

**GEOLOGICAL HISTORY OF THE ATIRA MONS LARGE SHIELD VOLCANO, BETA REGIO, VENUS.**

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**Introduction:** Atira Mons is a large shield volcano (maximum slope  $\sim 0.35^\circ$ ) located on the NW portion of Beta Regio, covering an area of  $\sim 310,000 \text{ km}^2$  and having an estimated volume of  $\sim 280,000 \text{ km}^3$ . It has an average diameter of  $\sim 600 \text{ km}$ , a height of  $0.9 \text{ km}$  and a central caldera that is  $\sim 100 \text{ km}$  across. Atira Mons is located between Kawelu and Guinevere Planities [1], being the youngest major global geological unit, superposed on groove belts (**gb**), regional plains (**rp1-2**) and plains with shield volcanoes (**psh**) [2].

Compared to previous geological mapping [1, 2], our work provides a more detailed map of the edifice and its context on a scale of 1:500,000 (Fig. 1), permitting the reconstruction of its stratigraphy and geological history and yielding insights on the relative timing and scale of the different evolutionary stages. For example, this will provide important data on the potential volcanic time-volume release of  $\text{CO}_2$  into the atmosphere, and contribute to our understanding of the history of the atmosphere [3]. Geological units are distinguished based on differences in radar properties, topography and morphology. Relative ages of units are assessed from embayment and cross-cutting relationships. To increase the detail and clarity of mapping, we divided Atira Mons into five distinctive sectors (Figs. 2-6). The Summit Sector is bounded by the central caldera rim, while the flank sectors are defined by sharp flow boundaries of widespread geological units.

**Summit Sector History:** From our mapping in the summit region (Fig. 2), eight geological units were distinguished, which cover an area of  $\sim 10,000 \text{ km}^2$  ( $\sim 3\%$  of the total area). They were formed in the following sequence of events: 1) caldera formation with greater collapse on the east side; 2) emplacement of flows on the floor of the caldera, which were later deformed by polygonal fractures and a small set of arcuate fractures [4]; 3) emplacement of younger flows covering part of the summit floor and fed from small shield volcanoes; 4) formation of a set of local wrinkle ridges deforming the youngest flows. The Summit Sector units can be seen covering younger flows on the South-Southwest and East-Southeast sectors, which implies that the caldera subsidence and flows were later events in the geological history of Atira Mons.

**North Sector History:** Sixteen geological units were identified in this sector (Fig. 3), covering an area

of  $\sim 70,000 \text{ km}^2$  ( $\sim 24\%$  of total area). The most pervasive units, radial-trending lobate flows of various widths and radar backscatter, originated on Atira Mons' summit (e.g., **fAM-N-1**, **-3**, **-4**). In addition, younger pulses (**fAM-N-6**, **-7**) originated from point sources outside the summit region and are less widespread. Other flow units (e.g., **fAM-N-9**) do not have a clear source, perhaps fed from a circumferential dyke swarm [5] or, more likely, formed before caldera subsidence.

**West Sector History:** This sector has five units (Fig. 4) and area of  $\sim 20,000 \text{ km}^2$  ( $\sim 6\%$  of total area, the least of all the flank sectors). Wrinkle ridges (**wr**) are the oldest units. They influence the direction of subsequent lava flows (**fAM-W-1** to **-3**) and are partially covered by them. Landslides (**ldsW-1**) (from the summit's rim) cover **fAM-W-2**, providing a timing constraint linking the caldera subsidence with the lava flows on the West Sector.

**South-Southwest Sector History:** Twelve geological units covering an area of  $\sim 110,000 \text{ km}^2$  ( $\sim 35\%$  of total area) are distinguished in this sector (Fig. 5). Wrinkle ridges (**wr**) are the oldest units and are partially covered by later flows. Early and middle flow units (**fAM-S-1** to **-7**) have lengths up to  $\sim 600 \text{ km}$  (e.g., **fAM-S-2**), while later units (**fAM-9** to **-11**) have a maximum length of  $\sim 250 \text{ km}$  and are confined to the vicinity of the summit region. Flow unit **fAM-S-2** has a varying width of  $\sim 180\text{-}50 \text{ km}$  along its length, which reflects changes in regional topography. We are assessing whether this is related to 1) presence of a flexural moat [6, 7], 2) changing lengths of superposed phases of lava flows and/or 3) a step-like topography of the edifice.

**East-Southeast Sector History:** The twenty-eight identified geological units (Fig. 6) cover an area of  $\sim 100,000 \text{ km}^2$  ( $\sim 32\%$  of total area). So far, age relationships are ambiguous and a stratigraphic column is in progress. This sector is characterized by a major arcuate fracture system, which is interpreted to overlie a circumferential dyke swarm [5]. This arcuate fracture system cuts across the majority of the lava flows on this sector, indicating that most of these fractures are younger than the flows. The presence of these arcuate fractures only on the E side could reflect the formation of a partial ( $<360^\circ$ ) circumferential fracture system [8]. We are currently assessing these arcuate fractures and

