KINEMATICS OF A LINEAR DEFORMATION BELT; THE EVOLUTION OF PANDROSOS DORSA, VENUS.

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Whether venusian crustal history is directional [1,2] or non-directional [3,4] continues to be a controversial issue. The directional model implies that certain processes and tectonic landform assemblages are associated exclusively, or nearly so, with specific intervals of relative time during the recorded history of the crust, whereas the non-directional model implies that major processes and tectonic landform assemblages are distributed in time and space. These conflicting models can be tested by very detailed stratigraphic and kinematic analysis of selected areas or features on Venus, and we are carrying out such studies at the present time. These studies are based primarily on maximum resolution Magellan images and mosaics (75m/pxl), but also make use of Magellan altimetry insofar as this much coarser data set contributes to determining the relative ages of structures and material units.

This paper reports results of a detailed analysis of Pandrosos Dorsa, a large and complex linear deformation belt in Vinmara Planitia. Pandrosos Dorsa is part of the "ridge belt plains-fan assemblage" defined from Venera data [5,6]. More recently, Magellan data have demonstrated that Pandrosos Dorsa consists of both contractional and extensional structures that are in many places about parallel to each other [7], in contrast to the deformation belts of Lavinia Planitia where the ridge and fracture belts are separate and trending at high angles to each other [8,9]. The proponents of the directional model for venusian crustal evolution argue that the materials and structures of these deformation belts are older than the widespread regional plains on a global scale [e.g., 2,10].

Most of Pandrosos Dorsa trends N-S and is centered on longitude 205^0 E. The south end of the belt is at ~52^0 N, the north end at ~67^0 N. At ~58^0 N the belt splits into a narrow northern continuation of Pandrosos Dorsa to the east and Anpao Dorsa to the west. The total length of Pandrosos Dorsa is 2190 km, and its width varies from 60 km in the north to 230 km in the south. This study is focused primarily on southern Pandrosos Dorsa, south of 58^0 N. The belt includes long, narrow ridges ranging in length from a few km to as much as 150 km, and in apparent width from 2 to 10 km. Most of these ridges occur in assemblages that are oriented about parallel to the overall trend of the belt, and which generally are separated from each other by zones of intense development of extensional structures, many of which are grabens. The ridge assemblages range in length from 150 to 1000 km, and in width from 25 to 75 km. Some extensional structures occur within these ridge assemblages, but they are much less abundant within the ridge assemblages than they are in those parts of Pandrosos Dorsa that are between the ridge assemblages. Because of the relatively low radar incidence angle at this latitude (~20-23^0) the ridge crests are significantly displaced westward, towards the radar; the higher ridges have very narrow radar-bright western flanks, and very wide radar-dark eastern flanks. Locally it is difficult to decide if this pattern of radar brightness represents foreshortening of a ridge, or simply relatively smooth material adjacent to a much lower ridge or to a zone of bright fractures. Although this introduces some local ambiguity into the mapping, the overall pattern of ridge assemblages separated by zones with many fractures and few ridges is not affected.

The belt zones between the ridge assemblages commonly include two or more sets of bright lineaments, some of which clearly are grabens but most of which are too narrow to resolve their geometry. Because sets of these narrow lineaments generally include some grabens, it is inferred that the parallel narrow lineaments are extensional fractures. Most lineaments trend approximately parallel to the overall trend of the belt and to the trends of the ridges and ridge assemblages. Belt-parallel lineaments vary widely in length, ranging up to 50 km long. They also are very abundant; on the order of one to several km apart. Additional sets of fractures and grabens are oriented at high angles to the belt trend; these sets are local, very diverse in trend and density, and include lineaments that commonly are only a few km long. Fractures generally terminate near ridges, and it is very uncommon for fracture sets to cross ridges.

Within Pandrosos Dorsa are areas with few or no ridges or fractures. These are low areas partially filled with ponded materials that sharply truncate and thus are younger than most belt structures. Some of the materials in these ponds are continuous with the young lavas that bound the east margin of the belt, and many of the areas entirely enclosed within the belt are filled with material that has radar backscatter identical to the flows east of the belt. There is no obvious source for these putative intra-belt volcanics. A few of the ponds contain abundant small shields and domes, suggesting that the ponded material in these places is lava derived from the small shields and domes. At the south end of Pandrosos Dorsa is a patch of tessera terrain that is incorporated into the belt. Tessera structures terminate against belt material, but the tessera also has been further deformed during belt formation. At various locations within and adjacent to Pandrosos Dorsa are relative large grabens (up to 5 km wide) that cut the oldest regional plains unit and almost all belt structures. These grabens have no consistent trend, and individual grabens commonly have right-angle bends or branches.

Southern Pandrosos Dorsa is bounded on the west by two of the three defined and mapped regional plains material units [7]. Along much of the length of southern Pandrosos Dorsa the oldest and radar darkest regional plains unit clearly embays the belt, indicating that at least along its western margin the structures and materials of the belt are older than regional plains. The eastern margin of Pandrosos Dorsa is bounded by large flow fields from its southern end northward to ~58^0 N. These flows clearly truncate extensional structures in the belt, and appear to embay belt ridges as well. However, some belt extensional structures cut the flows, and because these flow fields are superposed on regional plains, this relationship demonstrates that some of the belt extensional structures are younger than regional plains. It is not clear if some of the belt ridges also are younger. Although the relationships suggest that the flows are embaying the ridges, a ridge younger than the flows would result in topographic effects on backscatter that would be superposed on the typical flow backscatter, effectively masking any evidence that flow materials have been affected by younger arching.

At ~58^0 N the western margin of the belt steps eastward, providing a transverse contact between regional plains and the belt rather than the usual belt-parallel contact. At this step there is a clear contact between regional plains and the material making up the belt where this belt material is less deformed into ridges and fractures than is generally the case. The structures that are present on the belt material are sharply truncated at the contact with regional plains. At some places, however, the material between the ridge crests along the western belt margin has a low backscatter that appears similar to the low backscatter of the immediately adjacent regional plains unit, and to the low backscatter of the eastern slopes of the higher ridges within the belt. This observation permits three explanations: 1) The regional plains material has flooded low areas along the margin of the belt, 2) the low backscatter between ridge crests represents the eastern flanks of the ridges which commonly have low backscatter elsewhere in the belt, or 3) some ridges along the margins of the belt are younger than at least the oldest of the regional plains units. Although ambiguity remains, the third possibility is probably the least likely of the three.

Rosenberg [7] noted that those portions of Pandrosos Dorsa most intensely deformed by grabens and fractures stood at higher elevations than most of the ridge assemblages. She inferred from this that fractures and grabens formed first by extension normal to the belt trend, followed by partial burial of the lower parts of the belt during which early fractures in the low areas were covered. Then the entire belt was subject to transverse contraction forming the ridges. The more detailed analysis carried out for this study does not support this sequence, in part because there is significant overlap of ridged and fractured terrains within the belt. Furthermore, the tendency for fracture sets to terminate against ridge flanks argues for the ridges serving as barriers to fracture propagation. Finally, relative age relationships discussed here generally indicate that ridges are all older than regional plains whereas fractures and grabens are partly older and partly younger than regional plains. Kinematics and mechanics of the intricate patterns of extensional structures within the belt remain to be deciphered. Thus Pandrosos Dorsa has a complex deformational history, with transverse contraction and ridge formation almost certainly confined to a time prior to emplacement of regional plains, but transverse extension with fracture and graben formation extending from before regional plains emplacement to after most or all of these plains were in place. In summary, the evidence cited indicates that almost all deformation within the belt occurred prior to the emplacement of the surrounding regional plains.

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