CHARACTERIZATION OF A CALDERA CLUSTER (21.5 N, 201.5 E), NE OF ATLA REGIO QUADRANGLE (V-26), VENUS.

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Introduction: A typical caldera on Venus is described as "circular to elongate in shape, surrounded by an annulus of closely spaced fractures along the topographic rim, a floor from 1 to 3 km below the surrounding terrain, and evidence for associated surface volcanism" [1; see also [2]).

In this contribution we investigate the different collapse stages of a caldera cluster (or caldera complex) labelled C1 located in the NE corner of Atla Regio Quadrangle (V-26) (Fig. 1), by linking them with their fracture systems and lava flows, in order to understand the geological evolution of this caldera cluster. Three additional calderas (C2, C3 and C4) (Fig. 1) are present in the area. Detailed mapping of the Atla Regio portion of this quadrangle is being done by [3, 4]. The northern quadrangle V-14 (north of 25 N) has been mapped at a scale of 1:5,000,000 by [5], and the Ulfrun Regio region to the east has been mapped in detail for graben systems by [6].

Graben Systems: Four main graben systems (interpreted to overlie dyke swarms (e.g. [7]) are present (Fig. 2). The ENE-WSW trending dyke swarm (blue) covers almost the entire study area and possibly originates at Asintmah Corona (25.9°N, 208°E) located 800 km to the ENE. The N-S swarm (yellow) and the NNE-SSW trend of dykes (purple) must be coming from magmatic centers outside the area, but their specific sources are not yet identified. In addition, a dense network of wrinkle ridges with NW-SE trend is also present.

These three main regional graben sets (interpreted as dyke swarms) with trends ENE-WSW, N-S, and NNE-SSW), and also the NW-SE wrinkle ridges are cross-cut by caldera structures and caldera-associated lava flows, and are therefore older. The N-S graben set is observed being cut by the ENE-WSW graben set (associated with Asintmah Corona), and therefore is older. Additionally, wrinkle ridges crosscut clearly the two other graben sets (dyke swarms) and therefore, are younger.

Caldera and associated fractures*:* Four main calderas are present in the study area (Fig. 3a), three of them consist of at least two collapse stages, and the most complex caldera (C1), consists of more than 5 collapse stages (Fig. 3b; Table 1). Each caldera stage can be associated with annular structures, and in some cases, with volcanic lava flows. S1 and S2 represent circumferential fractures or dykes (with a diameter of about 100 km) belonging to the C1 caldera cluster, or perhaps an older larger corona (covered by C1).

Table 1: *Summary of the collapse history of the Caldera Cluster*

Caldera	Characteristics
Caldera a (C1a)	The most developed caldera in the region C1, it has an elliptic feature system (23 km length and 17 km width), with an elevation that reaches 800 m. The southeastern rim is slightly sloping. It consists of two stages.
Caldera cluster b (C1b)	Small, nested caldera with a circular feature system stretching for an arc distance of 170°, with an elevation that reaches 750 m.
Caldera cluster c (C1c)	Nested caldera with an elliptic feature system (32 km length and 24 km width), It consists of a depression which reaches -250 m depth.
Caldera cluster d (C1d)	Nested caldera (large one) with an elliptic feature system, almost completely covered by the younger calderas. It is present on the eastern and western sides of the cluster marked by a dense dyke/fracture swarm. It is also associated with lava flows.
Caldera cluster e (C1e)	Small, nested caldera with a circular fracture system, whose diameter is approximately 20 km.
Caldera cluster f (C1f)	Small, nested caldera in region 1 with a circular fracture system, whose diameter is estimated to be approximately 10 km.

Flows Associated with Caldera Collapse: The distribution of lava flows in the study area is heterogeneous, suggesting multiple phases of volcanic activity. The northern side of the most complex caldera that we label (C1) is covered by the down-slope distribution of a lava flow labelled fC1-a (Fig. 4). The source of this flow is from the youngest caldera that we call C1a, with an elliptical fracture system, and inferred magma reservoir below it. This makes it the youngest flow in this area. The center of C1a caldera is occupied by fC1-d and part of the fC1-c flow. The fC1-d is distributed in the form of separate lobes in northwest and southeast of C1, and it is covered by the fC1-c flow (Fig. 4). fC1-c originates from the C1c caldera. C1b is a small caldera with no apparent associated lava flows; although it is possible that its flows may have been covered by the younger flows. In the western part of C1 a radar-bright flow (fC1-g) appears to originate at a normal fault (part of the rift zone; see below) or at annular structures of a caldera stage. This flow appears younger than flow fC1-d because its boundary has a lobate shape on fC1-d (Fig. 4) and it is older than fC1-

h flow based on boundary geometry and cross-cutting relationships (flow lobes superimposed on the fC1-h flow; Fig 4). The origin of fC1-h flow is still unclear; we provisionally suggest that it is sourced from normal faults associated with a rift southwest of the Caldera complex C1. We are currently integrating our detailed mapping and stratigraphic relationships into an updated synthesis of the geological nad geodynamic history of the region.

