Where are the missing tessera craters on Venus?

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I. Introduction

• Tesserae are defined as having two or more sets of tectonic structures.
• Tesserae are stratigraphically older than the global volcanic plains and have a greater number of craters > 16 km in diameter [1, 2].
• However, there is a dearth of craters < 8 km in diameter, and craters of all sizes may be unrecognized in or deformed by tessera structures [2].
• 82 crater-like features (CLFs) have been identified and qualitatively evaluated as possible missing tessera craters [3].
• In this study, we seek to evaluate whether crater-like features may be missing craters by utilizing two new quantitative criteria.

We will refine the crater age of the oldest terrains on Venus which record its earliest geologic processes.

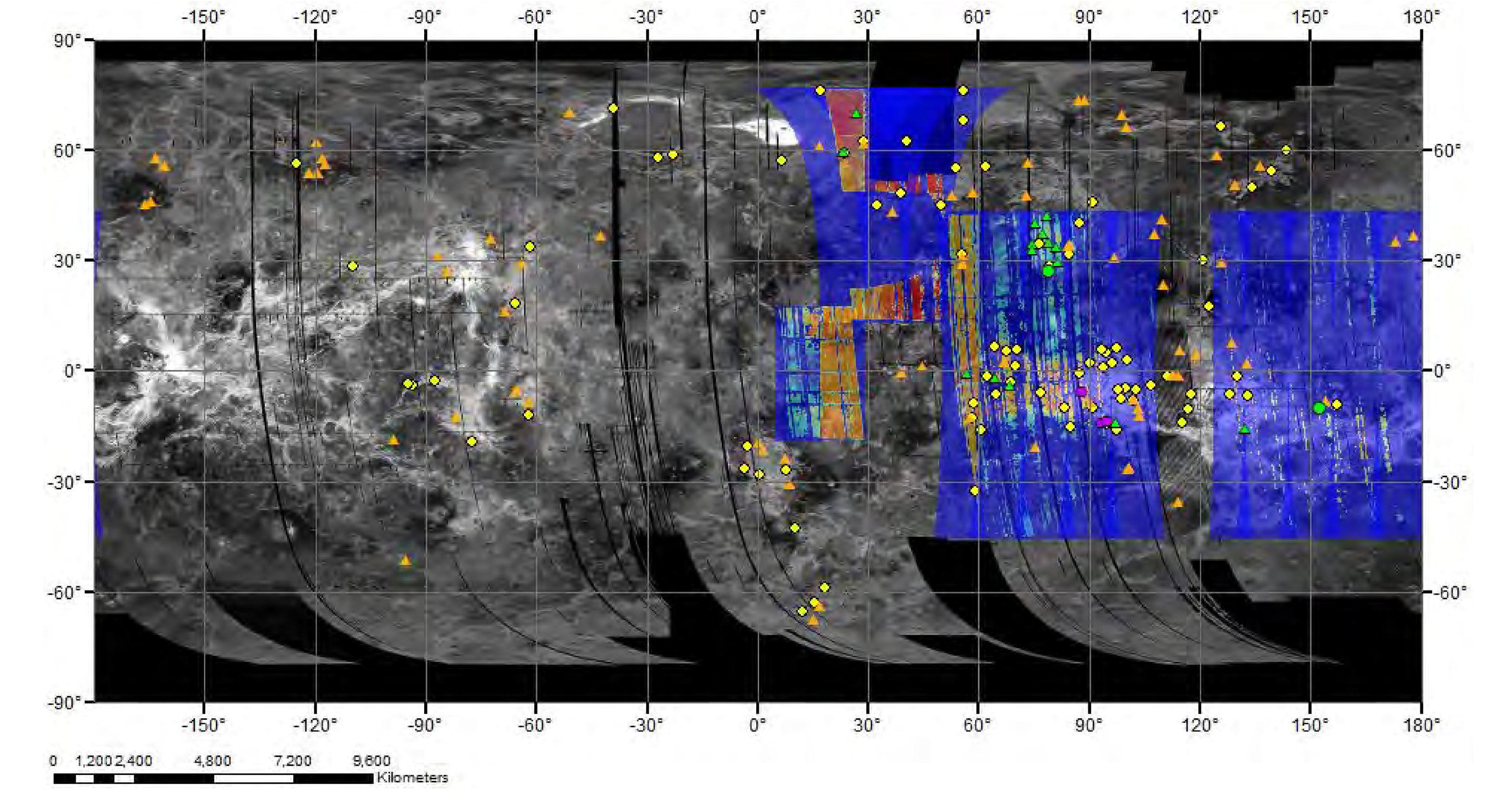

Figure 1: Magellan Synthetic Aperture Radar (SAR) FMAP Left Look Global Mosaic, 75 m/pixel, containing all crater-like features [3, 7], represented as orange and green triangles. Yellow circles are tessera craters. Stereo-derived DEM [4, 5] is transparent in back.

VII. Conclusions

• Volcanism and tectonics shallow the floors of tessera craters and CLFs. Areas of ejecta flow around CLFs may have similar backscatter as the surrounding rough terrain.
• Crater depths and radar backscatter coefficient ratio criteria are insufficient on their own, but can be used with qualitative morphological criteria [3] to classify crater-like features.
