. A major difficulty with radar imagery, especially at small incidence angles, is foreshortening, in which the radar-facing slope is shortened and the away-facing slope lengthened [7]. This effect reaches a maximum when the look angle (in this case 10°) equals the radar-facing slope. The apparent symmetry of the ridges thus implies either that all the ridges are asymmetrical, with shallow radar-facing slopes, or that all slopes are considerably shallower than 10°. Since it is unlikely that all ridges in an area of tens of millions of square kilometers are asymmetrical in the same direction, we conclude that the ridges have gentle slopes and are mostly symmetrical.

Above, the term 'ridge' has been used in a general sense to refer to a linear rise. In the following discussion, the use of this term is restricted to rises which have a sharp transition from bright to dark at the crest, and are 5-15 km wide. These ridges are either continuous or discontinuous. The continuous ridges are over 30 km long and form coherent ridge belts, while the discontinuous ridges are less than 30 km long and do not form a coherent ridge belt. We have divided the continuous ridges into three components [8]. (1) *Anastomosing ridges*, in which the individual ridges are sinuous and often meet and cross at small angles, are the most common component. The ridges in this component are often separated by 5-20 km of plains, but sometimes form adjacent to one another, with no plains visible in between. (2) The *parallel ridge* component also consists of well-defined ridges, often with plains separating the individual ridges, but the the ridges are more linear and rarely intersect one another. (3) *Parallel ridged plains* are composed of indistinct ridges, some of which do not have a distinctive bright-dark pattern. The distance between adjacent ridges is usually greater than 10 km. *Broad arches* are a fourth component also present within the ridge belts. They are more than 10 km wide, and there is no sharp bright-dark boundary at the crest, but rather a gradual transition from light to dark. They are similar to wrinkle ridges on the moon, Mars, and Earth, with their broadly curving crests, sinuosity and shallow slopes [9,10]. There are several possible origins for each of these components, ranging from extension and magmatism to compressional folding and faulting. We are assessing these origins by comparing component morphology with compressional and extensional features on the other terrestrial planets.

Much discussion has surrounded the origin of the ridge belts [5,6]. Evidence for compressional origin discussed by Frank & Head [5] is as follows: (1) the broad morphology of the arches is similar to the maria wrinkle ridges, which are interpreted to be formed by compressional and vertical movements [i.e. 9,10,11]; (2) the more detailed morphology of ridges within the belts is similar to the mountains surrounding Lakshmi Planum, which all workers have interpreted as compressional [12]; (3) ridge belts and the ridges within them are generally sinuous, as are compressional features on the Moon and Mars, while extensional features on the Moon and Mars tend to be more linear or broadly arcuate (this is consistent with Anderson's [13] observation that low-angle faults (i.e. thrust faults) tend to have more sinuous traces than vertical strike-slip faults); (4) lineaments that cut across ridge belts and adjacent plains often form a conjugate set, trending 60° to the ridge belts, and where there is evidence of some strike-slip motion it is often in a direction consistent with compression and shortening across the ridge belt (under extensional stresses, one would expect either a conjugate set of faults at 30° to the ridge belts, or transform-type faults near 90° to the ridge trend); (5) the curvature of ridges around the elliptical plains regions resembles deformation of less competent material around more rigid bodies. In this case the elliptical plains regions are interpreted as less deformed or undeformed blocks. In addition, in places the components and topography show an asymmetric pattern across the ridge belts, as expected in regions of low-angle thrust faults.

Sukhanov and Pronin [6] have proposed that ridge belts are of extensional origin on the basis of the following evidence: (1) some ridge belts are symmetrical about a central line, suggesting spreading within the belt; (2) volcanic structures are visible along ridge belts; (3) where ridge belts cross other structures, these structures are not visible within the ridge belts; and (4) ridges within belts sometimes turn into graben. These aspects, however, are not all unique indicators of extension. The graben, for example, are often oriented at an angle to the overall trend of the ridge belts, and could represent pull-apart basins which have developed along strike-slip faults. Furthermore, volcanic activity is not limited to regions of extension, but is common in compressional environments (e.g. island arcs). The symmetrical pattern, however, is a strong indicator of extensional origin, and the apparent symmetry of the ridges argues against large-scale thrust faults, although the sinuosity of the ridges supports low-angle faults.

The nature of deformation within the ridge belts is complex and not fully understood at present. Some belts show distinct signs of compression, while others have symmetrical patterns expected in extensional environments. Thus the ridge belts may have formed by more than one style of deformation; some may be extensional, while others are compressional. We are now systematically mapping of all the ridge belts, concentrating on symmetry relationships, in order to determine the locations of compressional and extensional deformation within the ridge belts.

References: [1] Barsukov, *et al* (1986) *JGR 91*, D378-D398. [2] Basilevsky, *et al* (1986) *JGR 91*, D399-D411. [3] Head (1989) *LPSC XX* 392-393. [4] Frank & Head (1989) *LPSC XX*, 311-312. [5] Frank & Head (1988) *LPSC XIX*, 350-351. [6] Sukhanov & Pronin (1989) *Proc. LPSC XIX* (in press). [7] Sabins (1978) *Remote Sensing--Principles and Interpretation;* MacDonald (1980) in *Remote Sensing in Geology*, Siegal & Gillespie, eds. [8] Frank & Head (1988) *LPSC XIX*, 348-349. [9] Watters (1988) *JGR 93*, 10,236-10,254. [10] Plescia & Golombek (1986) *GSA Bull 97*, 1289-1299. [11] Lucchitta (1976) *Proc. LPSC VII*, 2761-2782; Sharpton & Head (1986) *Proc. LPSC XVIII*, 307-317. [12] Campbell, et al (1983) *Science 221*, 644-647; Crumpler & Head (1986) *Geology 14*, 1031-1034; VorderBruegge & Head (1986) *LPSC XVII*, 917-918; Pronin (1986) *Geotektonika 4*, 24-41 (in Russian). [13] Anderson (1942) *The Dynamics of Folding and Dyke Formation, with Application to Britain*, Oliver and Boyd, Edinburgh.