Origin of Linear Deformation Patterns in the Fortuna and Itzpapalotl Tesserae, Venus

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Introduction

This study focuses on tesserae features in the Snegurochka Planitia quadrangle (V-1) area on Venus. Tesserae are surface units on Venus's crust distinguished by extensive linear deformation features that cross at near perpendicular angles. Two tesserae are observed, the Fortuna and Itzpapalotl tesserae. Using ArcGIS Pro and synthetic aperture radar (SAR) data from the NASA Magellan mission, lineations were mapped across both tesserae and compared using their orientations. In doing this, this study hopes to be able to determine similarities in the origin of separate tesserae and provide insight on how closely related their formations may be. The study is testing the hypothesis that individual tesserae formed in unique and isolated events.

Location

The two observed tesserae, the Fortuna and Itzpapalotl tesserae, are located in the northern polar region of Venus in the Snegurochka Planita quadrangle (V-1). Both tesserae lie around a latitude of 72°N, while the Fortuna tessera lies around a longitude of 17°E and the Itzpapalotl tessera lies around 315°E.

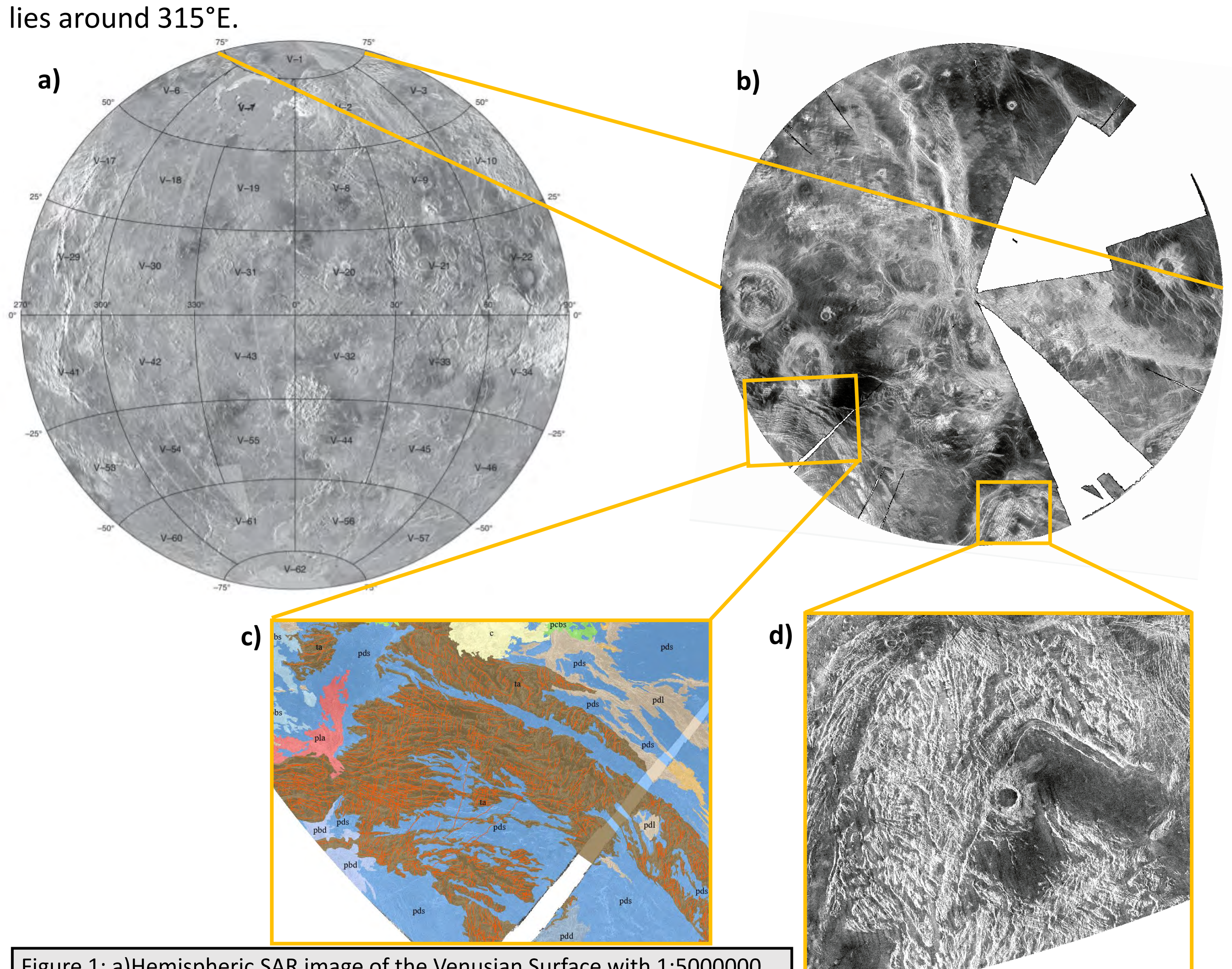

Figure 1: a)Hemispheric SAR image of the Venusian Surface with 1:5000000 scale quadrangles. b)The Snegurochka Planita quadrangle (V-1). c)The Itzpapalotl tessera as seen with geologic units. The tessera terrain is represented by brown (ta). The other geologic units are mostly dominated by volcanic plains, d) The Fortuna tessera in SAR imaging. The tessera terrain can be identified by the bright (white) area (Hurwitz and Head 2012).

