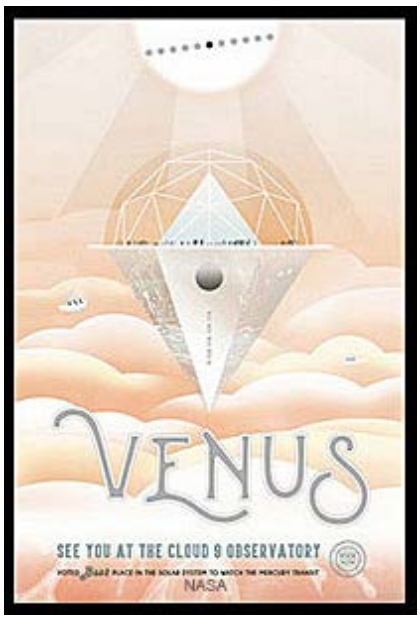
PLANETARY SCIENCE RESEARCH PSRD Discoveries

Headline Article

March 9, 2020

Greatest Show on Venus: Lavas are Hot and Fresh Out of the Mantle



--- Spectral observations of the surface of Venus and experiments determining rates of alteration due to the hot Venusian atmosphere indicate that some basalts on the planet's hot surface formed within the past several years.

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The surface of Venus is decorated with volcanoes and lava flows. Some of these lava flows exhibit a spectral feature at a wavelength of about 1 micron (µm), which will disappear over time due to the hot Venusian atmosphere reacting with the surface of rocks to form a weathered coating. Because some of the flows still display a 1-µm spectral feature, they are estimated to be relatively young, perhaps only a few hundred thousand to millions of years old. However, the actual rate of formation of the weathered coating is unknown, limiting the accuracy in estimating the ages of these lava flows. A group led by Justin Filiberto (Lunar and Planetary Science Institute), with colleagues there, and at the University of Hawai‘i and Wesleyan University, addressed this problem by performing experiments on lava rocks exposed to high temperatures (600 and 900 degrees Celsius) to determine the rate of alteration on Venus. The results suggest that weathering would remove the 1-µm feature in only a few years, at most. This suggests that at least some lava flows on Venus formed during the past few years.

Reference:

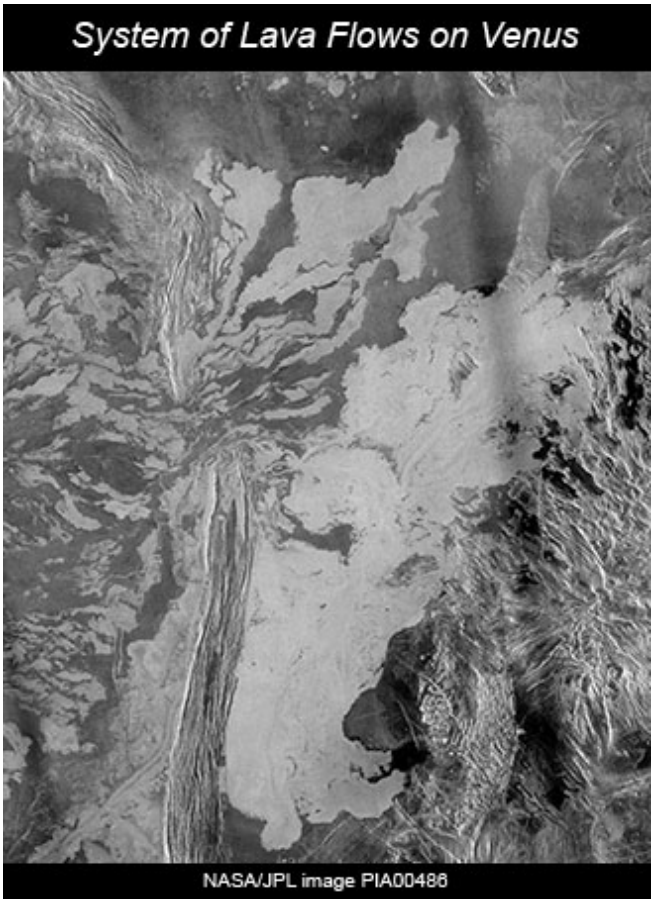
- Filiberto, J., Trang, D., Treiman, A. H., and Gilmore, M. S. (2020) Present-day Volcanism on Venus as Evidenced from Weathering Rates of Olivine, *Science Advances,* v. 6(1), eaax7445, doi: 10.1126/sciadv.aax7445. [**article**]
- **PSRDpresents:** Greatest Show on Venus: Lavas are Hot and Fresh Out of the Mantle --**Short Slide Summary** (with accompanying notes).

