TESTING CRUSTAL PLATEAU FORMATION MODELS FOR VENUS USING GEOLOGICAL MAPPING OF ISHTAR TERRA MARGINAL AREAS.

H. C. J. Cheng[1*], A. Alexander G. Webb[1], Joseph R. Michalski[1], William B. Moore[2,3], [1]Department of Earth Sciences and Laboratory for Space Research, University of Hong Kong, Pokfulam, Hong Kong, China, [2] Department of Atmospheric and Planetary Sciences, Hampton University, Hampton, Virginia, USA, [3]National Institute of Aerospace, Hampton, Virginia, USA. (* jupmira@connect.hku.hk)

Introduction: Crustal plateaus on Venus expose ancient tessera terrains across about 8% of the planetary surface [1], yet the origin of plateaus and tessera terrains is poorly understood. These highlands have small gravity anomalies with shallow apparent depths of compensation, indicating thickened crust [1]. Tessera terrains are defined by the complex deformation of at least two overlapping lineament sets [2][3]. Tessera often represents the locally oldest material, as demonstrated by the termination of its deformation by embayment of lava plains [2]. Any viable model must explain the thickened crust and complex deformation of tessera highland surface.

The origin of the tessera highlands has been explained in different ways. Models with predictions that may be testable via geological mapping include: (i) mantle downwelling resulted in thickening and horizontal shortening of the crust [1], (ii) an upwelling plume impinged upon early thin crust, and crustal thickening occurred by magmatic processes [4], (iii) the pulsating continents model suggests tessera terrains are continental crust that contracted during an episodic global subduction event [5], (iv) early heat pipe volcanism-dominated cooling developed crustal plateau in response to global radial lithospheric contraction before waning to stagnant lid cooling [6], and (v) a large bolide impact generated an enormous lava pond where massive partial melting formed a low-density residuum resulted in surface uplift of solidfied lava pond [7]. Most models agree tessera is the locally oldest unit, but the upwelling model suggests tessera is not everywhere older than plains because the volcanic plains are rapidly emplaced at the end of the tessera forming mobile-lid era [4]. The upwelling model also predicts extensional highland formation and minor contraction and extension afterward. The lava pond model predicts plateaus with both extensional fabrics and fold crests. All other models predict contractional highland formation [4]. The downwelling, pulsating continent, and waning heat pipe models predict significant compression along the tessera block edge [1][5] while the upwelling model predicts limited marginal contraction [4].

Here we perform detailed mapping along Ishtar Terra's margins to test the models. Ishtar Terra is a plateau on Venus located at 70.4°N 27.5°E with the dimensions of ~4500 × 2600 km. Due to its complex geology and morphology, four of the above models have been previously explored to explain its formation, (downwelling [8], upwelling [2], pulsating continents [5], and bolide impact with lava pond models [7]). Mapping along plateau margins helps to test predictions about the tessera-plain overlapping relationships and marginal deformations. Hence, Ishtar Terra margin is a good laboratory for the model testing.

Dataset and mapping method: Surface unit and structural mapping are conducted using Magellan synthetic aperture radar (SAR) imagery and topographic data. Left-looking full resolution SAR images with 75 m resolution are used as base maps. Topographic data is also used with a horizontal resolution of 4641 m and vertical resolution around 100 m.

Surface materials are defined primarily by their radar brightness and texture. Units are classified into three categories: tessera, lava plains, and impact crater. This mapping focused on distinguishing tessera-plain margins and identifying their overlapping relationships.

Structures are mapped based on radar contrasting lineaments and then grouped by their appearances, patterns, and trends. These sets of discrete and continuous structures are interpreted in their possible formations including compression, extension, and other ways. Lastly, interpretative maps are produced to show the "end-member" possibilities and test the models.

Preliminary Result: Here we present a detailed map of Ishtar Terra's northern margin (Figure 1).

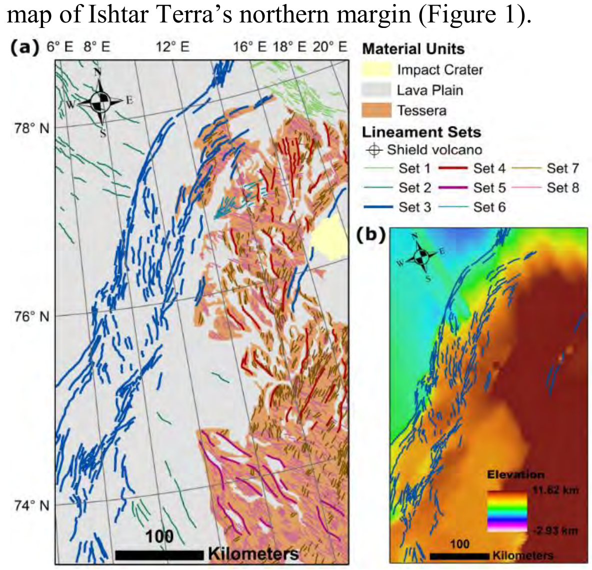

Figure. 1 (a) Detailed geological and (b) topographic map overlaid by lineament set 3 of northern Ishtar Terra margin

The mapped tessera terrains are all embayed by lava plains, indicating that tessera is the older unit. This is consistent with all the considered models.

