National Aeronautics and Space Administration

FY23 Strategic Initiatives Research and Technology Development (SRTD)

Venus Science Into the Next Decade

Principal Investigator: Laura Barge (322)**; Co-Investigators:** Jessica Weber (322), Suzanne Smrekar (322), Leah Sabbeth (322), Leo Martire (335), Siddharth Krishnamoorthy (335), Attila Komjathy (335), John-Paul Jones (346), Joann Stock (California Institute of Technology), Jennifer Jackson (California Institute of Technology)

Strategic Focus Area: Venus Science and Technology Initiative | **Strategic Initiative Leader:** Jeffery L Hall

Background:

The science community's growing interest in Venus should be accompanied by a strong research initiative to ensure JPL is the leader for Venus exploration. This task provided the quantitative scientific motivation for future Venus missions from 2 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) estimate rates of weathering, including of rock indicative of past water (Venus' putative granitic continents). This task addressed the essential elements needed to enable the selection of such a mission: 1) provide a comprehensive estimate of likely active seismicity on Venus, based on a range of possible seismic sources (volcanos, shallow faulting, and deep, phase-change driven quakes), 2) provide seismic detectability estimates via comprehensive modeling of seismic wave propagation in Venus' atmosphere, and 3) assesses mineralogy as a way to identify and provide an age estimate for recent volcanism. This work could also be used to justify other types of measurements of seismicity from orbit and surface landed missions to investigate mineralogy and weathering.

Significance/Benefits to JPL and NASA:

Revealing Venus' geological history is key to our understanding of how Earth-like planets have evolved. NASA has not visited Earth's twin planet in 30 years; now, there are two NASA missions selected to return to Venus, including VERITAS. JPL has also recently invested in balloon studies for long term atmospheric and surface investigations on Venus. Both VERITAS and an atmosphere balloon mission would map surface composition at different resolutions, and would look for geologic activity using different approaches. This initiative focused on the science case for seismology and surface mineralogy. Evidence suggests that Venus may have seismic activity; and that the crust of Venus has experienced stress, causing strain release expressed in a wide range of structural features - however, the contemporary rate of strain release is unknown, and no mission to date has had the capability of detecting a venusquake. Weathering 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. We began to use the new Venus reactor lab facility, which became operational in Y3, to provide this valuable information with experiments on Venus analog minerals.

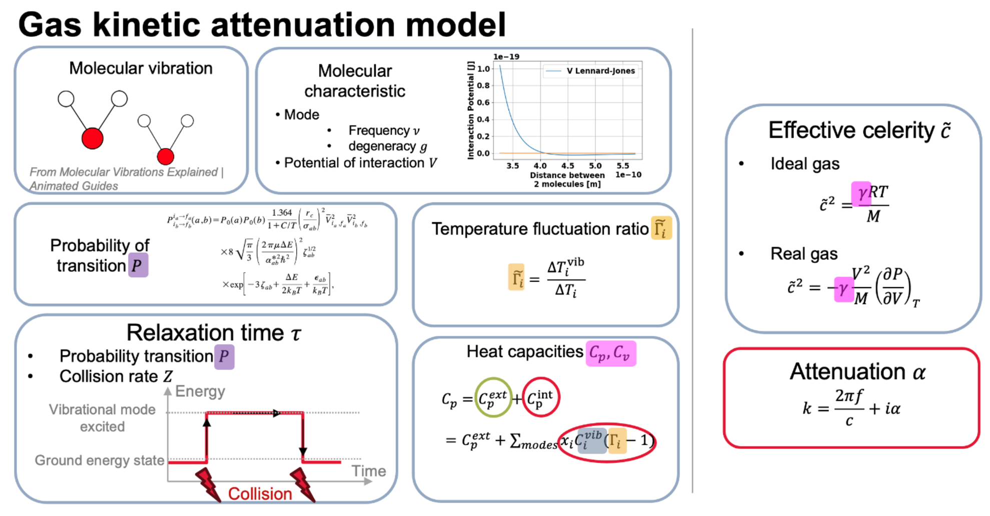

Figure 3. In this task we developed and tested a chemical kinetics-based model to examine impact of supercritical CO_2 on acoustic attenuation, and also examined ideal gas vs. Peng-Robinson equation of state (real gas) effects

Objectives:

- **Objective 1A:** Shallow Seismicity. In this Objective we identified seismic 'type locales' based on geologic setting identifying the fault dimension, type, and likely magnitude; and determine likely active sources. These Tasks were integrated to produce a defensible estimate of seismicity on Venus.
- **Objective 1B:** Deep Seismicity. In this Objective we identified likely regions of subduction, lithospheric dripping, and crustal thickening, to estimate potential sources of deep seismicity. We also planned to conduct laboratory measurements to explore the characteristics of hydrous and anhydrous (metastable) phase transitions at depth.
- **Objective 1C:** Surface-atmosphere coupling. Seismic events and propagation of related pressure waves in Venus' atmosphere were investigated through seismo-acoustic modeling in order to understand detectability (a crucial aspect of future mission designs).
- **Objective 2:** Mineral Weathering. We performed weathering studies on minerals under Venus surface conditions using the newly operational Planetary Geochemistry Simulation Facility.

