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TECTONIC EVOLUTION OF LAVINIA PLANITIA, VENUS. Steven W. Squyres, Cornell University, Sharon L. Frank, Brown University, George E. McGill, University of Massachusetts, Sean C. Solomon, Massachusetts Institute of Technology

High-resolution radar images from the Magellan spacecraft have revealed the first details of the morphology of the Lavinia Planitia region of Venus. Lavinia is a broad lowland over 2000 km across, centered at about 45° S latitude, 345° E longitude. The geology of Lavinia is discussed in detail in another abstract in this volume [1]. In this abstract, we discuss the tectonic evolution of Lavinia, and its possible relationship to processes operating in the planet's interior. Our discussion is restricted to the area observed in Magellan image mosaic C1-MIDR.45S350, which covers the region from 37.3 to 52.6° S latitude and from about 340 to 0° E longitude.

One of the most interesting characteristics of Lavinia is that the entire region possesses a regional tectonic framework of striking regularity. This framework is exhibited by a variety of the region's structural features, but is shown most clearly by the small ridges and grooves that are common on the volcanic plains separating the major belts of deformation. Across most of Lavinia, intersecting patterns of small sinuous ridges and long narrow grooves are common. The ridges are interpreted as compressional features, and the grooves as extensional. In nearly all cases where they occur together, the ridges lie orthogonal to the grooves, indicating a lithospheric stress pattern in which the most compressive stress was perpendicular to the axes of the ridges, and the least compressive stress was parallel to them. Considering the thin lithosphere that is expected on Venus, the regularity of this regional tectonic framework across such broad areas is remarkable. In the western part of the region, the inferred orientation of the most compressive stress is NW-SE to WNW-ESE. In the central and northeastern portions, it transitions gradually to E-W, and in the east-central portion to ENE-WSW. Only in the southeastern portion of the region is the inferred stress pattern significantly less regular. The origin of the stresses responsible for this regional pattern is not known, but similar patterns are seen on the plains in a number of other regions of the planet [2].

Lavinia Planitia is also transected by a complex pattern of belts of intense tectonic deformation [1,2], known as ridge belts. They are broad, curvilinear features that can exceed 100 km in width and 1000 km in length. Topographically, they consistently lie higher than the plains that bound them, with typical elevations above the plains of several hundred meters. This clear topographic expression suggests that the belts are the consequence of crustal shortening and thickening across the belt.

Despite the gross topographic similarity of all of the ridge belts in Lavinia, they exhibit two rather distinct styles of near-surface deformation [2]. Both are described in more detail in [1]. One type is composed of sets of broad, arch-like ridges rising above the surrounding plains. They are typically sinuous, and they tend to bifurcate and merge along strike, producing a complex anastomosing pattern. Both their morphology and their orientation parallel to the axes of the belts within which they lie lead us to conclude that they are folds. Some of the ridges are asymmetric and/or possess narrow, rugged, sinuous secondary ridges along their crests, giving an appearance very similar to that of lunar mare or "wrinkle" ridges. These characteristics may indicate that formation of some of the ridges also involves thrust faulting.

In the other type of belt, on the other hand, obvious fold-like ridges are rare to absent in the radar images. Instead, the dominant structural features observed are linear to arcuate faults and fractures, some paired closely to form narrow graben. In some such belts, a larger scale of fault spacing is also evident. Faults in these belts are concentrated into bands of intense deformation that are separated by bands of little or no apparent deformation. The typical spacing between individual deformed bands is 20-30 km, consistent with deformation of the entire thickness of a strong upper crustal layer [3]. Detailed correlation of radar images with Magellan altimetry shows that, within such belts, the areas of most intense fracturing are also the areas that are most elevated. This characteristic, the morphology of the faulting, and the small widths of the observed graben lead us to conclude that much of the deformation in the ridge belts of this sort involves flexure and extensional failure of a thin, brittle surface layer across the crests of uplifts that are caused by crustal shortening and thickening.