Methods

In order to map lineations across the two tesserae the Geologic Map of the Snegurochka Planitia Quadrangle (V-1), Venus: U.S. Geological Survey Scientific Investigations Map 3178 was imported into ArcGIS Pro for reference on unit locations and the necessary coordinate system. With the base map in ArcGIS Pro, mapping of lineations within tesserae could begin with the two target locations being fully mapped. Units from the imported map were used to identify the Fortuna and Itzpapalotl tesserae terrains in order to keep consistent with the terrain being mapped. The mapping of the SAR data's lineations was done at a 1:900000 scale using polylines. 2366 lineations were mapped with 804 in the Fortuna tessera and 1562 in the Itzpapalotl tessera.

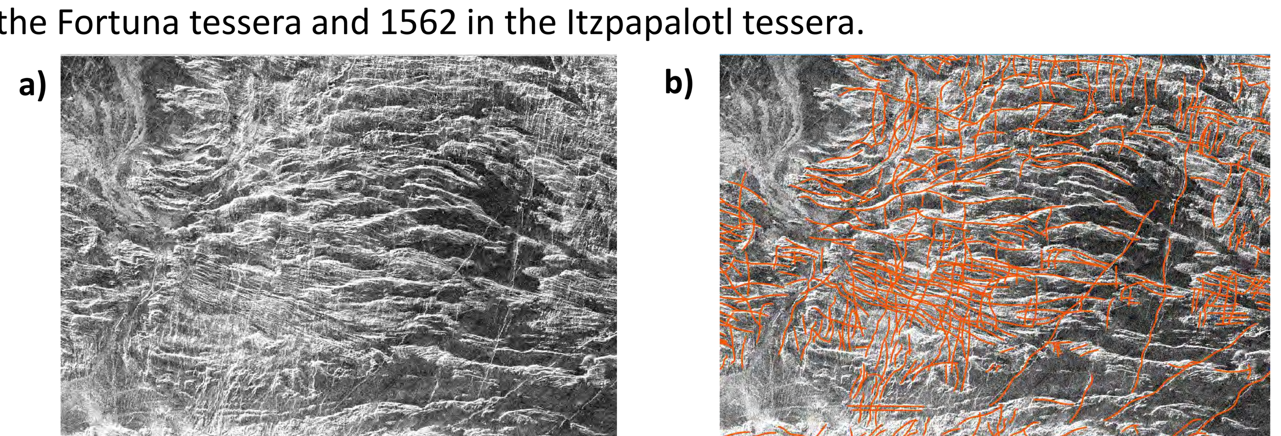

Figure 2: a)SAR image of a section of the Itzpapalotl tessera. b)Mapped lineations in the Itzpapalotl tessera.

With the mapping complete two sets of lineations were observed: those in the Fortuna tessera and those in the Itzpapalotl tessera. Using ArcGIS Pro a bearing was found for each lineation. Those values were then exported to Microsoft Excel for further data analysis. Using Excel, each bearing value was converted to its equivalent value lying between 0° and 180°. Each of the two lineation sets being looked at were then put into a frequency diagram with ten degree bins. An additional frequency diagram containing both data sets was created for comparison.

