FORMATION AND EVOLUTION OF TESSERA TERRAIN ON VENUS: OUTSTANDING PROBLEMS: James W. Head, III, Department of Geological Sciences, Brown University, Providence, RI 02912 USA

Introduction: Tessera terrain on Venus is complexly deformed by multiple cross-cutting deformational structures[1], stands high relative to the surrounding volcanic plains (which embay them and contrast distinctly in their much lower levels of tectonic deformation)[2], has several distinctive patterns or facies of deformation[1,3,4], is usually characterized by initial compressional deformation and later extension[5-6], with shear throughout, is distributed non-randomly over less than 10% of the surface[6], is primarily concentrated in large regions with areas $>2 \times 10^6$ km^2, generally appears shallowly compensated[7], may underlie a much larger percentage of the stratigraphically younger volcanic plains[6], and does not appear to differ significantly in age from the surrounding volcanic plains that dominate the surface of Venus[8-9]. Tessera terrain is of significant importance in understanding the geologic history of Venus because of the extreme contrast in surface deformation and apparent near-synchroneity of its surface age with the vast volcanic plains which embay it, and the relevance this has to models for the formation, evolution, and present state of the planet. Understanding the formation and evolution of the tessera terrain is essential to determining whether Venus has evolved monotonically (either through broad changes in the style of convection and surface deformation[10], or through evolutionary changes in the near-surface thermal gradient[11]), or episodically (through cycles of plate tectonics[12] or catastrophic overturn of a depleted mantle layer[13-14]). In this contribution, some of the outstanding problems in the analysis of the nature, formation and evolution of tessera terrain are outlined.

What is the Nature of the Tessera Terrain?: Major unknowns remain in terms of the basic characteristics of tessera terrain. What is its global extent? Are the small isolated exposures of tessera that make up the vast number (but not the area) of tessera occurrences[6] linked to an underlying basement of global tessera terrain, with the large continuous exposures simply linked to greater crustal thickness, or do they represent the surface exposures of a different type of deformation? What is the composition of the tessera materials; does the diversity of Venera lander compositions[15] and the relation of steep-sided domes[16] and festoons[17] to tessera mean that they may be compositionally diverse? Can the nature of proto-tessera materials be determined through detailed geologic mapping? What role do the abundant patches of intratessera plains play in the petrogenetic evolution of the tessera?[18] What do the gravity signatures of the different tesserae mean in terms of mode of formation?[7] Can all be explained in terms of different levels of shallow compensation and crustal thickness variations or is there evidence for dynamic support? How do we account for the diversity of structure, size, and mode of occurrence within tesserae?[1,6] Why is Western Ishtar so different from other tessera occurrences?[19-20] Do these different occurrences represent different basic modes of formation of tesserae, or do they simply reflect different aspects of a common origin? Minimal erosion means that older features are dominated by tectonic overprinting; can detailed mapping deconvolve the sequence of deformation characterizing each tessera occurrence? What is the relation of tessera to other terrain types such as volcanic rises (e.g., Atla), basins (e.g., Lavinia), etc.? Is there an evolutionary trend[21-22], or do they represent different manifestations of a common synchronous event or its aftermath?[14] Is there evidence for deformed impact craters or sequences of deformation that might represent different temporally distinct periods of tessera formation?[23]

What are the Processes of Formation?: Understanding tessera formation requires consistent interpretation of the nature and sequence of tectonic structures and facies. Because of the demonstrated presence of compression, extension, and shear, and their clear superposition and even contemporaneity, the complexity of the resulting terrain is often overwhelming. Detailed analyses (e.g.,[5, 23-26]) must be continued to address the following questions: What are isolated examples of individual features making up the complex tessera fabric, and how are they interpreted? What is the relative importance of compressional, shear, and extensional deformation in the formation of these structures and fabrics? How did these vary as a function of time? Is there evidence for interference folding, or do complex structures result largely from extension and shear modification of older terrain? Is there any correlation between intensity of deformation and topography that might be related to crustal thickness differences?[11] Do similar structures and sequences exist in different tessera and does this represent a commonality of formational process? How much shortening and extension is involved in tessera formation and how is it accommodated elsewhere? What is the sense of deformation; is tessera collapsing outward[27], or underthrusting inward?[28] What it the duration and style of formation; is it fast or slow, sequential or multiple, ongoing or inactive? How do tessera characteristics relate to models of upwelling, downwelling, hot spots, cold spots, catastrophic overturn or cyclic plate tectonics? What are implications for planetary degassing and changes in the atmosphere relative to different models for tessera formation?

What are the Processes of Tessera Evolution?: Tesserae may be long-lived blocks of thickened crust that have been subject to repeated episodes of tectonic deformation, often external in origin and related to large-scale stresses. If this is true, the level of deformation observed in the highlands would depend in part on its age; for example, differences in tectonic deformation in two tessera occurrences could be due in part to a greater age for a crustal thickening event. Do apparent steps in the tectonic sequence represent sequential or contemporaneous deformation? What are the time scales involved? What is the evidence for multiple deformation phases (e.g., tessera cores representing older events distinctly separated in time from tessera margins, representing later deformation and accretion)?[23] Is there evidence for thickened crust enhancing deformation?[11] Is there evidence of crustal loss during or after tessera formation?[29] What are the latest deformation features and how are they related to the surrounding plains? Is there any evidence that tessera underwent modification during or subsequent to plains formation? Is tessera still changing? What is the role of post-formation surface radar property modification? Can this be used to determine paleo-altitudes?

Crucial Measurements and Observations: Detailed mapping of the structure and stratigraphy of tessera occurrences across Venus are required to address many of these questions. Stratigraphic analyses of adjacent plains will also provide important evidence for the interaction and chronology of apparently nearly synchronous units. Assessment of high-resolution Magellan gravity data will help to delineate the range of characteristics of tessera and models of tessera evolution, and will sharpen predictions which can be tested with detailed mapping analyses. In the longer term, spacecraft missions to the surface of Venus will be required to address many substantial questions. For example, Venera-like landers in tessera terrain[30] could determine chemical composition, aspects of mineralogy, and reveal detailed structure and morphology in surface panoramas. Balloons with instrumented gondolas could provide chemical measurements in several different places and high resolution images along traverses between touchdown sites, while long-term landers could help determine the levels of present seismic activity on Venus. Data in hand from Magellan will clearly address many of the basic questions and help to frame the next level of questions for the future.

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