• Most CLFs are interpreted to be embayed tessera structures.
• We have identified 5 candidate craters based on this criteria. Added to the 10 identified by [3], we find 15 additional craters.

Our survey of crater-like features recognizes 15 new possible craters, increasing the age of the tesserae by a minimum of ~10-15%.

II. Methods: Depth measurements

Can we more rigorously constrain crater depths so as to allow comparison between known craters and observed crater-like features?

• Digital elevation models (DEMs) of tessera craters and crater-like features were utilized from the work of [4, 5].
• 100 elevation values are taken up to 1 crater radii, iterating around the rim as specified by a user-reported angle θ, with the crater depth d defined as the maximum elevation value minus the minimum. For the preliminary results of this study, θ is set to 1°, producing 360 unique radial topographic profiles, which are then averaged to produce a mean crater depth.

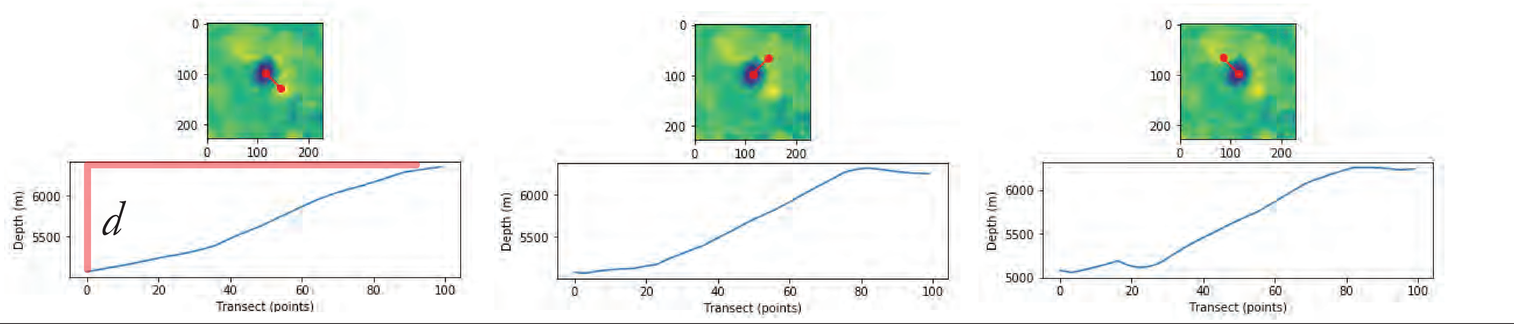

Figure 2: Three digital elevation models (DEMs) of the impact crater Carter (5.3°N, 67.3°E, 19.3 km diameter) along with corresponding topographic profiles, illustrating three iterations of the crater depth measurement method described. In the first plot, the crater depth d is highlighted. The angle θ is set to 45° in this example. Axes of the DEMs are in pixel coordinates.

III. Methods: Radar backscatter ratios

Can the ratio of ejecta to background terrain radar backscatter coefficients provide an identifiable crater "signature?"

