# Venus Science Into the Next Decade

**Principal Investigator: Laura Barge (322); Co-Investigators: Suzanne Smrekar (322), Leah Sabbeth (322), Jessica Weber (322), Léo Martire (335), Joseph Schools (322), Joann Stock (Caltech), Jennifer Jackson (Caltech)**

**Program: FY21 R&TD Strategic Initiative** **Strategic Focus Area: Venus Science and Technology 1**

**Objectives:** This project provides the quantitative scientific motivation for future missions from two objectives: I) the first ever comprehensive estimation of Venus' seismicity from both shallow and deep sources, along with modeling of seismic wave propagation into the atmosphere validated using earth data, and II) essential lab work to estimate rates of weathering, including of rock indicative of past water (Venus' putative granitic continents).

**Background**: Revealing Venus' geological history is key to our understanding of how Earth-like planets have evolved. Venus is the only terrestrial for which we can't answer such basic questions as 1) what are the youngest geological processes? 2) What processes are active? 3) What is the composition of the surface? 4) Is there chemical evidence for past surface water? The morphology of the structural features as well as the youthfulness of the planet's surface testify to the potential for seismic activity. There is evidence that both the crust of Venus has experienced stress, causing strain release expressed in a wide range of structural features, and relatively recent volcanic activity. However, the contemporary rate of strain release, seismicity associated with volcanism, and detectability estimates are unknown. Weathering of rocks and minerals on Venus is also not well understood. Limited data on surface composition, lower atmospheric chemistry, and the challenges of conducting experiments under Venus conditions have resulted in a dearth of much needed experimental constraints.