Data Analysis

Bearing measurements of lineations in the Itzpapalotl tessera and Fortuna tessera were collected and used for analysis. Tesserae are defined by two groups of lineations that cross at near perpendicular angles with each of those groups defining a direction of deformation. A frequency diagram was chosen in order to determine the most common direction of deformation in each of the tesserae's lineation pairs. In comparing these deformation directions between the two tessera, it is possible to identify potential similarities between the origin of these features.

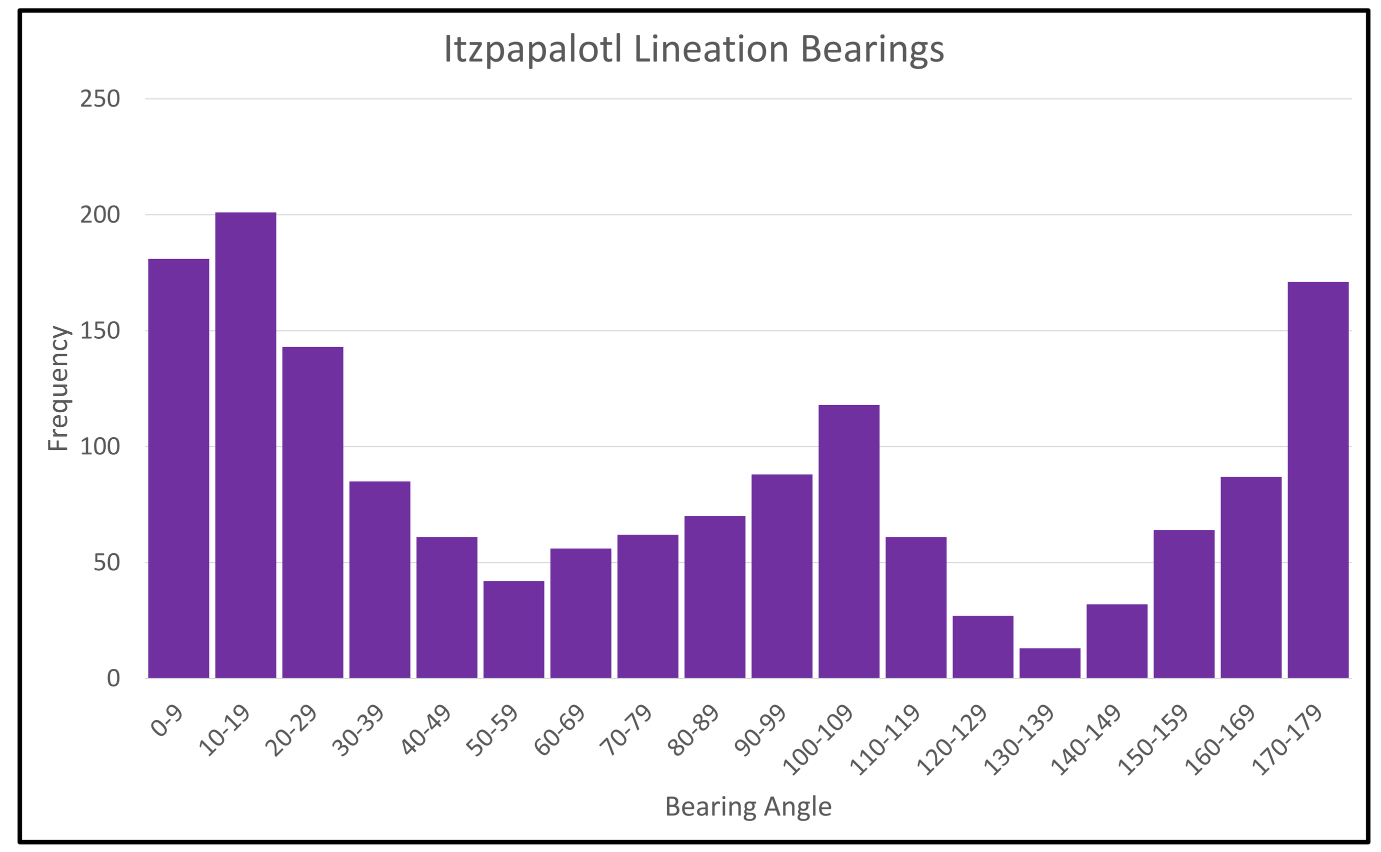

Figure 3: The distribution of bearing angles within the itzpapalotl tessera. The x-axis gives bearings in 10° bins with angles from 0° to 180°. The y-axis gives the number of times a bearing angle is observed within a bin.