Lava Flows on Venus

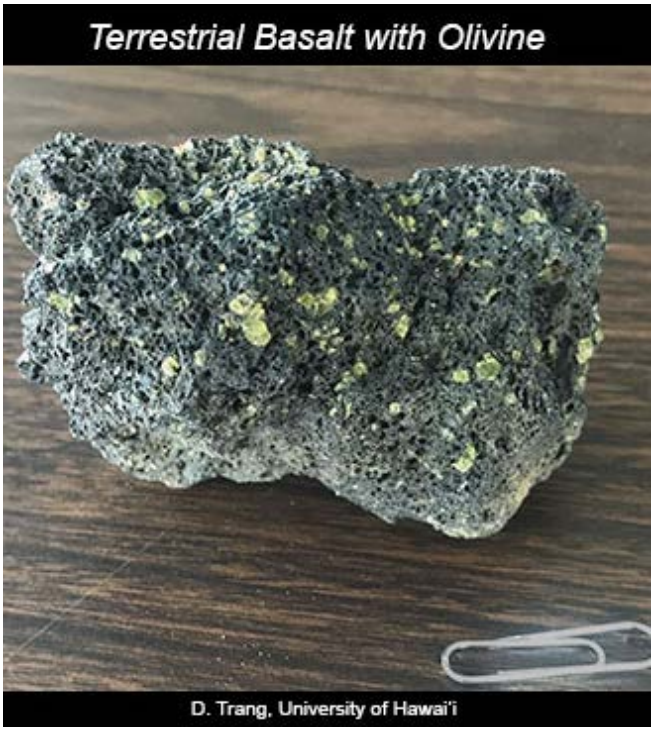
There have only been a handful of missions to study Venus' surface and geology because observing the surface is difficult due to the atmosphere blocking most visible to near-infrared light. One solution to seeing the planet's landscape is to place a lander on the surface, similar to the series of Soviet probes named **Venera**. However, the atmosphere is hot, corrosive, and thick, which only allows probes to operate for a few hours

before succumbing to the unforgiving environment. Nonetheless, Venus' atmosphere has not crushed human determination to understanding its geology.

Although Venus' atmosphere prevents the use of common methods to observe and study the surface from orbit, such as visible cameras, several missions have used other methods to probe the surface, which include using microwaves and a few specific **wavelengths** in the near-infrared to see through the thick clouds. Also, the Soviet's Venera Lander Missions (circa 1981) lasted long enough to provide very important compositional information of the surface. These missions revealed that Venus contains a variety of volcanic structures and that one of the dominant rock types is **basalt**, a type of volcanic rock commonly observed on the surface of Earth in lava flows in Hawai‘i, the ocean seafloor, and Iceland.