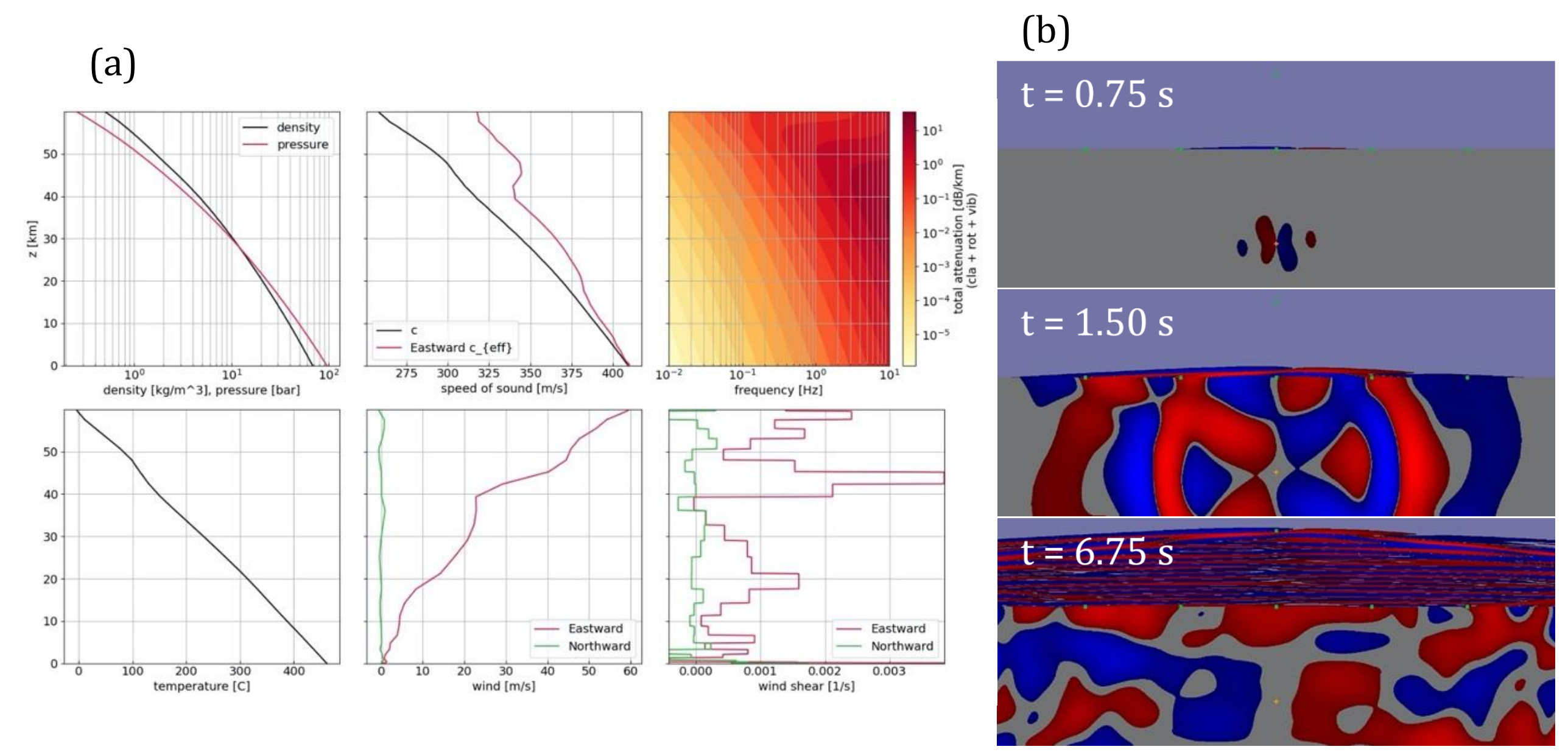

Figure 1: Venusquake modeling (Léo Martire, JPL Postdoc). (a) Venus' atmospheric model, extracted from LMD's (Laboratoire de Météorologie Dynamique, Paris, France) Venus Climate Database (VCD, based on data assimilation and global circulation models). (b) Full-wave SPECFEM2D-DG (Brissaud et al., 2017, Martire et al., 2021) coupled seismo-acoustic 2D simulation snapshots. The ground model is chosen as an Earth analogue, the crust under the Tarim Basin (39.2N, 82.2E), based on (Byrne et al., 2021). The source is a 2.5 km deep thrust fault (dip=30, rake=90), based on wrinkle ridges characteristics.

