STRUCTURAL ANALYSIS AND GEODYNAMIC IMPLICATIONS OF TESSERA TERRAIN, VENUS; V.L. Hansen and J.J. Willis; Dept. Geol. Sci. SMU, Dallas TX 75275

Summary. Understanding processes of tessera formation is fundamental to Venus tectonic and geodynamic models. We examined tessera terrain in Ishtar Terra, crustal plateaus, and as inliers within the plains using high-resolution Magellan SAR imagery. We describe several major types of tesserae—each found in specific geologic or geomorphic regions. *Fold* and *S-C tessera terrain* are found only in Ishtar Terra; *lava flow* and *basin-and-dome terrains* reside within the interior of crustal plateaus, whereas *folded ribbon terrain* and *extended folded terrain* comprise margins of crustal plateaus; and *star terrain* lies within central Phoebe. Inliers are divisible into *fracture-dominated and graben-dominated tesserae*, which may represent ancient flooded coronae-chasmata and crustal plateaus, respectively. Thus tesserae might form in several tectonic environments, including as a result of (1) subsurface flow in Ishtar Terra, (2) as sequences of surface-layer extension and contraction in crustal plateaus, (3) as highly-extended, previously-deformed crustal plateaus which have deflated or sunken, and become flooded and thus preserved as large plains inliers, and (4) as densely-fractured surface layers—fractured as a result of corona and chasma formation—which have since sunken and become flooded, and thus preserved as isolated, scattered, highly-fractured inliers. If these models of formation are correct, tesserae would not form a global onion skin; they would not represent a globally synchronous unit; they would not record a single period of deformation; and it would not infer a single mechanism for tesserae formation.

Introduction. Tessera terrain, originally termed parquet terrain, is characterized by at least two intersecting sets of structural elements, high relief compared to the surrounding volcanic plains, and unusually high surface roughness at cm- to m-scale [1-6]. Tesserae constitute about 8-10% of the Venusian surface [e.g.,7-8], and occur as a dominant tectonic terrain of crustal plateaus and Ishtar Terra and as small islands, or inliers, primarily within the plains. Additional tesserae are almost undoubtedly present but are covered by volcanic plains [e.g., 4].

When and how tesserae formed is a challenging piece to Venus' history puzzle. Prior to Magellan (and even post-Magellan) many authors considered that tesserae record complex deformation histories [e.g., 1-2, 9-13] , and that tesserae represent some of the oldest preserved crust on Venus [e.g., 14-19]. The interpretation that tesserae comprise the oldest crust on Venus has led to the implication that tesserae are of similar age globally, and can therefore be used as a global time-stratigraphic marker, and further, formed during a global phase of tesserization [e.g., 18-23]. Tesserae as a global stratigraphic unit might appeal to geologic mappers, because if this hypothesis is true, regional correlation becomes less challenging. In addition, accepting that Venus underwent an early period of global tesserization might appeal to dynamic modelers, because it begins to delineate stages of Venusian evolution; a stage of tesserization might be taken as a time of globally weak lithosphere and can be dynamically modeled [*e.g.*, 20-22]. As appealing as global synchroneity of tessera formation might be to planetary geologists and geophysicists, we must be able to prove, or at least robustly support, global synchroneity of tessera formation, not assume it.

Observations. We examined tessera terrain in Ishtar Terra, crustal plateaus, and as islands (or inliers) within the plains. We describe several major types of tesserae—each found in specific geologic or geomorphic regions [24-25]. Fold terrain, the structurally simplest of the tessera types, is found only in the Ishtar deformed belts, montes and tesserae, and in contractional ridge belts. Fold terrain records a simple structural history and likely results from stress transmitted from below [*e.g.*, 26-28]. Lava flow terrain, comprised of anastomosing and curvilinear fold ridges, displays geometries similar to folds preserved on the surface of pahoehoe lava flows—and may have formed in a manner similar to pahoehoe surfaces whereby the upper Venusian crust is displaced and deformed differentially by movement, uniform or not, of material beneath the deformed surface layer. Western Itzpapalotl Tessera, Ishtar Terra, hosts S-C terrainmarked by a regionally consistent asymmetric fabric that formed within a left-lateral non-coaxial bulk strain regime [29]. Extended fold terrain comprises fold ridges locally cut by wide lens-shaped graben within the margins of crustal plateaus and large tesserae. Folds and graben, typically coaxial, represent the same overall bulk strain regime (no rotation of principal strain axes). A smaller, less well-developed, but regionally continuous, structural fabric that locally parallels the lens-shaped graben is common throughout crustal plateaus. This fabric, referred to descriptively as "ribbon terrain" is comprised of thin long ribbon-like troughs. Ribbon terrain formed prior to fold fabrics, or basin-and-dome fabrics, and may represent an early stage of some tessera formation in which a <1 km-thick brittle surface layer fractures above a substrate which deforms in a ductile fashion—much like a stretched chocolate-covered caramel bar. Surface extension might be as much as 50-100%. Basin-and-dome terrain, preserved within the interior regions of crustal plateaus, consist of arcuate ridges and troughs. These tesserae may have formed by consecutive polyphase folding followed by late extension, or they may represent lava flow terrain that has been cut by graben, or both. Early ribbon terrain development is evident in many cases of basin-and-dome terrain. Not all tesserae result from contractional strain. Classic tesserae at central Phoebe Regio is comprised of dominantly, if not solely, of fractures and extensional graben, which locally describe a "star" pattern. Uplift and dilation of a previously fractured crust might be responsible for the formation of star terrain.