Both types of ridge belts show evidence for small amounts of shear distributed across the belts [2]. In the ones dominated by faulting, this is most clearly shown by instances where graben bend sharply to produce rhombohedrally-shaped downdropped blocks. In the ones dominated by folding, the best evidence for distributed shear comes from deflection of older tectonic lineaments as they cross the belts.

Formation of all the belts was not contemporaneous. Lava sheets on the plains serve as stratigraphic markers in Lavinia, and lavas are present that partially or largely bury old belts and that are in turn deformed by the formation of later ones. Belt formation apparently took place over a significant period, with volcanism occurring intermittently throughout that period.

If both types of belts are the consequence of crustal shortening, why are there two such distinct styles of near-surface deformation? The answer appears to be related to the orientation of each belt with respect to Lavinia's regional tectonic framework. With very few exceptions, the belts that lie perpendicular to the regional axis of lithospheric compression are dominated by folding, and those that lie perpendicular to the regional extensional axis are dominated by faulting. Even more telling are the characteristics of belts that change substantially in orientation along their length. In these belts, where the belt axis changes from perpendicular to the most compressive lithospheric stress direction to parallel to it, there is a clear change in the structural character of the belt from domination by folds to domination by faults.

Despite the regularity of the regional tectonic framework across the Lavinia region, the belts within it display a full range of orientations, apparently unrelated to this framework. It is only the character of the near-surface deformation in the belts that appears to be influenced by the framework, not the orientations of the belts themselves. The process responsible for ridge belt formation seems, then, to be largely independent of whatever produced the regional stress pattern. Similar behavior is seen in many coronae on Venus, where fracturing in a corona's annulus is stronly influenced by a regional lithospheric stress pattern that appears to be independent of the process responsible for the corona's formation [4].

What is responsible for the crustal shortening and thickening involved in ridge belt formation, and for the concentration of this thickening into curvilinear belts? Several possibilities exist. It has been suggested that deformation with characteristic spacings of 10-30 km on Venus is a result of compressional instability in a strong, near-surface crustal layer, and that deformation spaced hundreds of km apart may reflect a similar instability in a strong layer in the upper mantle [3]. In this case, the ridge belts themselves may reflect deformation controlled by the strength properties of the upper mantle, while the observed faulting and folding in each belt would reflect the response of the upper crust. The independence of belt orientations from the regional tectonic framework would be attributed to a mechanical decoupling of the strong upper crust from the strong upper mantle. A possible difficulty with this hypothesis is that the spacings and orientations of Lavinia's belts are far from regular. Another possibility is that relatively small-scale mantle convection cells exert an influence on belt formation. Sheet-like convective downwellings may be common in the venusian mantle, and one would expect belt-shaped crustal thickening and uplift to take place above a linear convergence of flow. In this case, individual belts might have formed by crustal thickening above such downwellings, with the upper crust deforming in response to both the thickening and the regional stress pattern. Activity in the downwellings for which evidence is preserved is unlikely to have been concurrent, consistent with the inferred spread in belt ages. Again, the orientation of the belts would be independent of the regional tectonic framework. The difficulty with this hypothesis is that most mantle convection models for Venus predict that the scale of convection cells should be substantially larger than several hundred km. However, our emerging understanding of coronae on Venus suggests that convective upwellings with dimensions far smaller than those predicted by the same models are very common [5]. In fact, the convective scales inferred to be involved in corona formation are effectively the same as those that would be required for ridge belts.

There are other regions on Venus where ridge belts are common. As the Magellan mapping mission continues, examination of these regions should shed further light on the process of ridge belt formation and on its relationship to processes in Venus' interior. Expanded coverage will also allow mapping on a global scale of the as-yet poorly understood regional tectonic framework seen in areas like Lavinia.

References

[1] Frank, S.L., *et al.*, *LPSC XXII*, 407 (1991). [2] Solomon, S.C., *et al.*, *Science*, in press. [3] Zuber, M.T., *J. Geophys. Res.* **92**, E541 (1987). [4] Squyres, S.W., *et al.*, this volume. [5] Stofan, E.R., *et al.*, *LPSC XXII*, 1335 (1991).