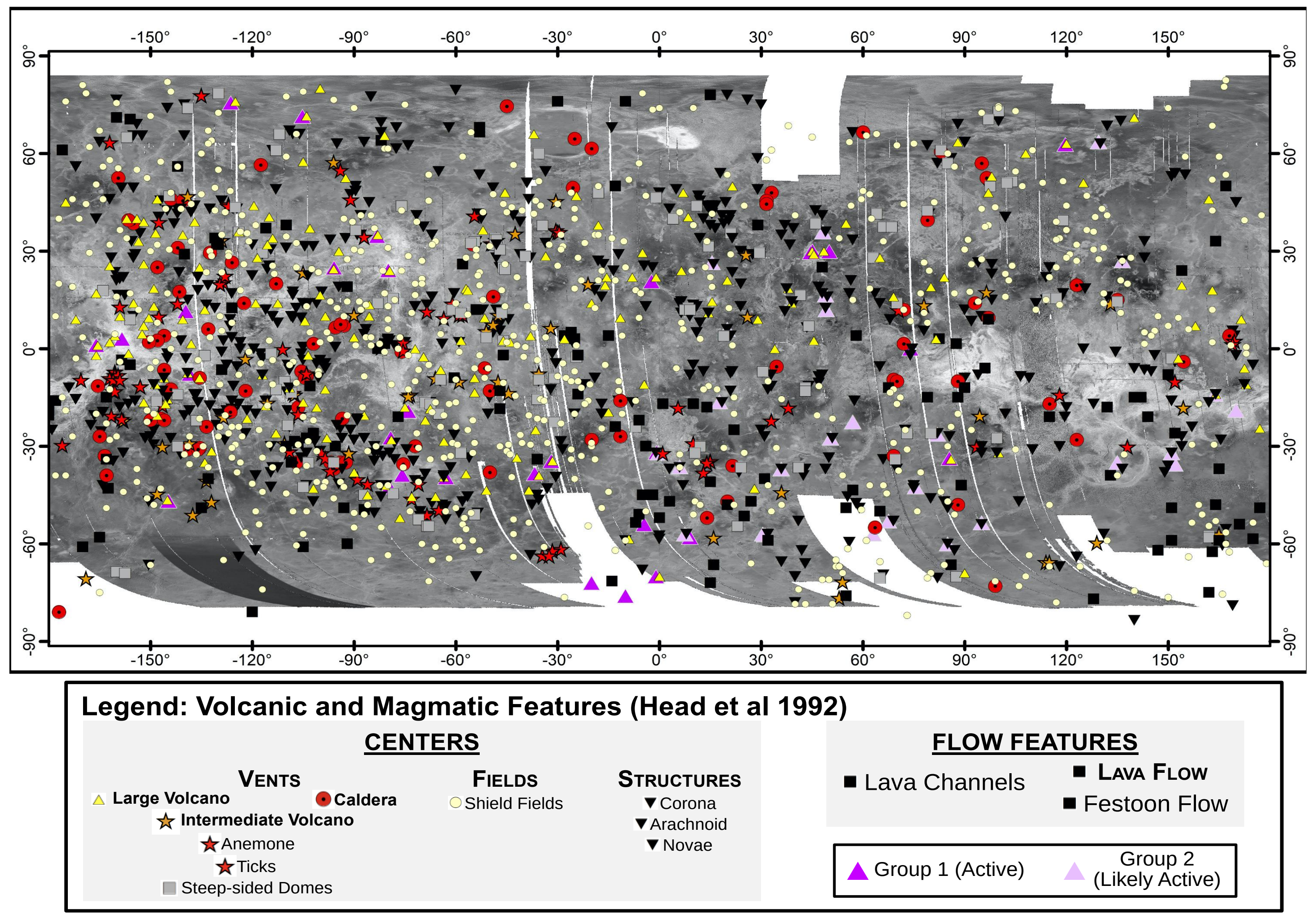

Figure 2: Mapped volcanic and magmatic features mapped on Venus, which are classified as shown in the legend (Head et al., 1992). Calderas are the most likely sources of infrasound due to their common collapse features. Anemones and ticks are also likely sources of infrasound due to their morphology, since they are prone to landslides and rockfalls. Steep-sided domes are formed by highly viscous material which does not erupt, and are likely incapable of producing infrasound via an eruption or collapse event. Tremors, which have been detected with infrasound on earth, are the result of magma movement in any magmatic feature. Thus, features including large coronae, shield fields, and even steep-sided domes and flow fields may be capable of producing infrasound. Purple triangles indicate features and regions which have been studied in literature and have evidence for activity. Group 1 (Active, dark purple) includes Venusian highlands with geoid-topography ratio anomalies indicating recent formation (Smrekar & Phillips, 1991), areas with VIRTIS emissivity anomalies (Helbert et al., 2008) and those indicating hotspot volcanism (Smrekar et al., 2010), and coronae and volcanoes with Magellan emissivity anomalies indicating a lack of weathering (Brossier et al., 2020). Group 2 (Likely Active, light purple) includes and coronae and volcanoes with a smaller signature in Magellan emissivity anomalies that indicate a lack of weathering (Brossier et al., 2020), as well as coronae with morphological evidence for recent formation (Gülcher et al., 2020). (JPL postdoc, Leah Sabbeth).

**National Aeronautics and Space Administration**

**Jet Propulsion Laboratory**
California Institute of Technology
Pasadena, California

www.nasa.gov

**PI/Task Mgr Contact**
**Email: Laura.M.Barge@jpl.nasa.gov**

**Significance to JPL/NASA:** NASA has not visited Earth's twin planet in 30 years; there is growing momentum to return to Venus and now there are two new missions selected: VERITAS (PI: Smrekar) and DAVINCI. JPL also recently invested in balloon studies for long term atmospheric and surface investigations as a possible candidate mission for the next New Frontiers call. Both VERITAS and a New Frontiers mission would map surface composition at different resolutions, and would look for geologic activity using different approaches. This initiative focuses on the science case for seismology and surface mineralogy. A balloon mission would focus on detecting seismic waves propagating into the atmosphere and near IR observations of surface mineralogy. This proposal provides the quantitative scientific motivation for a variety of future mission architectures.