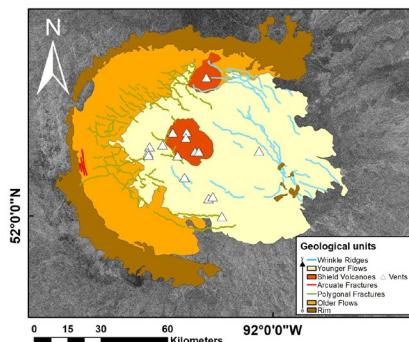
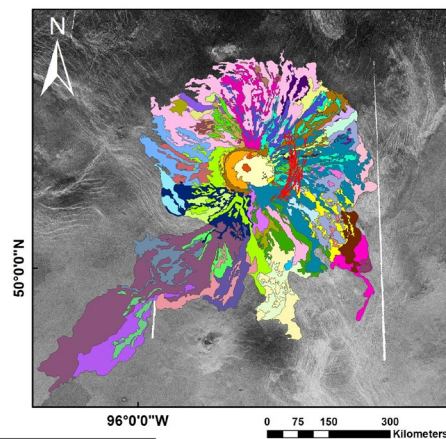
their relation to caldera subsidence and similar features seen in coronae.

**Discussion:** The current state of our mapping allows us to conclude that: 1) The units in the Summit Sector are younger than the flank flows; 2) The caldera subsidence happened late in the volcano's history; 3) The arcuate fracture system on the E is younger than most of the flows on that flank; 4) Generally, larger volumes of magma were emplaced during the early history of Atira Mons; 5) At  $\sim 280,000 \text{ km}^3$ , Atira Mons is almost three times the minimum size for a Large Igneous Province (LIP) on Earth ( $100,000 \text{ km}^3$ ; [9]).

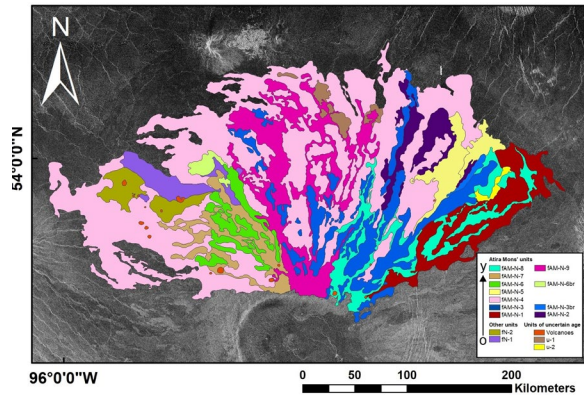
**Acknowledgments:** Magellan SAR images obtained from <https://astrogeology.usgs.gov/search/?pmitarget=venus> based on data from <https://pdsimaging.jpl.nasa.gov/volumes/magellan.html#mgnFMAP>.

**References:** [1] Dohm J. M. et al. (2011) *USGS Sci. Inv.*, Map 3158. [2] Ivanov M. A. and Head J. W. (2011) *PSS*, 59, 1559-1600. [3] Way M. J. and Del Genio A. D. (2020) *JGR*, V. 125 (5), № e2019JE006276. [4] Smrekar S. E. et al. (2002) *JGR*, 107(E11), 8-1 to 8-17. [5] Buchan K. L. and Ernst R. E. (2019) In: *Srivastava et al. (eds.) Dyke Swarms of the World – A Modern Perspective*. Springer, 1-44. [6] McGovern P. J. et al. (2014) *Geology*, 42, № 1, 59-62. [7] McGovern P. J. and Solomon S. C. (1997) *JGR*, 102(E7), 16,303-16,318. [8] Ernst R. E. et al. (2019) *JVGR*, 384, 75-84. [9] Ernst R. E. (2014) *Large Igneous Provinces*. Cambridge U. Press.

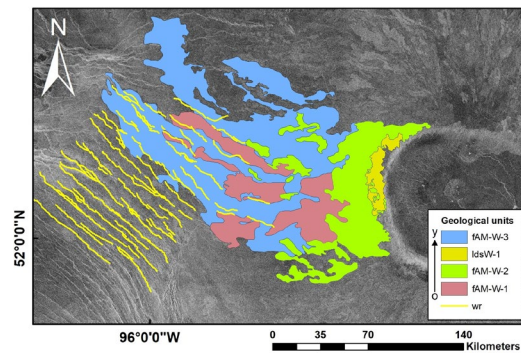
**Figure 1** – Currently mapped geological units. Colors indicate different generations of lava flows, while red lines represent arcuate fractures.



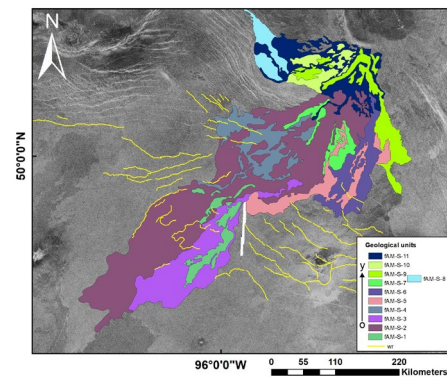
**Figure 2** – Geological map of the Summit Sector.



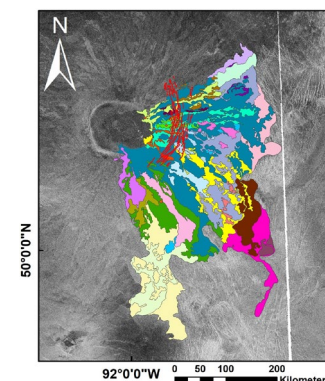
**Figure 3** – Geological map of the North Sector.



**Figure 4** – Geological map of the West Sector.



**Figure 5** – Geological map of the South-Southwest Sector.



**Figure 6** – Geological map of the East-Southeast Sector.