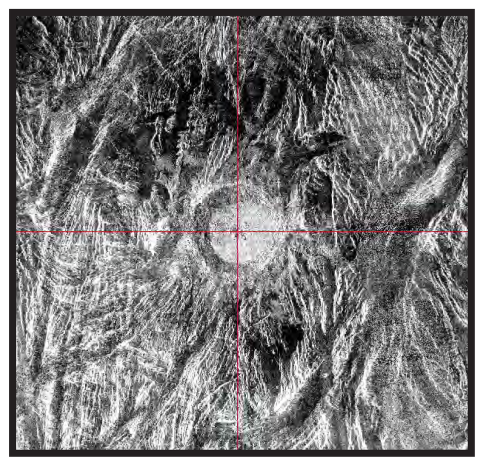

Figure 3: ENVI window featuring SAR image of the impact crater de Beausoliel (-5°N, 102.8°E, 27.8 km diameter).

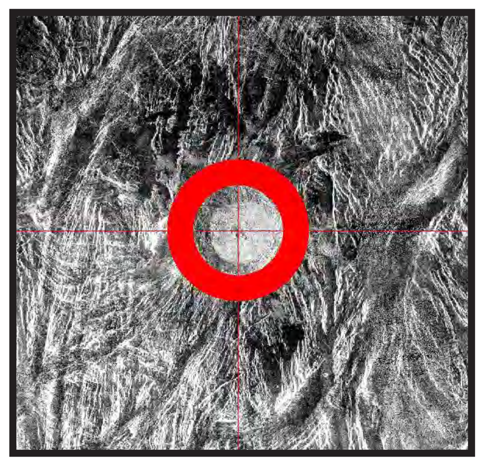

Figure 4: SAR image of de Beausoliel, featuring the area of maximum hummocky ejecta flow (outlined in red) [6].

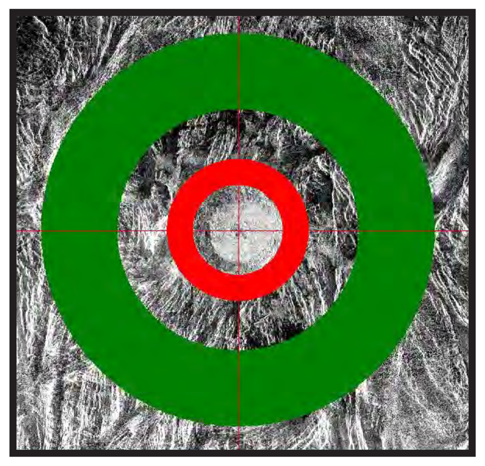

Figure 5: The crater background terrain (outlined in green), defined as being one continuous ejecta radius past the outer edge of the maximum continuous ejecta flow [6].

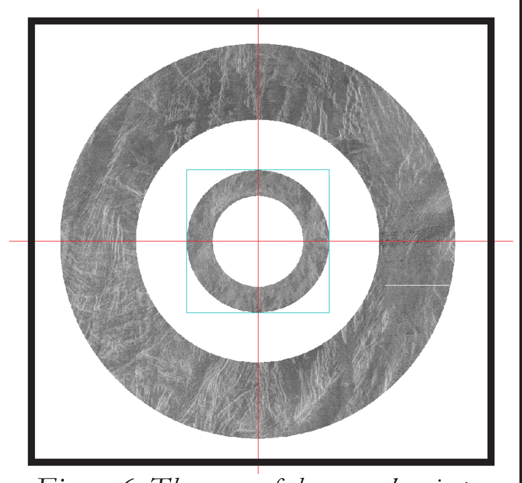

Figure 6: The area of hummocky ejecta and background terrain for de Beausoliel. The mean backscatter coefficient in decibels (dB) was compared between the two regions for each tessera crater and CLF.