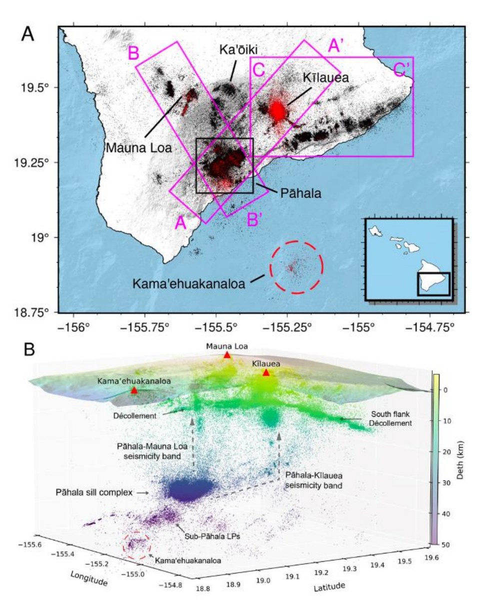

Figure 1. Caldera Collapse: we know volcanic caldera collapses produce impressive sustained seismicity (Wilding *et al. Science*, 2022)

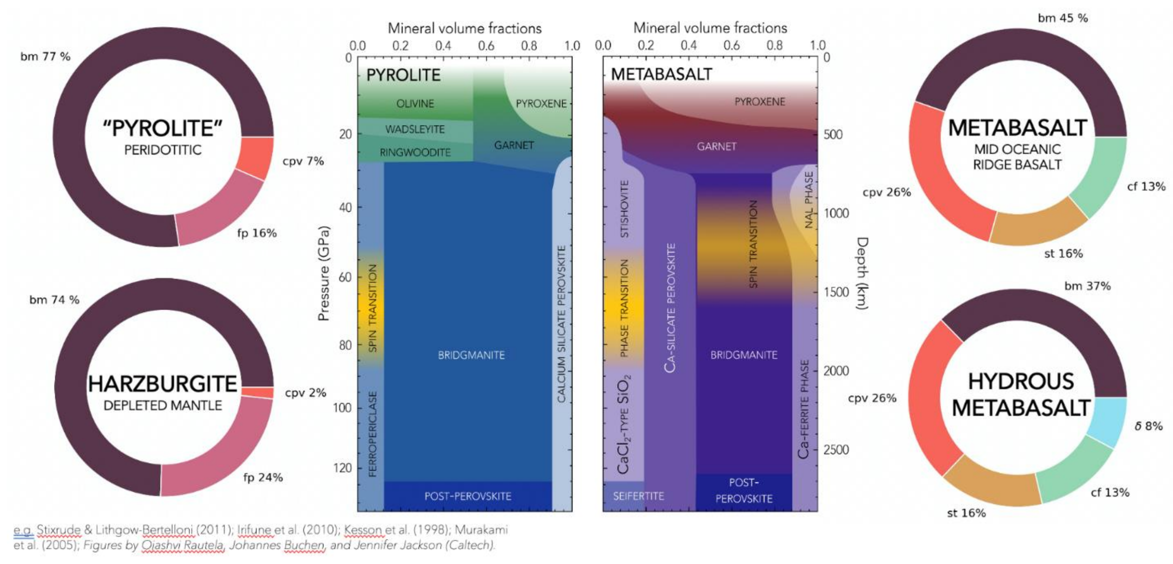

Figure 2: Candidate mantle rocks for Venus and their chemically distinct mineralogy

