THE FORMATION AND EVOLUTION OF TESSERA AND INSIGHTS INTO THE BEGINNING OF RECORDED HISTORY ON VENUS: GEOLOGY OF THE FORTUNA TESSERA QUADRANGLE (V-2).

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Introduction: Today, and throughout its recorded history, Venus can be classified as a "one-plate planet." The observable geological record of the planet comprises only the last 1/4 or less of its overall geologic history. As shown by many authors, it started with intensive deformation in broad regions to form tessera [1-6] during the Fortunian period of history [7]. The period of tessera formation quickly changed to numerous zonal deformational belts of ridges and grooves that were followed by emplacement of vast volcanic plains (shield plains, regional plains) [7,8]. During the final epoch of the geologic history of Venus, large but isolated centers of volcanism formed extensive fields of lavas, with tectonics concentrated within fewer very prominent rift zones [8,9]. The observable changes in intensity and character of volcanism and tectonics suggest progressive changes from thin lithosphere early in the geologic history to thick lithosphere during later epochs [6,10]. We have little idea of the character of the first 3/4 of Venus' history. So, what does the earliest period of recorded history tell us about the transition from the Pre-Fortunian to the Fortunian period and what insight does this give us into this earlier period?

Major problems to address: About 60% of the area of the Fortuna Tessera quadrangle (V-2) forms one of the largest tessera regions on Venus [11-12] as well as surrounding deformational belts and broad plains units. Relationships of intratessera structural domains with the surrounding tectonic and volcanic features can be investigated in detail. This provides the basis to establish major sequences of events that operated near the visible beginning of the geologic history of Venus. Arranging of the events into a stratigraphic order is key to addressing a number of important questions in the geology of Venus. What is the nature of the transition from the currently observed geological record to that of the first ca. 75% of the history of Venus? What were the dominant geological processes operating at the transition? How do they compare to those operating in the ensuing history? What do these features and processes tell us about the nature of the transition from earlier history to later history? Was this transition a peak of activity or a more gradual transition? What do the features and processes tell us about the nature of Venus in the first 3/4ths of its history?

The strategy: The area of the V-2 quadrangle represents one of the most fundamental areas showing the earliest recorded stratigraphic record, Fortuna Tessera (the type area for the Fortunian Period). A main goal of our mapping within this quadrangle is to analyze the tessera unit in detail to understand its morphologic nature, the topographic configuration, structural patterns/subtypes, boundaries, and stratigraphic relations of tessera with the surrounding units/terrains. Is there any evidence for "pre-tessera" terrain? What can we learn about the sequence and internal structure of Fortuna (syntaxis, ribbons, troughs, etc. [13,14])? How do these characteristics of Fortuna relate to other tesserae on Venus and what are the key differences [5]? The synthesis of these observations will provide insight into both the processes of tessera formation and contrasts between pre- and post-Fortuna history of Venus.

Results of preliminary mapping: During preliminary mapping of the V-2 quadrangle we have defined ten material units (including two units related to impact craters) and two structural units and placed them in a stratigraphic sequence using embayment and cross-cutting relationships. From older to younger, these units are as follows. <u>Tessera material (t)</u> represents one of the most tectonically deformed types of terrain [12,15,16]. Both the material and tectonic structures play a key role in the definition of the unit. Tessera occupies the majority of the quadrangle (~50%, Fig. 2) and occurs in two major regions: Fortuna and Laima Tesserae. Type locality: 63.4°N, 19.5°E. <u>Densely lineated plains material (pdl)</u> heavily dissected by numerous densely packed narrow (<100s of m), short (10s of km), parallel and subparallel lineaments (fractures). Type locality: 52.4°N, 9.7°E. <u>Mountain belts (mb)</u> represent a structural unit that surrounds Lakshmi Planum and forms the highest mountain ranges on Venus [15,17-21]. Densely packed ridges that are 5-15 km wide and tens to a few hundreds of kilometers long characterize all mountain belts. Within the quadrangle, only the eastern portion of Maxwell Montes is represented. Type locality: 65.5°N, 0.9°E. <u>Ridged plains material (pr)</u> These are characterized by the morphology of lava plains and are deformed by broad (5-10 km) and long (10s of km) linear and curvilinear ridges. In places, the ridges are concentrated into prominent belts. Type locality: 53.2°N, 27.8°E. <u>Groove belts (gb)</u> represent a structural unit, which consists of dense swarms of linear and curvilinear subparallel lineaments (fractures or graben). Occurrences of the unit have a distinct belt-like shape. Between the structures within the belts, small fragments of preexisting units are seen in places. These fragments are usually too small to be mapped at the scale of the mapping (1:5M). Type locality: 56.4°N, 25.3°E.