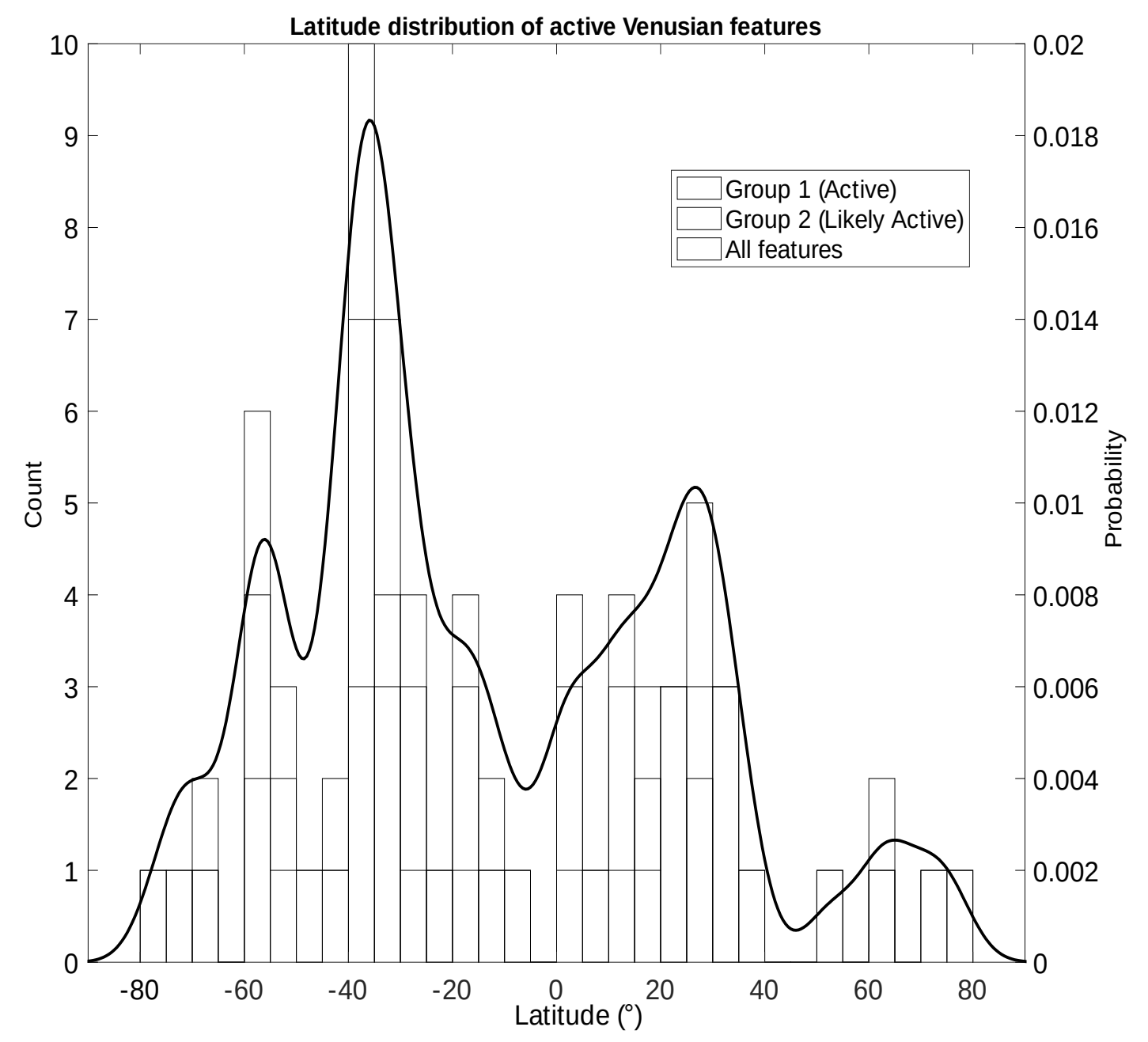

Figure 3: Latitudes of features studied in literature with evidence for activity from Figure 2. Pink bars represent Group 1 (Active), blue bars represent Group 2 (Likely Active), and grey bars represent the sums of Groups 1 and 2. Probability density function is shown for all features (black line). Most features lie within -40° and +40° latitude. JPL postdoc, Leah Sabbeth).