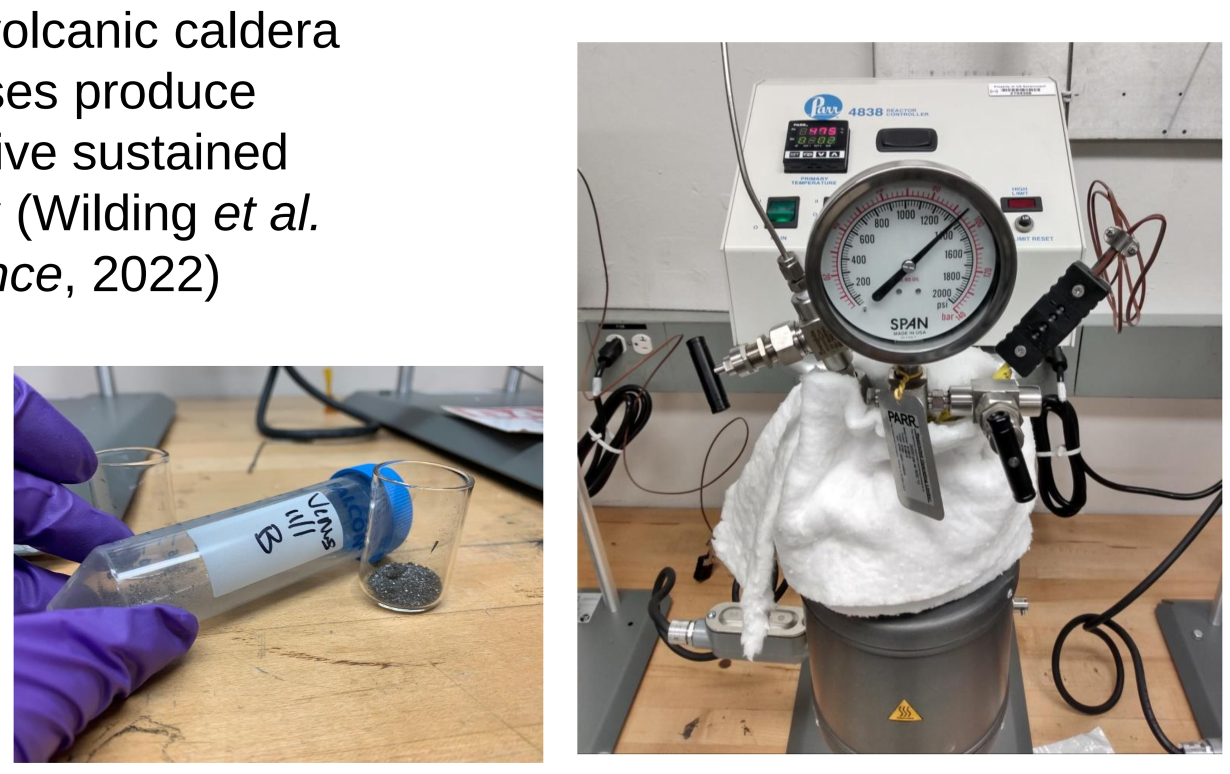

Figure 4: L) Photo of magnetite mineral after a 5 day weathering experiment (450 °C, 92 atm) in the JPL Venus reactors. R) one of the five operational Venus reactors in the JPL Planetary Geochemistry Simulation Facility

Publications:

- Sabbeth, L., S. E. Smrekar, and J. M. Stock. "Estimated seismicity of Venusian wrinkle ridges based on fault scaling relationships." Earth and Planetary Science Letters 619 (2023): 118308.
- Sabbeth, L., Smrekar, S. E., & Stock, J. M. (2023). Using InSight data to calibrate seismicity from remote observations of surface faulting. Journal of Geophysical Research: Planets, 128, e2022JE007686. https://doi.org/10.1029/2022JE007686
- Dobrosavljevic, V.V., D. Zhang, W. Sturhahn, J. Zhao, T.S. Toellner, S. Chariton, V.B. Prakapenka, O.S. Pardo, and J.M. Jackson (2023, under review): Melting and defect transitions in FeO up to pressures of Earth's core-mantle boundary, Nature Communications, in press.
- Pardo, O.S., V.V. Dobrosavljevic, W. Sturhahn, T.S. Toellner, B. Strozewski, and J.M. Jackson (2023): Lattice dynamics, sound velocities, and atomic environments of szomolnokite at high pressure. Physics and Chemistry of Minerals, in press.
- Wilding, J.D., W. Zhu, Z. Ross, and J.M. Jackson (2022): The magmatic web beneath Hawai'i. Science, 10.1126/science.ade575. Evidence for sustained seismicity due to caldera collapse.

PI/Task Mgr. Contact Information: Laurie Barge

(3-8209, laura.m.barge@jpl.nasa.gov)

National Aeronautics and Space Administration

Jet Propulsion Laboratory
California Institute of Technology
Pasadena, California

www.nasa.gov

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