**MULTIPLE TECTONIC AND VOLCANIC EVENTS: GINA CRATER AREA, VENUS.** 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 (eroberts@lpi.usra.edu); [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 ~1.5 Ga, 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.

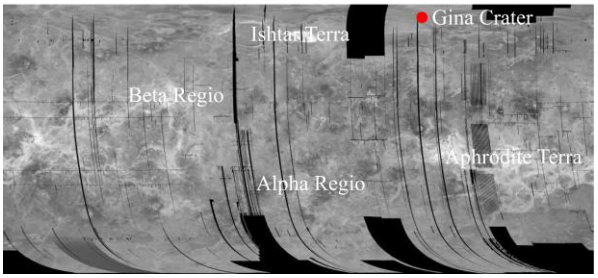


**Figure 1**. Location of Gina Crater at 78.1°N, 76.3°E.

**Data & Methods:** We used the Magellan SAR left-look global mosaic (nominally ~75 m/pix resolution) as the basemap. The area was not imaged in Magellan SAR right-look or stereo-look campaigns. The image was acquired from USGS Map-A-Planet 2 [10]. We used ArcMap 10.6 to compile our observations and the JMARS web interface for general visualizations.

*Morphologies:* Morphologies are defined by shape, orientation, and SAR backscatter. Tectonic features are classified as fractures/ridges, grabens, faults, and lineaments. Fractures/ridges are distinguished by their superposition & cross-cutting relationships, lengths, and connectedness. Grabens are mapped as paired SAR-dark and SAR-bright slopes. Faults are mapped where surface features are offset. Lineaments are mapped as bright, straight lines.

*Map Units:* Map units are identified based on differences in radar brightness, morphology, texture, and stratigraphic relations, according to USGS guidelines [11]. Units are generally defined based on observations of emplaced material, but when material is obscured by deformation, the unit is characterized by deformation. The geologic history of the area is constructed by examination of stratigraphic relationships among units, with an emphasis placed on superposition, crosscutting, and embayment relationships. Contacts are defined by embayment relationships, radar brightness, and deformation morphology and volume.

**Results:** The descriptions of mapped units (Fig. 2A) 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 (*pdl*). The ridges average 1.5 km wide and are separated by 0.5-4 km. The belt is embayed by regional plains units (Fig. 2C) and is cut by fractures/faults of several orientations.

*Regional Plains:* South of the fold belt and west of Szél-anya Lineae is an area of low-backscatter plains. We distinguish eight units. Six units have low radar backscatter and are differentiated by deformation characteristics. The *pdf* unit is densely fractured or cracked in a pattern of connected polygons and is cut by wrinkle ridges. The *pdd* unit has fewer polygonal fractures, which are less obviously connected; it shows wrinkle ridges, but they are smaller and more localized than in *pdf*. The *pds* unit grades by increasing backscatter into other plains units. *Pds* shows few fractures and few short wrinkle ridges, both of which tend to be isolated from each other. The *pbn* runs adjacent to the main fracture belt. *Pbn* contains very fine-scale fractures and large wrinkle ridges that superpose *pdf* and *pdd*. The *pdb* and *pdub* units have a very low SAR backscatter and are surrounded by *pdf*, *pdd*, *pds*, and *pbn*. *Pdb* is recognized as sharply bounded patches and shows no evidence of deformation (perhaps from its low SAR backscatter), whereas *pdub* patches are diffuse. Two plains units have greater radar backscatter. The *pbs* unit is relatively smooth and is deformed by long, sinuous wrinkle ridges and lineaments, whereas *pbd* has shorter wrinkle ridges and is commonly embayed.

*Gina Crater:* The Gina impact crater is at the border between Szél-anya Lineae and regional plains to the west. It is recognized by its rim (*cw*), ejecta (*cre*), and floor materials (*cfh*, *cfg*) (Fig. 2B). The crater is shorter E-W than N-S, perpendicular to the dominant fabric of Szél-anya Lineae. Hills and wrinkles on the crater floor are parallel to that tectonic fabric. On the

crater floor is a small patch of low SAR-backscatter material (*cfd*, like *pdb*). Ejecta from Gina impinges on regional plains units (above) to its west; ejecta lobes to the east (onto Szél-anya Lineae) are indistinct.

*Fracture Belt / Tessera:* Szél-anya Lineae is a belt of heavily deformed rock on the east of the mapped area. Its structure is primarily N-S, marked by rock layering, fractures, and faults. These are crosscut by structures oriented ENE-WSW & SW-NE, and then by others oriented NW-SE. With such multiple deformations, the area is technically tessera [8].

*Shield Volcanos:* Shield volcanos occur on all units (except Gina). They are recognized as domes or mounds <10 km across and are of intermediate SAR backscatter. Many have depressions at their summits, and some show lobate extensions like lava flows. In most cases, fractures and faults do not extend into/across shield volcanos from the surrounding terrain. However, some shields (& their flows) are cut by faults/fractures and obscure others (Fig. 2D).