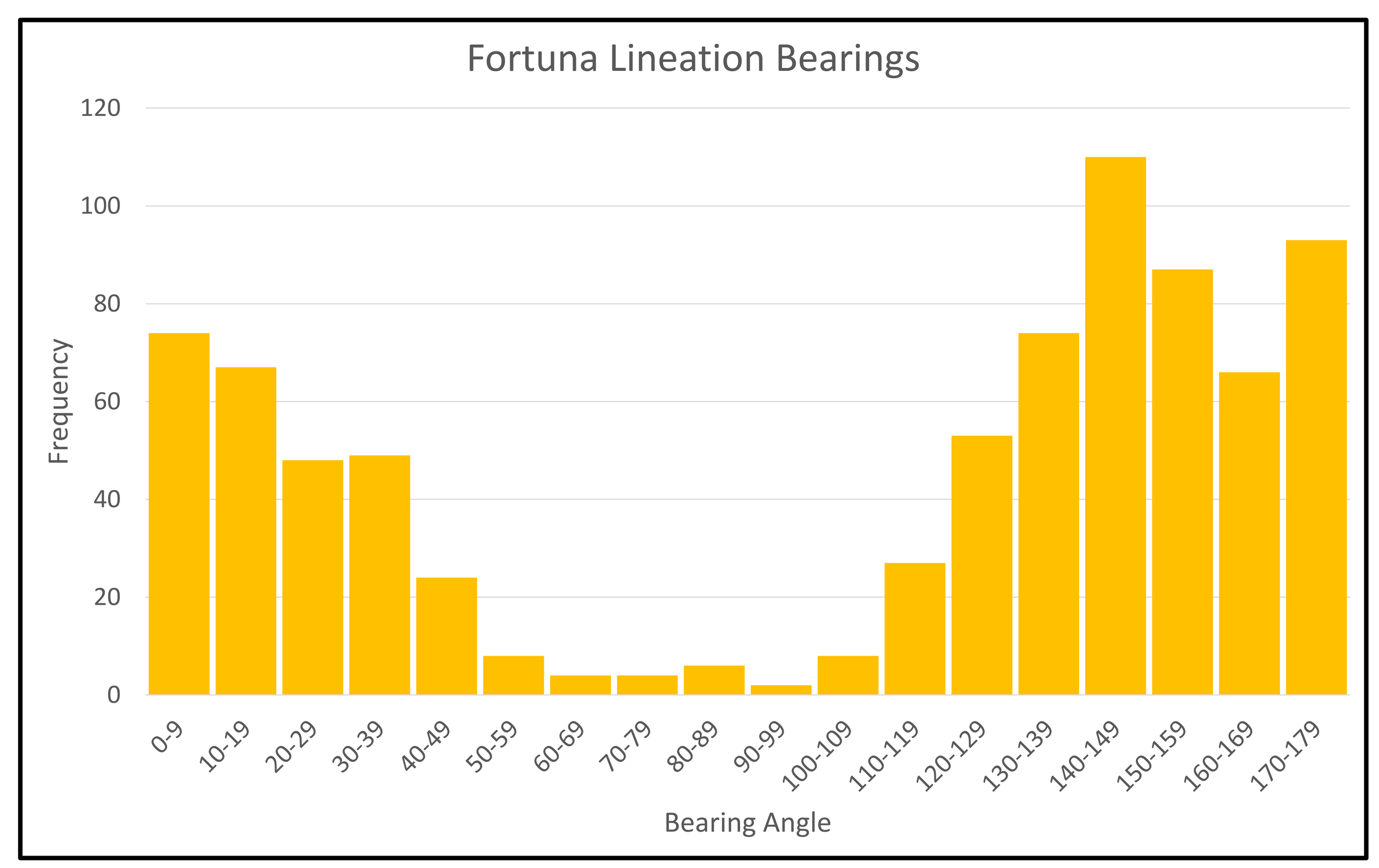

Figure 4: The distribution of bearing angles within the Fortuna tessera. The x-axis gives bearings in 10° bins with angles from 0° to 180°. The y-axis gives the number of times a bearing angle is observed within a bin.