IV. Results: Depth measurements

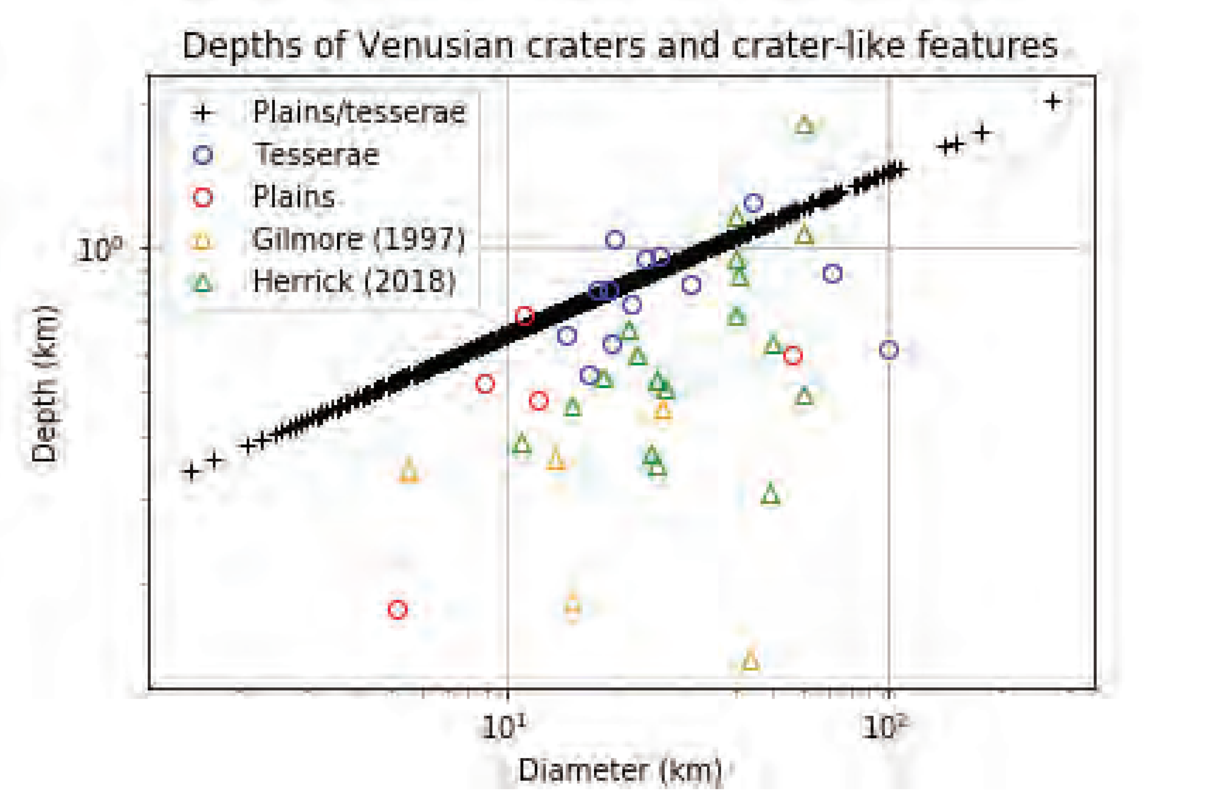

Figure 7: Depths of known craters and crater-like features as a function of crater diameter . Black plus signs indicate crater depth-to-diameter ratio from the power-law function described by [6]. Blue open circles are known tessera craters. Orange and green triangles are crater-like features reported by [3] and [12], respectively. Red open circles are plains craters.

• The majority of measured craters and crater-like features have shallower depths than the calculated depths derived from [6]. Although CLFs tend to be shallower than tessera craters, their values do overlap.
• CLFs are statistically separable from and shallower than known tessera craters.
• Conducting a Welch's t-test on the known tessera crater and CLF populations, we find there to be a statistical difference between the mean values of both groups (p-value < 0.0001).

