GINA CRATER AREA, VENUS: MULTIPLE OVERLAPPING DEFORMATION AND VOLCANIC EVENTS SUGGEST COMPLEX ACTIVE TECTONICS. Emily K. Roberts[1], Allan H. Treiman[1], Gabriel L. Eggers[1], and Justin Filiberto[2]. [1]Lunar and Planetary Institute, USRA, 3600 Bay Area Blvd., Houston, Texas 77058 (kroberts.emily@gmail.com); [2]Code XI, NASA Johnson Space Center, Houston, Texas.

Introduction: A current controversy in the geology of Venus centers on the age(s) of its highlands – the tesserae. One view of Venus' past is that it experienced a global resurfacing event at 700-800 Myr, now represented mostly by volcanic plains, and that the tesserae represent earlier crust deformed in that event [1,2]. It is also argued that the resurfacing represents multiple volcanic events over long times [3,4]. The ancient age of tesserae has recently come into question [5,6]. Some tesserae include distinct morphologic units that could represent deformed plains material [5,6]; in other cases it is possible that tesserae are forming today [7]. To address this question, we are mapping a tessera-plains transition around Gina Crater, near Venus' north pole.

Gina is a ~15 km diameter crater at 78.1°N, 76.3°E (**Fig. 1**), in the Snegurochka (V1) quadrangle [8]. Gina is on the western boundary of the Szél-anya Lineae belt (mapped mostly as tessera [8]), where it abuts a broad area of regional volcanic plains [9]. The area is complex, with evidence for multiple episodes of tectonism and volcanism and was specifically chosen to help constrain the timing of deformation events relative to those of volcanic emplacement.

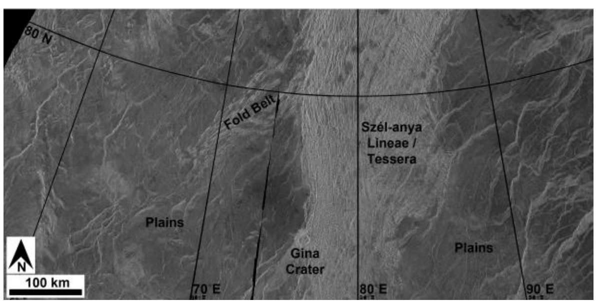

Figure 1. Locations of mapped area. Gina Crater is at 78.1°N, 76.3°E.

Data: We used Magellan's SAR left-look global mosaic (~75 m/pix) as the basemap. We acquired the image from the USGS Map-A-Planet 2 website [10]. ArcMap 10.6.1 was used for mapping, and JMARS was used for general visualizations.

Methodology: Morphologic features are defined by shape, orientation, and SAR backscatter. Map units are defined based on differences in radar brightness, morphology, texture, and stratigraphic relations [11]. Units are generally defined based on the radar brightness of emplaced material, but when material is obscured by deformation, the unit is instead characterized by that deformation. Contacts are defined by embayment relationships, radar brightness, deformation morphology, and the density of fractures.

Mapped Units: Twenty-nine units have been identified among the geologic provinces: fold belt, tessera, volcanic, plains, and crater. The descriptions of mapped units are in approximate chronological order.

Fold Belt: Northwest of Gina Crater and the regional plains is a belt of SAR-bright discontinuous parallel ridges, trending NE/SW (**Fig. 2A**). The belt is embayed by regional plains units, cut by fractures/faults of several orientations, and truncated by the Lineae/tessera.

Lineae / Tessera: Szél-anya Lineae is a belt of heavily deformed rock on the east of the mapped area. Its dominant tectonic fabric is oriented N/S and is marked what appear to be rock layering, fractures, and faults. This fabric is crosscut by faults and fractures oriented ENE/WSW and SW/NE, which themselves are crosscut by lineations oriented NW/SE. With evidence for multiple orientations of deformation, Szél-anya Lineae can be classified as tessera terrain [8].

The Lineae/tessera materials include ten mapped units that are distinguished by their dominant deformation fabrics and the intensity of those deformations. We characterize them into three groups: heavily deformed, volcanically embayed, and arcuate ridged.

The heavily deformed group includes five units that are embayed on the east by regional plains material. These units show evidence for multiple compressional and extensional tectonic events.

The volcanically embayed group includes three mapped units that fall in the center of the Lineae/tessera. These units are relatively smooth with small knobby patches, implying that the underlying material was subjected to tectonic deformation before subsequent volcanic embayment. They have a strong N/S deformation fabric and are cut by linear features trending NNE/SSW, ENE/WSW, and WNW/ESE..

The arcuate ridged group includes two distinct units that are embayed on the west by regional plains material. These units have a sinuous N/S fabric and distinctive E/W gash-like features.

Lineae / Tessera Volcanics: Volcanics constructs superpose all Lineae/tessera units. We distinguished five such units, based on volcanic morphology, degree of deformation, and type of deformation fabric. Small shield volcanos occur in clusters and some are randomly distributed. In most cases, fractures and faults do not extend into/across shield volcanos from the surrounding terrain. However, some shields (and their flows) are cut by faults/fractures and obscure others (**Fig. 2D**). Inferred flows without shield-like volcanic constructs are massive and have mottled SAR-reflectances. Some are undisturbed, others are deformed and cut by fractures.