There are eight sets of subparallel linear features interpreted to record deformation. Sets 1 and 2 are plain fractures. Set 3 is a ridge belt (Semuni Dorsa) along the highland margin on plains, suggesting a young deformation. Sets 4 and 5 are lineaments with distinctive ridge features on tessera, and crosscutting sets 6, 7 and 8, which are fragmentary tessera fractures with width of a single radar resolution cell. Both the tessera ridges and fractures are crosscut by embaying plains, indicating an early tessera deformation.

To test the models, we consider "end-member" interpretive maps of this area because the textures shown on SAR image are inadequate to distinguish contractional and extensional deformations. The Semuni Dorsa and tessera ridges are interpreted separately in both contractional and extensional deformations resulting in four possible cases (Figure 2).

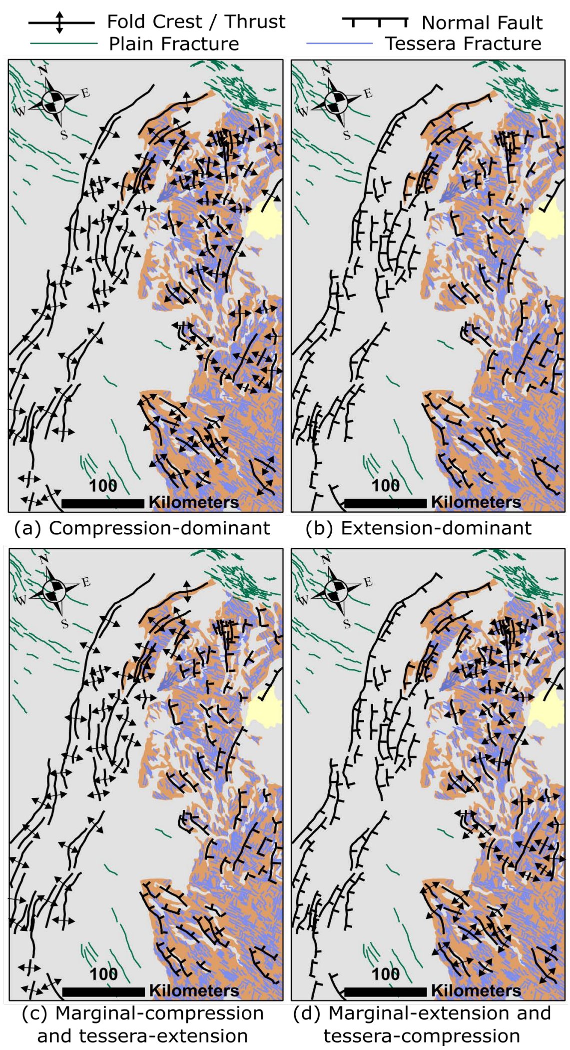

Figure. 2 End-member interpretative maps

Compression- (Fig. 2a) and extension-dominant (Fig. 2b) evolutions are possible, which the area is shaped by either folding or normal faulting respectively. The extension-dominant case fits the upwelling model predicting significant extension during the crustal plateau formation. On the other hand, the compression-dominant case is consistent with the remaining contractional highland models.

Also, the marginal ridges can be formed under compression or extension, whereas the older tessera ridges are formed by the other type (Fig. 2c and d). Previous researchers have considered Semuni Dorsa as a contractional deformation belt with the type of tessera deformation unknown (Fig. 2a and c) [10]. This case fits the downwelling, pulsating continent and the waning heat pipe to stagnant lid models that predict marginal contractions. The upwelling model has difficulties in creating such compression without accompanying a larger-scale extension in the region, which is not observed in this case. However, Semuni Dorsa can also be formed by extensional bookshelf faulting (Fig. 2b and d), which the accommodation of fault rotation tilts fault blocks forming parallel ridges.

Therefore, the type of deformation (compressional vs. extensional) of the tessera ridges and Semuni Dorsa is a critical issue to determine the highland formation, yet this mapping is unable to distinguish it.

Conclusion and Future Work: We seek to test models by mapping to see which predictions are robust, but thus far the mapping fails to falsify any existing model. Comparable studies of other marginal areas of Ishtar Terra and other tessera highland will be the future work to test the models and reexamine the effectiveness of the mapping work with the available radar data.

Our future work also includes applying Io's heat-pipe compression numerical models to Venus boundary conditions with the goal of examining the lithospheric deformation predicted by this newly proposed model.

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