V. Results: Radar backscatter ratios

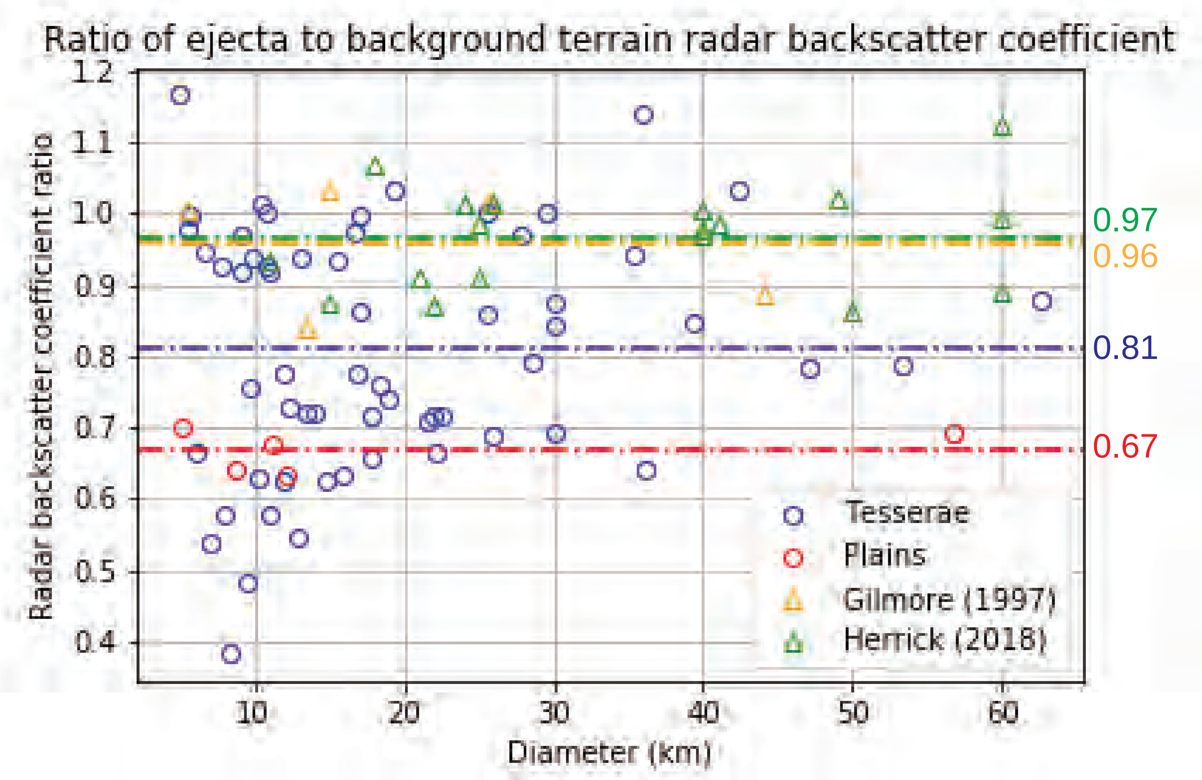

Figure 8: Ratio of the mean radar backscatter coefficient of the area of maximum hummocky ejecta flow (Fig. 4) with the background tessera region (Fig. 5). Blue open circles are known tessera craters. Orange and green triangles are crater-like features reported by [3] and [12], respectively. Red open circles are plains craters. Horizontal lines are the mean value of each population as denoted by the appropriate color. A backscatter coefficient ratio < 1 indicates the hummocky ejecta area is brighter than the surrounding terrain.

• Both plains and tessera craters have the majority of their values < 1, indicating that the hummocky ejecta is brighter than the background terrain.
• CLFs have values closer to 1, indicating the area of hummocky ejecta has similar backscatter to surrounding terrain
• Conducting a Welch's t-test on the known tessera crater and crater-like feature populations gives a p-value < 0.0001.

VI. Results: Morphology of crater-like features

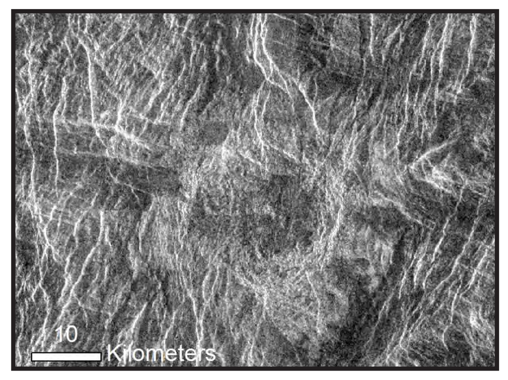

Figure 9: Gilmore (-6.7°N, 132.8°E), cross-cut by tectonic features.