Regional Plains: South of the fold belt and west of Szél-anya Lineae is an area of low-SAR-backscatter plains. We recognize eight units in these plains, distinguished by radar backscatter (i.e., roughness) and surface deformation features (**Fig. 2C**). Six units have low radar backscatter and range in level of deformation: undeformed, very-fine scale disconnected fractures, connected polygonal fractures, and large wrinkle ridges. Two units have greater radar backscatter. They are relatively smooth and deformed by short and long, sinuous wrinkle ridges and lineaments. Shield volcanos occur on all regional plains units. They are recognized as domes or mounds and are of intermediate radar backscatter. Many have depressions at their summits, and some show lobate extensions like lava flows.

Gina Crater: The Gina impact crater is at the border of the Szél-anya Lineae/tessera and regional plains to the west (**Fig. 2B**). The crater is shorter E/W than N/S, perpendicular to the dominant fabric of Lineae/tessera. Ridges on Gina's floor are parallel to the Szél-anya Lineae fabric, and a few its structures appear to cut Gina's rim. Ejecta from Gina impinges on regional plains units to its west; ejecta lobes to the east (onto Szél-anya Lineae) are indistinct.

Discussion: The Gina area is complex, with evidence of many episodes of eruption and deformation. The oldest feature in the area is the fold belt. It is embayed by, and thus older than, the basaltic plains. It is also truncated by, and thus older than, the Lineae/tessera. The tessera record at least three distinct deformation fabrics: NE/SW fractures, NW/SE fractures, and N/S trending structures (the orientation of Szél-anya Lineae) consistent with being thrust fault traces. The plains, presumed to be basaltic flood lavas, have been deformed in multiple events. Gina Crater is on the boundary of the Szél-anya Lineae and plains units. It post-dates the emplacement of the plains and pre-dates some E/W compression of the tessera/Lineae.

The history of the plains and tessera are difficult to link but have their interaction with Gina in common. While Gina post-dates emplacement of plains units, it appears to have been emplaced into tessera material and is deformed as was the tessera. Volcanic constructs in the tessera exhibit a range of levels of deformation: undeformed to crosscut by fractures and faults of several orientations. This suggests episodic volcanism continued during ongoing deformation of the tessera. This complex history of volcanic, tectonic, and impact events is consistent with the hypothesis that Venus has been recently tectonically active. This interpretation is specific to the Gina Crater area and may not be applicable to all tesserae.

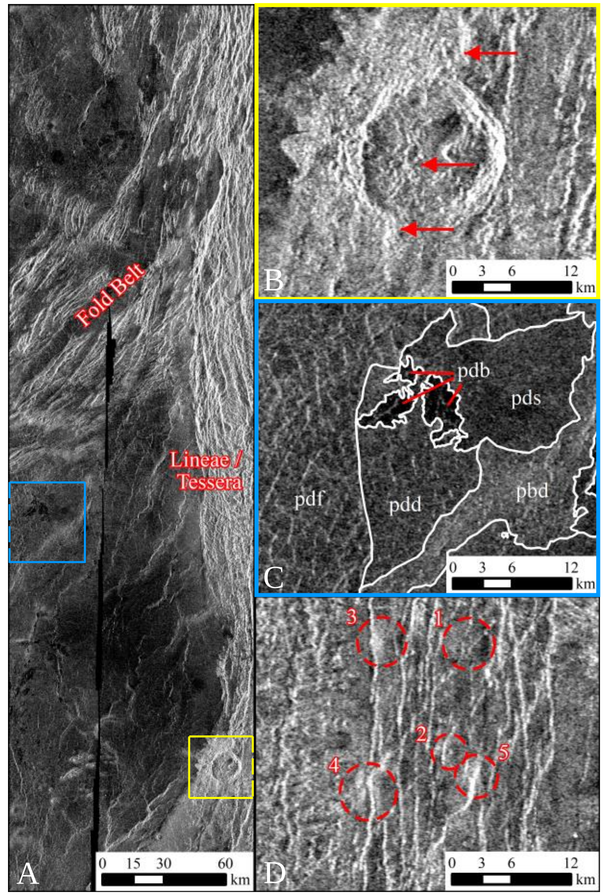

Figure 2. (A) Fold belt embayed by plains and truncated by Lineae/tessera materials. Mercator Projection centered at Gina. North is up. Colored boxes show locations of panels B-C. (B) Deformed Gina Crater with Lineae/tessera. Arrows indicate tectonic fabric trending N/S. (C) Adjacent plains units with different radar backscatter and fracture densities. (D) Shields 1-5 (ordered least to most deformed) cut by faults / fractures with N/S and NE/SW orientations.

Acknowledgment: Supported by NASA SSW grant 80NSSC17K0766.

References: [1] Gregg T. et al. (2022) Planetary Volcanism Across the Solar System 1, 271-286. [2] Strom R. et al. (1994) JGR-P 99, 10899-10926. [3] Phillips R. et al. (1992) JGR-P 97, 15923-15948. [4] Hauck S. et al. (1998) JGR-P 103, 13635-13642. [5] Ghail R. et al. (2002) JGR-P 107, 5060. [6] Byrne P. et al. (2021) Geology 49, 81-85. [7] Byrne P. et al. (2022) LPSC 53, #1197. [8] Hurwitz D. et al. (2012) USGS, SIM 3178. [9] Ivanov M. et al. (2013) PSS 84, 66-92. [10] Akins S. et al. (2014) LPSC 45, #2047. [11] Tanaka K. et al. (1993) USGS, OFR 93-516.