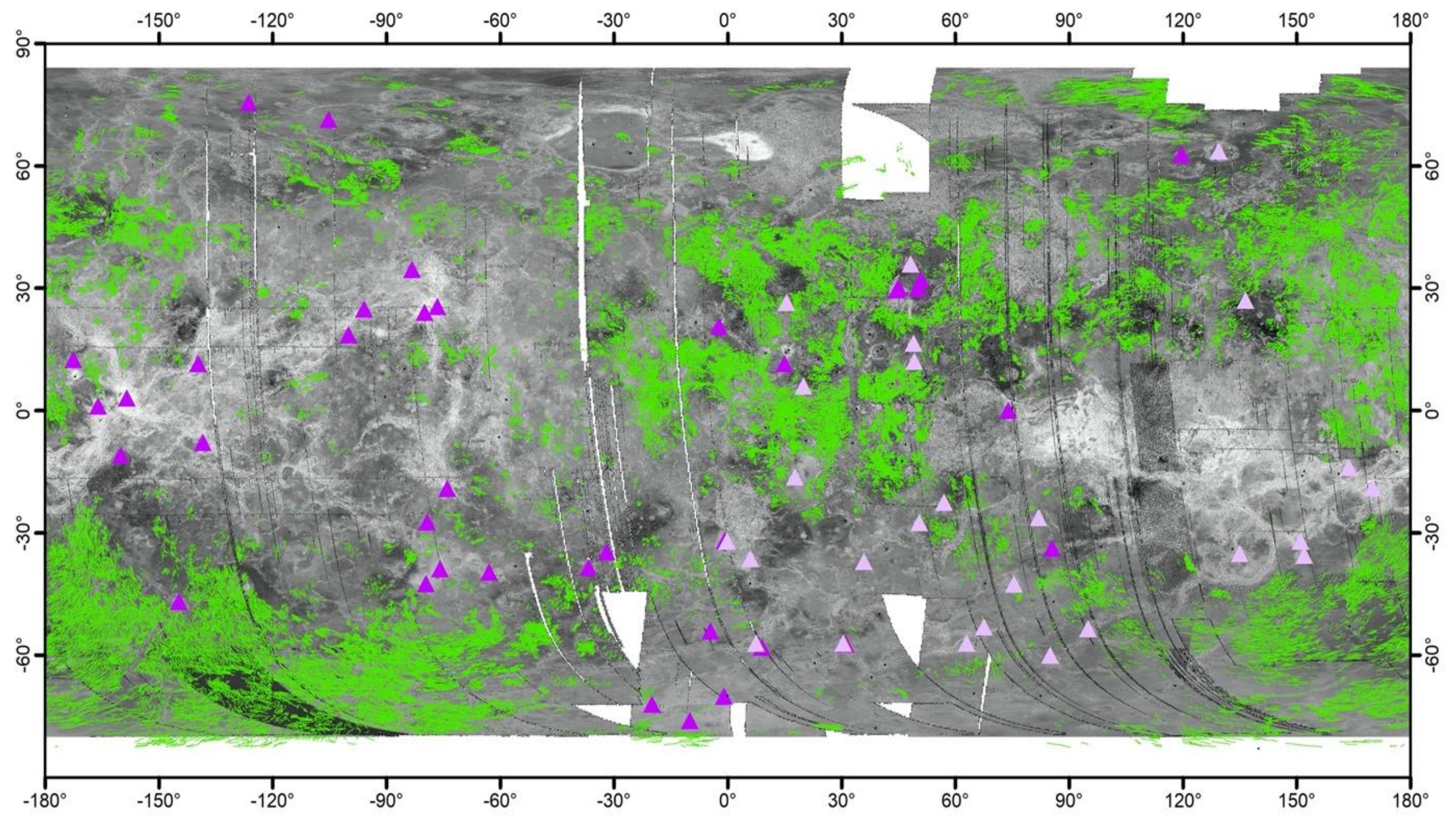

Figure 4: Green lines are wrinkle ridges (Bilotti & Suppe, 1999), with active features from Figure 2. Note the wrinkle ridges overlap with areas with purple triangles, which indicate regions and features that have been studied and have evidence activity (Figure 2). (JPL postdoc, Leah Sabbeth).