Reconnaissance survey of tessera inliers revealed that inliers are broadly divisible into fracture-dominated and graben-dominated tesserae. Fracture-dominated inliers lack folds and typically lack lens-shaped graben, and they are comprised of narrow fractures with two or more orientations. Fracture-dominated inliers are small, relative to graben-dominated inliers, which comprise the large inliers. Graben-dominated inliers are radar-bright making

structural analysis difficult in many cases. In some cases graben-dominated inliers host early contractional fabrics, such as large inliers with arcuate high-standing boundaries—some large inliers are themselves large arcs. The arcs typically host folds parallel to their trend, which are cut by graben. Large inliers also locally host basin-and-dome terrain, and early-formed ribbon terrain is present locally.

Discussion. The broad differences in the structural histories, and the geologic or geomorphic locations of the several tessera types (1) demonstrate that tesserae are not necessarily formed by complex geologic histories, (2) illustrate that not all tesserae are created equal, and (3) bring into question the treatment of tesserae as a single global map unit. If tesserae cannot be justified as a single map unit, the hypothesis that tesserae formed at the same time, or represent a globally coherent stratigraphic unit is without foundation.

Accepting that different types of tesserae form in different geologic environments we can make some preliminary proposals about tesserae. Fold and S-C terrain are found only in Ishtar Terra, and thus we will consider that their style of formation is unique, as Ishtar is unique [27-28]. The observation that lava flow and basin-and-dome terrains reside within the interior of crustal plateaus whereas folded ribbon terrain and extended folded terrain lie within the margins of crustal plateaus certainly places limits on models of crustal plateau formation. This coupled with the observation that large inliers also hosts these types of tesserae is suggestive of a model in which large tessera inliers represent old flooded crustal plateaus [e.g., 27, 30]. In contemporary crustal plateaus extended folded (±ribbon) terrain lies within the high-standing topographic margins [e.g., 12-13, 27], and thus would be the most likely portion to be preserved with "sinking" of crustal plateaus. Graben-dominated tessera inliers may represent the extensional remains of parts of ancient collapsed crustal plateaus. In contrast, small inliers marked by densely fractured terrain display evidence of very minor extension. The fracture patterns of these small inliers are similar in size, style, variation, and changes in orientation to fracture patterns associated with coronae and chasmata [e.g., 31]. It is possible then that these tessera inliers represent flooded (deflated or "sunken") ancient coronae-chasmata chains such as Parga or Hecate.

Thus it is possible that tesserae—which are really nothing more than deformed surface layers—could form in several types of tectonic environments, including as a result of (1) subsurface flow in Ishtar Terra, (2) as variable sequences of surface-layer extension and contraction in crustal plateaus, (3) as highly-extended, previously-deformed crustal plateaus which have deflated or sunken, and become flooded and thus preserved as large plains inliers, and (4) as densely-fractured surface layers—fractured as a result of corona and chasma formation, likely within a dominantly-tensile crustal environment, which has since sunken, perhaps as a result of cooling, and become variably flooded, and thus preserved as isolated, scattered, highly-fractured inliers. Therefore tessera terrain would *not* form a global onion skin; it would not represent a globally synchronous unit; it would not record a single period of deformation in Venus' tectonic history, nor would it require a single mechanism for its formation. In the same sense that deformed rocks on Earth formed (and continue to form) in a wide variety of tectonic environments, tessera terrain records a range of spatially and temporally discreet tectonic processes. If there is any validity to the view of tesserae outlined above, it brings to mind a picture of Venus which is not catastrophic, but rather cyclic or evolutionary. Plains regions form above mantle downwellings, and corona-chasmata and crustal plateaus form above diffuse mantle upwellings. Mantle upwellings and downwellings change location through time, and plains provinces may become "intruded" by coronae and cut by chamsata, whereas coronae-chasmata regions may flounder and become plains as the upwellings beneath them decay. Tessera inliers represent flooded crust originally defomed within coronae-chasmata and crustal plateaus. This view of Venus and the role of tessera formation in her evolution remains to be tested, but the view broadly fits available data, yet does not require tectonic catastrophism.

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