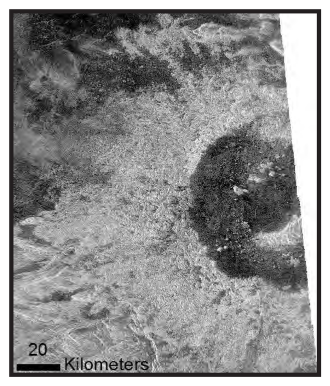

Figure 11: The floor of Joliot-Curie (-1.6°N, 64.4°E) is covered with lava plains; it is one of the shallowest craters measured in this study.

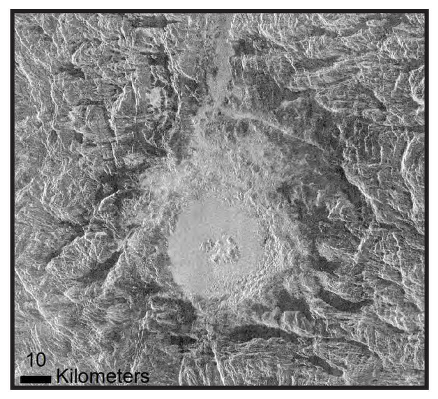

Figure 13: Khatun (40.3°N, 87.2°E), a bright-floored crater. Khatun has the deepest tessera crater depth measured in this study.

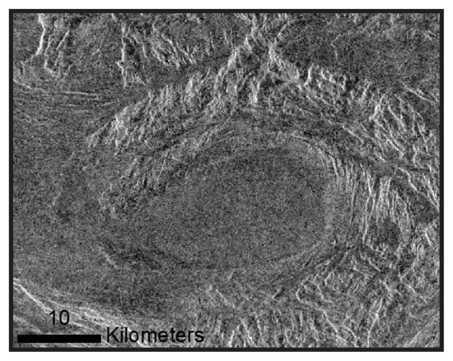

Figure 10: A crater-like feature studied by [3], one of the 5 potential craters using the criteria of this study.

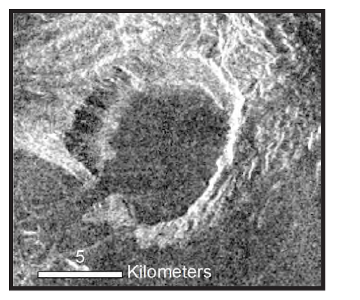

Figure 12: A crater-like feature studied by [3] and a potential crater.

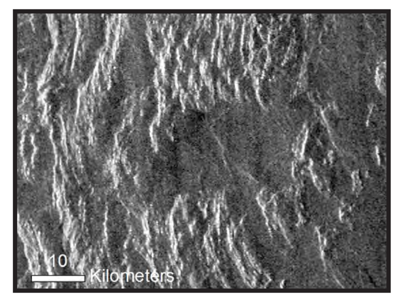

Figure 14: A crater-like feature studied by [7], likely embayed tessera material.

VII. Discussion

• Shallower depths for tessera craters and CLFs than the power-law function [6] indicate modification processes occuring to fill these features, including volcanic flooding and debris from tectonic faulting.
• Most tessera and all plains craters have ejecta blankets with high backscatter relative to their backgrounds, however, ejecta backscatter may be equivalent to background for some tessera craters. Although CLFs have high values, they plot within the tessera crater range.
• We cannot use radar backscatter coefficient ratio on its own as a determinant of whether a given CLF is a crater, though it can be used a non-interpretive proxy for the presence of ejecta. [3].
• Using morphologic criteria such as the presence of a rim, wall, and absence of similar neighbor features [3], we utilize our radar backscatter coefficient ratio values to put forth 5 new possible craters or ambiguous cases (Fig. 10, 12).

References: [1] Ivanov, M. A. and J. W. Head (1996) JGR, 101, 14861. [2] Ivanov, M. A. and A. T. Basilevsky (1993) GRL, 20, 2579. [3] Gilmore, M. S. (1997) Ph.D. dissertation [4] Herrick, R. R., et al. (2012) EOS, Trans., American Geophys. Union, 93, No. 12, 125. [5] Herrick, R. R. and M. E. Rumpf. (2011) JGR, 116, E02004, doi:10.1029/2010JE003722 [6] Herrick, R. R. and R. J. Phillips (1994) Icarus, 111, 387. [7] Herrick, R. R, (2018) LPSC XLIX, #1740

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