Shield plains material (psh) is characterized by abundant small (<10 km) shield and cone-like features that are interpreted as volcanic edifices [22-25]. In places, the shields form clusters of structures. In contrast to the above units, the material of shield plains occurs at lower elevations and is mildly deformed by tectonic structures (wrinkle ridges and sparse fractures/graben). Type locality: 61.4°N, 33.9°E. Material of the lower unit of regional plains (rp_1) is characterized by a morphologically smooth surface with a homogeneous and relatively low radar backscatter. The surface of the unit is mildly deformed by wrinkle ridges. The lower unit of regional plains occurs within low-lying areas and embays the heavily tectonized units and shield plains material. Type locality: 51.5°N, 25.6°E. Material of the upper unit of regional plains (rp_2) has a morphologically smooth surface that is moderately deformed by wrinkle ridges that belong to the same family of structures that deform unit rp_1. The unit (in contrast to the unit rp_1) shows higher radar albedo and often forms flow-like occurrences that are superposed on the surface of the lower unit of regional plains. Type locality: 52.9°N, 7.2°E.

Smooth plains material (ps) has a morphologically smooth, usually dark and featureless surface, which is tectonically undisturbed. The unit makes small equidimensional and elongated patches a few tens of km across. Type locality: 54.8°N, 2.4°E. Lobate plains material (pl) is characterized by a morphologically smooth surface with an albedo pattern consisting of numerous bright and dark flow-like features. The material of lobate plains is tectonically undisturbed and fields are associated with several medium-sized (a few hundreds of km across) volcanic centers near the northern and southern edges of the quadrangle. Type locality: 50.5°N, 22.0°E.

Impact crater materials, undivided (c) includes materials of the central peak, floor, walls, rim, and continuous ejecta. Type locality: 59.7°N, 26.8°E (crater Goeppert-Mayer). Impact crater outflow material (cf), type locality: 61.6°N, 36.2°E (outflow from the crater Baker).

Evolutionary trends: Consistent relationships of cross-cutting and embayment among the mapped units/structures suggest progressive decline of the amount of tectonic deformation from heavily tectonized units such as tesserae, densely lineated plains, ridged plains, and deformational belts through mildly deformed plains units (psh, rp_1, rp_2) to tectonically undeformed smooth and lobate plains. The elevated regions within the quadrangle correspond to the occurrences of the older and heavily tectonized units and mildly tectonized plains occur in topographic lows. This correlation suggests that the regional topographic patterns within the quadrangle were established during the earlier stages of the geologic history and that the processes of crustal thickening/thinning mostly operated at this time.

Clear morphological differences between the broad and mildly deformed plains units as well as their consistent age relationships suggest that there were significant changes in the volcanic style from shield plains (distributed small sources) through regional plains (volcanic flooding) to lobate plains (several major volcanic centers).

Tentative conclusions: 1. Tessera represents a distinctive beginning of recorded history with focused deformation that shows a fundamental difference from later processes. 2. This early period (Fortunian) was characterized by "intense" regional (continental-scale) deformation that implies very large-scale lateral movement measured in hundreds of kilometers and associated lateral deformation and crustal thickening processes. 3. Later periods were characterized by less intense distributed deformation (wrinkle ridges) and localized deformation (ridge belts, fracture belts, rift zones). 4. The patterns in Fortuna Tessera show that pre-Fortunian crust was deforming at scales that imply a thin lithosphere, variations in crustal thickness, large-scale lateral movement, crustal underthrusting and imbrication, and possible subduction. 5. The Fortunian Period took place over a short period of time, as indicated by the small number of superposed craters. This implies either: 1) that the deformation was a peak, or 2) that if the deformation was simply transitional the transition occurred very rapidly and the rates of earlier processes were very high. 6. The nature of Fortunian/Pre-Fortunian geodynamics: The regional patterns of deformation and tessera preservation require that the following things were occurring at this time: Local downwelling and upwelling, regional plate boundary-like deformation, Archean-like ductile deformation: Delamination and sub-lithospheric spreading and subduction.

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