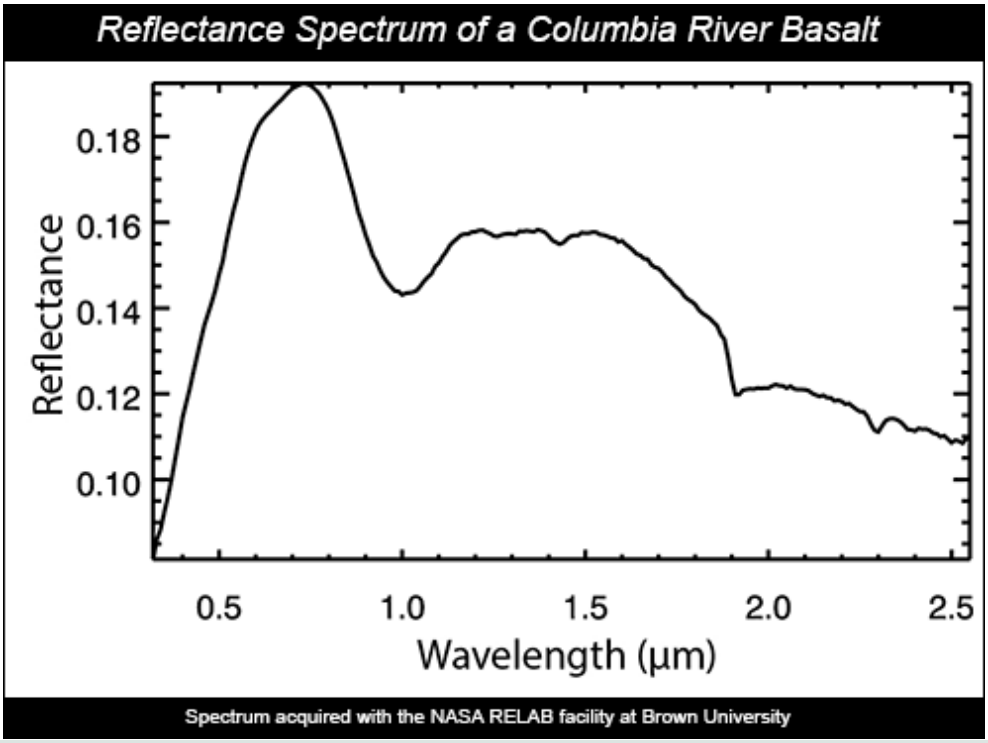


This mosaic of radar images from NASA's Magellan spacecraft (1989-1994) shows the radar-bright and dark lobes of lava flows on Venus. As the lava flows moved from left to right across this 550-kilometer-wide scene, they breached a north-south ridge belt (vertical stripes seen left of center), then pooled in a large, radar-bright deposit (right half of scene). Click for more information.



Photograph of a basalt rock with olivine, from Papakōlea on Hawai‘i island. The composition of this rock type is similar to the composition of the rock type found on Venus. This rock contains large green crystals of olivine. Olivine crystals in basalt can range in size, including down to microns.

Luckily, the specific wavelength within the near-infrared that could be used to observe Venus' surface from space is also critical to understanding the composition of basalts; this wavelength is at 1 µm. Basalts that contain any amount of iron will exhibit a 1-µm absorption feature (see below). Therefore, it is possible to observe the distribution of basalts and their iron contents. However, Venus' hot, high-pressure, CO_2- and sulfur-rich environment will cause chemical alteration to the basalt, called **weathering**. As a result, this 1-µm absorption feature will disappear as basalt forms reddish-brownish oxidation minerals on the surface of the rock, namely **hematite** and **magnetite**. Therefore, observations of the 1-µm absorptions on Venus' lava flows would indicate that the lava flow is relatively young because it did not have time to weather. In fact, there have been observations of the 1-µm absorption, which led some researchers to conclude that volcanoes on Venus are active with 'recently' erupted material. In the geologic context, 'recent' means thousands to millions of years and in the case of Venus, the best estimates suggest that the lava flows are 250,000 to 2.5 million years old. However, the actual ages of these flows are not known because the rate of weathering causing these 1-µm absorptions to disappear is unknown.