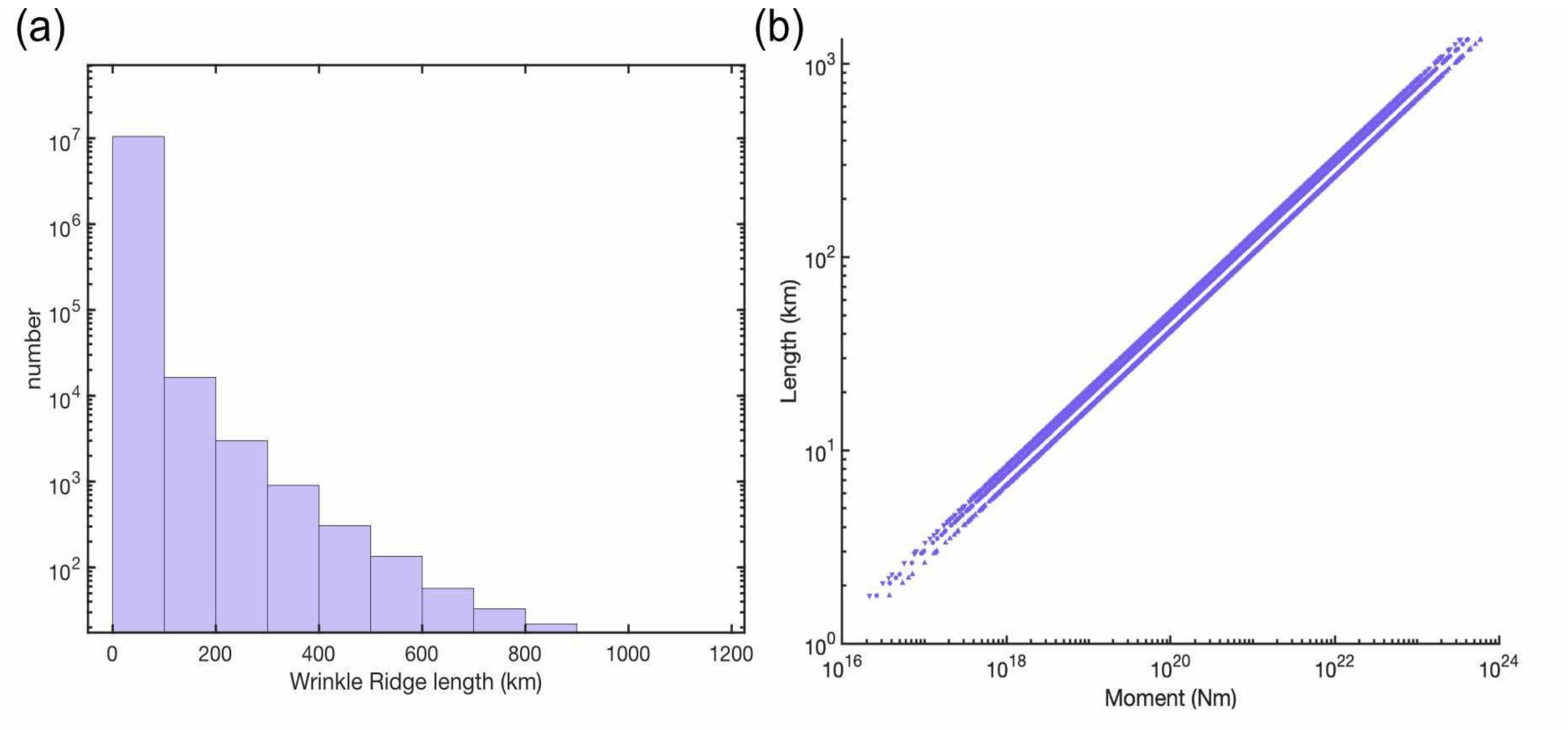

Figure 5: Histogram of wrinkle ridge lengths shown in Figure 4 mapped by Bilotti and Suppe (1999) (a). Using a fault length-moment release scaling relationship (Leonard, 2010), we are able to determine moment releases of venusquakes on these wrinkle ridges (b) for a shear modulus of 57 GPa (triangles), 70 GPa (circles), and 100 GPa (upside-down triangles). For reference, a moment release of $10^{16}$ is approximately a $M_w$ 5 event, and a moment release of $10^{24}$ is approximately a $M_w$ 9 event. Probably wrinkle ridges are rupturing in segments (i.e., shorter lengths included here) in $M_w$ 5 events. Work to understand segmenting of fault ruptures is ongoing.

**Clearance Number: CL#21-4368**
**RPC/JPL Task Number: R21010**