References: [1] Crumpler L.S. and Aubele J.C. (2000), in Encyclopedia of Volcanoes, Acad. Press. [2] Head J.W. et al. (1992), *JGR, 97*, 13153-13197. [3] El Bilali, H. et al. (2021) LPSC Abstr. 2529. [4] El Bilali, H. et al. (2022) LPSC Abstr. 1256. [5] Grosfils, E., et al. (2011). USGS SIM 3121 [6] Studd, D. et al. (2011). Icarus, 215, 279-291. [7] Buchan, K.L. and Ernst, R.E. (2021) Gondwan. Res., 100, 25–43

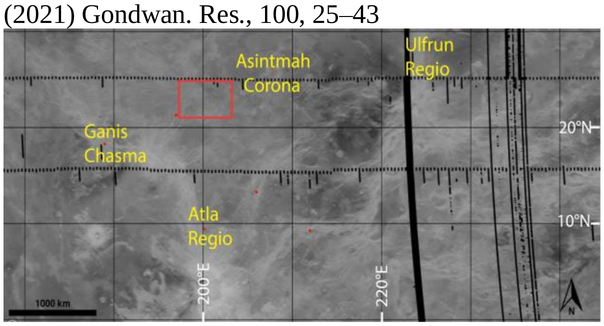

Figure 1. *Regional setting with red box locating study area.*

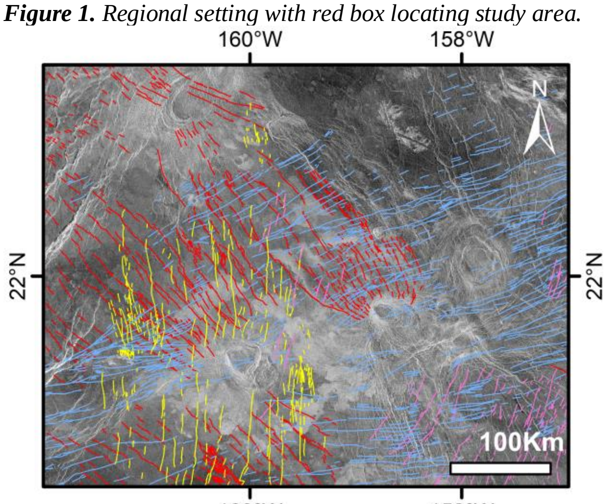

Figure 2. *Distribution of linear graben sets (interpreted to overlie dykes) in the study area: ENE-WSW trend (blue), N-S trend (yellow), NNE-SSW trend (purple) and NW-SE trending wrinkle ridges (red).*

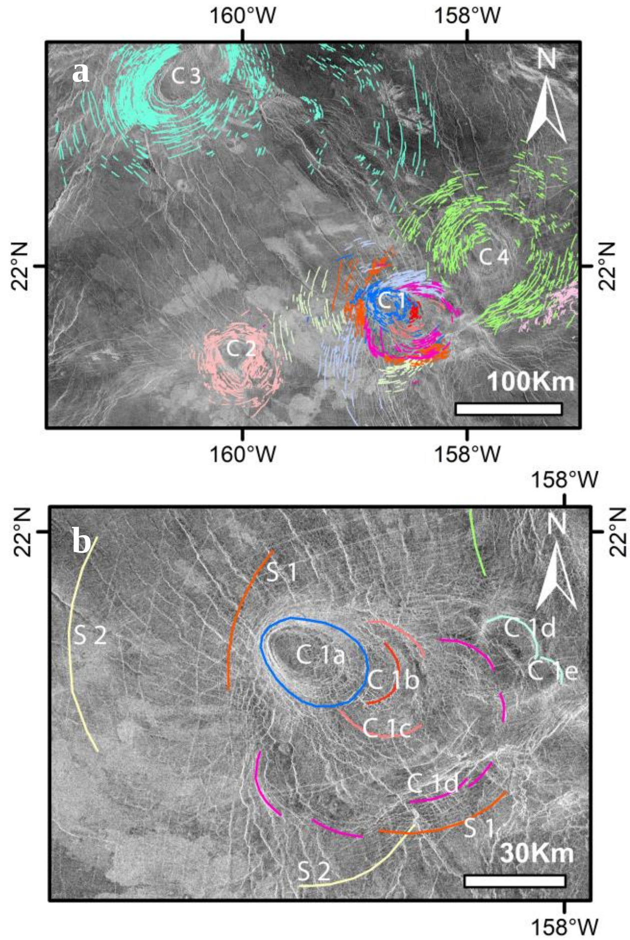

Figure 3. *Circumferential graben systems, superimposed on Magellan SAR image. a) detailed linework of the broader study area; b) generalized linework related to different stages of the Caldera complex C1.*

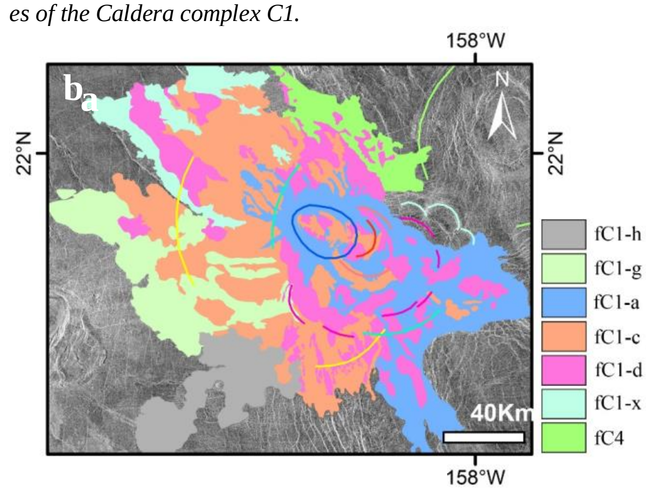

Figure 4. *Distribution of mapped lava flows in C1 Caldera complex area. a) Magellan SAR image, b) Mapped lava flows in C1 Caldera complex superimposed on Magellan SAR image. (fC4 and fC1-x are not described in the text; fC4: flow seems originate at Caldera C4 in the east, fC1-x is an older flow with unknown source).*