**Interpretations:** The Gina area is complex, with many episodes of eruption and deformation. The fold belt (*pdl*) is the oldest feature, pre-dating all the plains units. The plains are inferred to be basaltic but without detectable vents. The plains units have been deformed in multiple events. The tessera record at least three distinct deformation fabrics: NE-SW fractures, NW-SE fractures, and N-S deformation consistent with thrust faults (matching the orientation of Szél-anya Lineae). Gina Crater is on the boundary of the Szél-anya Lineae and plains units. Its ejecta lies on the plains units, so it post-dates their emplacement. Gina pre-dates some of the E-W compression of the 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 impacted into tessera material and is deformed, as was the tessera. This suggests that the tessera formed in multiple episodes of deformation while ongoing volcanism emplaced neighboring units. While the specific interpretation and geologic sequence of events seems reasonable for the Gina Crater area, it may not be applicable to all tesserae.

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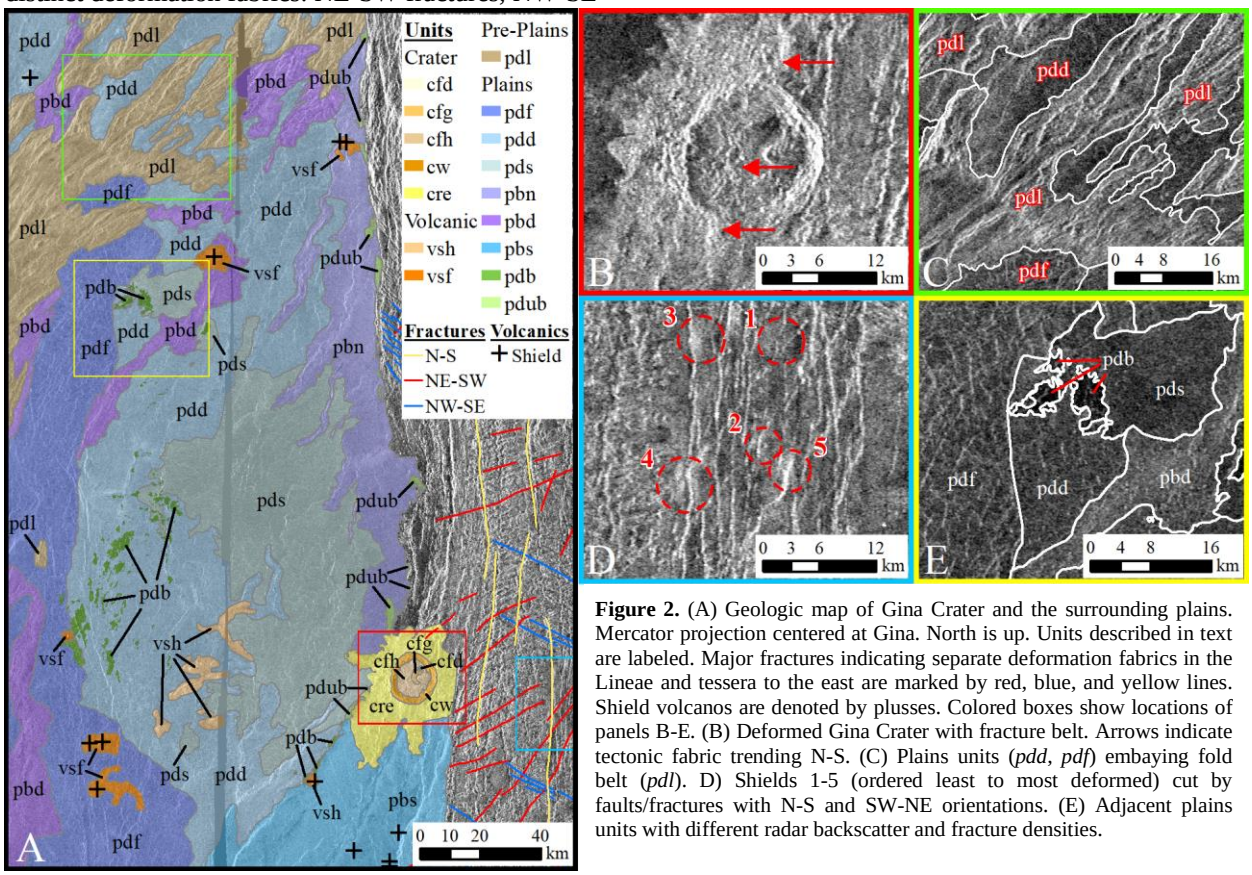


**Figure 2.** (A) Geologic map of Gina Crater and the surrounding plains. Mercator projection centered at Gina. North is up. Units described in text are labeled. Major fractures indicating separate deformation fabrics in the Lineae and tessera to the east are marked by red, blue, and yellow lines. Shield volcanos are denoted by plusses. Colored boxes show locations of panels B-E. (B) Deformed Gina Crater with fracture belt. Arrows indicate tectonic fabric trending N-S. (C) Plains units (*pdd*, *pdf*) embaying fold belt (*pdl*). D) Shields 1-5 (ordered least to most deformed) cut by faults/fractures with N-S and SW-NE orientations. (E) Adjacent plains units with different radar backscatter and fracture densities.