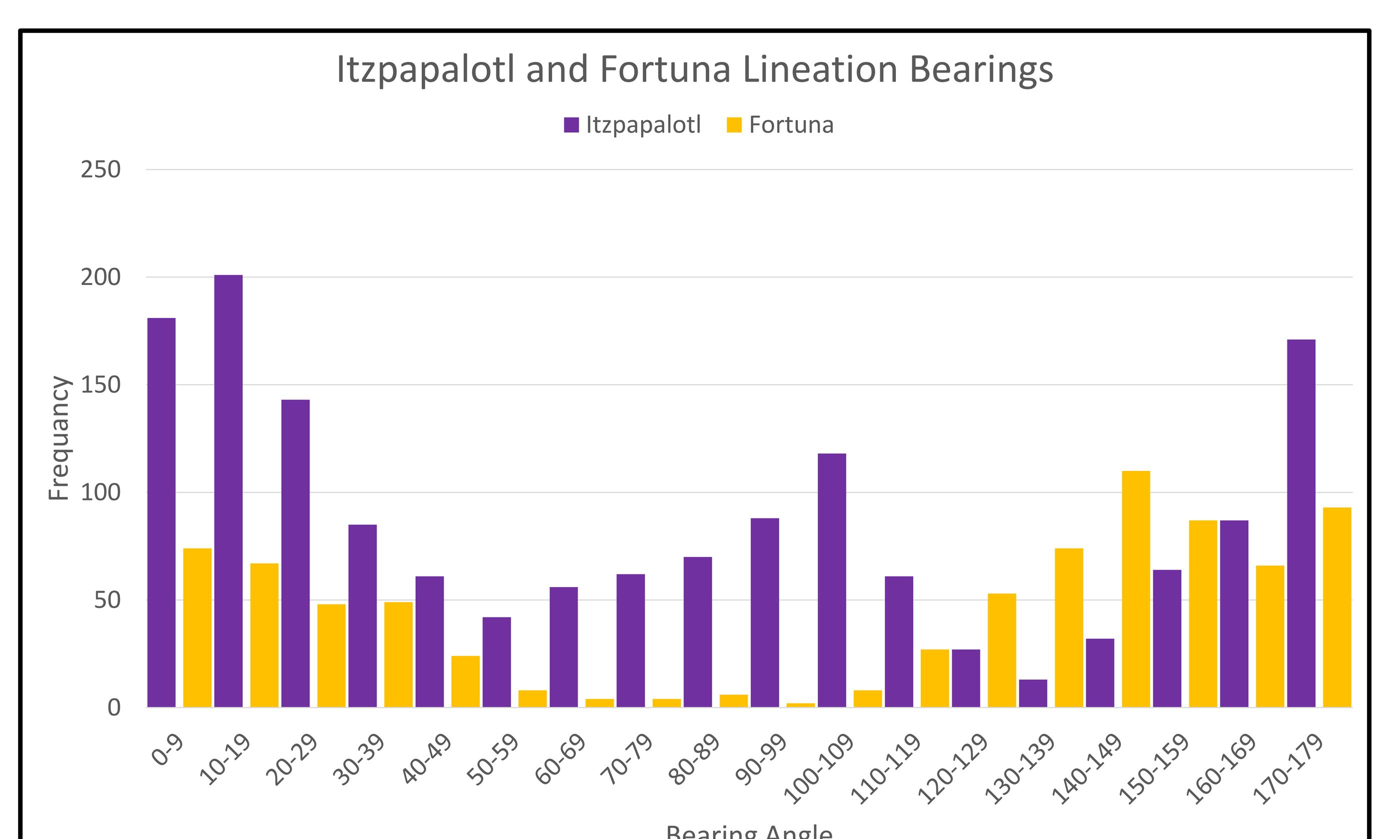

Figure 5: The distribution of Itzpapalotl tessera bearings (purple) compared to the distribution of Fortuna tessera bearings (gold). The x-axis gives bearings in 10° bins with angles from 0° to 180°. The y-axis gives the number of times a bearing angle is observed within a bin.

