EVOLUTION OF TECTONICS ON VENUS. M. A. Ivanov[1,2] and J. W. Head[2], [1]Vernadsky Institute, RAS, Russia, Moscow, mikhail_ivanov@brown.edu, [2]Department of Geological Sciences, Brown University, Providence, RI 02912 USA.

Introduction: Large-scale tectonic deformation of planetary surfaces is often related to mantle circulation patterns and represents one of the manifestations of the process of global internal heat loss [e.g., 1]. The surface of Venus displays several tectonized terrains in which the morphologic characteristics of the original materials are almost completely erased by superposed tectonic structures whose dimensions (100s to 1000s of km) suggest formation related to the mantle convection. The characteristics of these tectonized terrains are in contrast to volcanic units in which tectonic structures are less significant or absent and thus do not hide the volcanic character of the units. Here we describe the temporal distribution of tectonized terrains, their stratigraphic relationships with volcanic units, and how these outline the major episodes in the geological evolution of Venus.

Major tectonized units: The following five tectonized units are the most important on Venus and make up ~20% of its surface [2]. (1) Tessera (t, 7.3% of the surface of Venus, Fig. 1) displays intersecting sets of contractional and extensional structures [e.g., 3]. High-standing occurrences of tessera (Fig. 1) vary in size from a few tens of kilometers up to a few thousands of kilometers [4]. (2) Densely lineated plains (pdl, 1.6%, Fig. 1) are dissected by numerous densely packed parallel fractures. Occurrences of pdl are slightly elevated relative to the surroundings. (3) Ridged plains/Ridge belts (pr/rb, 2.4% Fig. 1) are deformed by broad and long ridges that often form elevated belts. In this paper, mountain belts around Lakshmi Planum are included into the pr/rb unit as a topographically specific facies of ridge belts. (4) Groove belts (gb, 8.1%, Fig. 1) are swarms of extensional structures that completely obscure the characteristics of underlying materials at the scale of the mapping. (5) Rift zones (rz, 5.0%, Fig. 1) consist of numerous parallel fissures and troughs that usually completely erase the morphology of underlying terrains. On average, structures of rz are broader, longer, and less densely packed than structures of gb. Rift zones preferentially occur within the dome-shaped rises. The hypsograms of all tectonized units are shifted toward higher elevations (Fig. 1).

Age relationships with volcanic units: Clear relationships of relative age are often seen among the tectonic and volcanic units at the global scale [2]. Structures of pdl and pr/rb usually cut tessera but in some places they appear to be incorporated into the tessera structural pattern. Graben of gb cut occurrences of tessera, pdl, and pr/rb. Vast expanses of mildly deformed plains units (shield- and regional plains) embay all occurrences of t, pdl, and pr/rb and the majority of groove belts. Structures of rift zones cut the vast plains and are contemporaneous with the younger lobate plains.

Discussion: The majority of tectonized terrains (t through gb) are the products of tectonic resurfacing and are embayed by the vast volcanic plains and, thus, are older. There are no units with either mildly- or non-tectonized surfaces that interleave the tectonic terrains, which would be expected if the tectonic resurfacing operated only during specific phases in discrete regions. The major tectonized terrains thus define a tectonically dominated regime of resurfacing that occurred at the global-scale near the beginning of the observable geological history of Venus.

This ancient tectonic regime began with formation of the oldest unit, tessera. Both contractional (ridges) and extensional (graben) structures form tessera and the relative age relationships between thse strucutres are usually ambiguous [5,6]. In some areas, however, volcanic plains embay the tessera ridges and are cut by the graben [7]. This provides robust evidence for the relatively old age of the ridges and suggests that formation of tessera was due to large-scale compression that resulted in regional thickening of the crust [8,9].

Tectonic units such as pdl and pr usually occur away from tesserae, preventing consistent determination of their exact stratigraphy. In places where t, pdl, and p are in contact, two situations occur: (1) more often, materials of pdl and pr embay tessera and their tectonic structures cut tessera [10]; (2) in a few places, pdl and/or pr are additionally deformed and their surfaces resemble that of tessera (the tessera transitional terrains, ttt, [11]). These relationships suggest that formation of tessera was mostly completed prior to emplacement and deformation of pdl and pr. In some areas, formation of tessera continued and affected surrounding units but it did not last long because the areas of ttt are usually small and occur sporadically.