Discussion

Tesserae are considered the oldest terrain on Venus with the rest of the planets surface consisting mainly of volcanic plains (Hansen, Banks, and Ghent 1999) It has been considered that tesserae could represent a global layer beneath the volcanic plains. The more favored idea however, proposes that each tessera is the product of separate deformation events (Hansen, Banks, and Ghent 1999). This study works to compare the deformation of the Itzpapalotl tessera and the Fortuna tessera and in turn compare their respective origins relative to each other. Through this it will test the hypothesis that the two tessera experienced separate deformation events having no relation to each other.

In the data analyzed for the Itzpapalotl tessera two peaks can be defined as seen in Figure 3. The first peak lies around 10° to 19° representing a near north to south trend for one of its lineation sets. The second peak represents a near east to west trend with the peak lying at 100° to 109°. The first peak mentioned shows more lineaments than the second peak, which shows that deformation was more active in the north to south orientation. Also worth noting are the relatively low amount of lineations found near 50° to 60° and 130° to 139°. The data analyzed for the Fortuna tessera shows much less disparity between lineation sets as the two peaks lie within 40° of each other as seen in Figure 4. The first peak lies around 140° to 149° representing a north/northwest to south/southeast trend. The second peak lies around 170° to 179° representing a near north to south trend. There is also relatively few lineations from 40° to 119°.

When comparing, the two tesserae show little overlap in their respective lineation bearings. The Itzpapalotl tessera's trend around 100° to 109° has no correlation to any trend seen in the Fortuna tessera as there is a low amount seen in and around this range. Both tesserae show a trend around north to south oriented lineations, however they still differ by up to 20°. When looking at Figure 5 it can be observed that the east to west trend in the Itzpapalotl tessera and the north/northwest to south/southwest trend in the Fortuna tessera correspond to low points in the bearing counts of the other tessera. The shared north to south trend can be seen in Figure 5 as well, however it can also be seen that the two peaks don't overlap as one peak lies slightly east of north and the other lies slightly west of north. This shows evidence for separate deformation events in the origin of each tessera. Also in support of this is the large difference in lineation bearing distribution across the two tessera. For the Itzpapalotl tessera, in Figure 3 it can be seen that there are two defined peaks with defined low points separating them. These two peaks also appear at an approximately 80° difference showing near perpendicular interaction between the sets of lineations The Fortuna tessera differs in this respect as can be seen in Figure 4, where the two peaks occur with a significant low point separating them on one side while the other separation is rather shallow. This shows a large number of lineations with bearings from 120° to 39° with almost none at other bearings. When comparing this information it shows that the Itzpapalotl tessera has much more distinct sets of lineations in comparison to the Fortuna tessera's. When looking at the separation of peaks another difference can be seen. The Itzpapalotl tessera's peaks lie around 80° apart while the Fortuna tessera's lie about half that at around 40°. All of this points against the notion of a global tessera layer that has been partially covered by volcanic plains. Since the Itzpapalotl tessera has well defined lineation sets and the Fortuna tessera has relatively poorly defined lineation sets a difference in deformation origin can be deduced. Also, with a larger separation between its lineation set's bearings, the Itzpapalotl tessera has experienced deformation in directions that were near perpendicular to each other. The Fortuna tessera on the other hand has experienced deformation across a much smaller angular difference.

Conclusion

This study looked to determine how closely related the origin of the Itzpapalotl tessera and Fortuna tessera were in order to determine if they may have experienced similar or the same deformation event. In testing the hypothesis that the two tesserae are separate in formation, lineations within the tesserae had their bearings taken and compared. It can be concluded from analyzing the data that the two were likely unrelated in origin as their lineations showed large disparities with each other. This does not prove that the two have no relation with each other however, as other possible explanations could show reason for these differences, such as post formation deformation. In line with what this study shows, some explanations for tessera formation involve mantle plumes underneath a thin lithosphere causing extensional regional tectonics as well as lithosphere thickening (Ghent and Tibuleac 2002). The idea of independent regional activity resulting in tessera is the more favored of tessera origin possibilities at this time. With further research and newer Venusian mapping data, it could be possible to come reach more definite conclusions over the origin of tesserae.

References

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