Ridged plains often represent pronounced belts of contractional structures. This suggests that the belts formed under compressional stresses applied within relatively narrow but very extensive zones [12,13]. These characteristics of rb resemble those of terrestrial thrust-and-fold belts that occur over large thrust faults and may be related to plate tectonics. If ridge belts formed due to shortening of crustal materials, it may indicate lateral movements of lithospheric blocks on Venus. The relatively low relief of ridge belts (hundred meters high [14]) suggests that these movements and related contraction were rather limited and may correspond to immature (arrested) stages of plate tectonics. The distinctive exceptions to this are the mountain belts [15]. The belts are high and their relationships with the surroundings provide evidence for large-scale collision and underthrusting [16,17]. The mountain belts exist only around Lakshmi Planum, which suggests that even if the belts formed by the processes akin to subduction, they were fairly restricted on Venus.

Groove belts are the youngest features of the ancient tectonic regime. In contrast to ridge belts, they are abundant and pervasive (Fig. 1), and mark zones of extension. The contractional structures/zones that are spatially and stratigraphically complementary to groove belts are absent. Instead, branches of groove belts compose the tectonic components of many coronae [18] suggesting that these features are genetically related (e.g., mutual development of mantle diapirs and zones of extension [e.g., 19]) and that coronae may have punctuated the final stages of the ancient tectonic regime.

This regime was followed by emplacement of the vast volcanic plains, such as shield and regional plains, the surfaces of which are extensively deformed by the global network of wrinkle ridges [20]. Emplacement of the plains has defined the second, volcanically dominated regime [21], representing a time when surface tectonic deformation related to the mantle convection waned.

Rift zones are the stratigraphically youngest manifestations of regional-scale tectonic deformation on Venus. Rifts are spatially and temporarily associated with the youngest lava flows and often cut the crest areas of large, but isolated, dome-shaped rises. Structures of rift zones always cut the surface of the vast plains, which means that rifts are separated in time from the ancient tectonic regime, post-date the regional plains, and represent a new phase of tectonism that was contemporaneous with the late volcanism of lobate plains. Rift zones and lobate plains define the third, volcano-tectonic, regime of resurfacing that was related to late stages of evolution of the dome-shaped rises.

Summary: (1) The observable geologic history of Venus appears to consist of three contrasting regimes of resurfacing. The majority of the tectonized terrains that may be related to regional/global mantle convection patterns define the first, tectonically dominated, regime. During this time, large regions of thickened crust (tesserae) were formed; a limited contraction and possible underthrusting along specific zones resulted in formation of ridge and mountain belts. The later phases of the ancient tectonic regime were manifested by the mutual development of groove belts and many coronae. All tectonized terrains of the first regime represent local- to regional topographic highs in the background topography (Fig. 1). (2) During the second, volcanically dominated regime, the vast plains preferentially covered the surface in regional lows. This suggests that the principal topographic features of Venus (i.e., regional plateau-like highlands and broad lowlands) were formed by the end of the ancient, tectonic regime. (3) The density of craters on regional plains suggests that the first two regimes (tectonic and volcanic) operated during about the first one-third of the observable history. (4) Contemporaneous rift zones and lobate plains define the third, volcano-tectonic regime. This regime dominated the last two-thirds of the observable geologic history and likely was linked to the later stages of evolution of the dome-shaped rises.

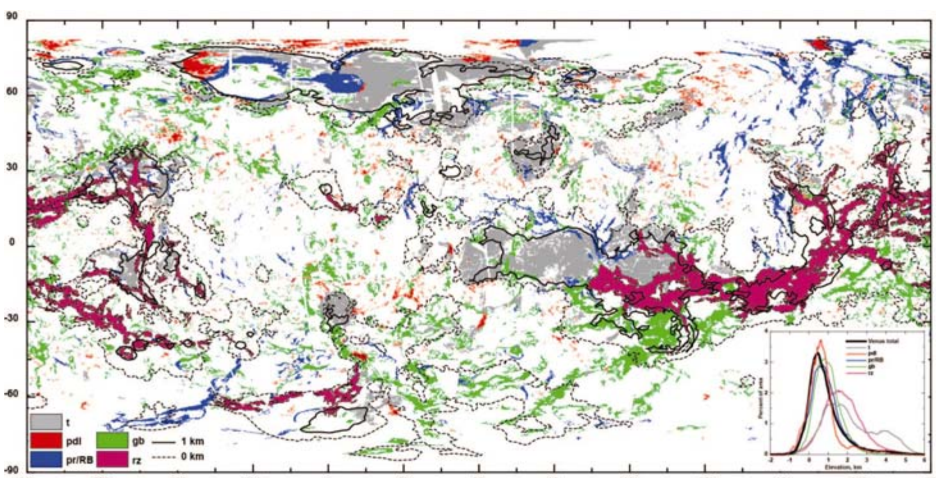

Figure 1: The geological map of Venus [2] with tectonized units highlighted.

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