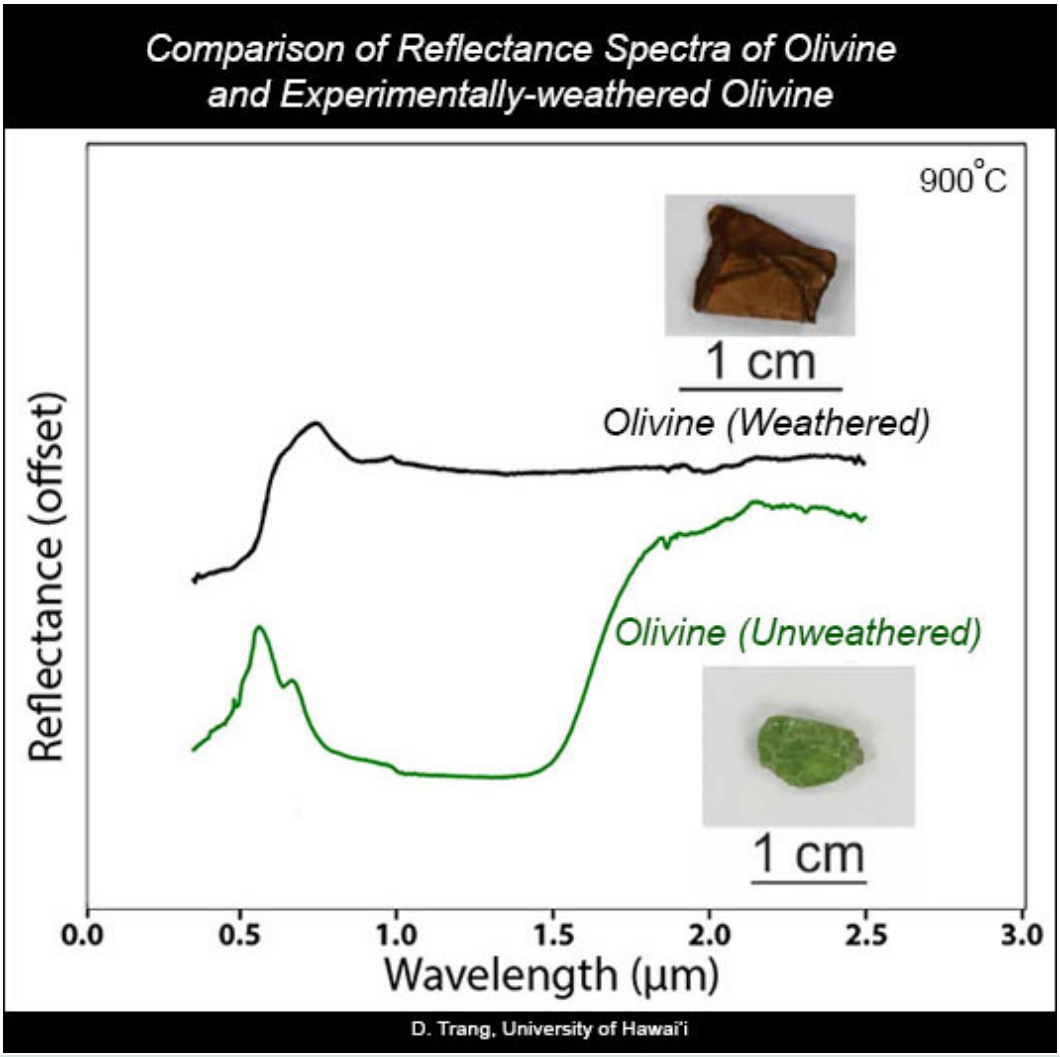


Reflectance spectrum of a Columbia River basalt measured by the Keck/NASA Reflectance Experiment Laboratory (**RELAB**) at Brown University. This basalt exhibits a 1-µm absorption, a common feature found in this rock type.

Hot Weathering Experiments

Justin Filiberto and friends (which includes me!) became interested in the actual ages of these lava flows on Venus. To determine the ages, the team performed experiments to determine how long it took for the 1-µm absorption feature to disappear. To do this, Filiberto and team took a common mineral found in basalts, **olivine** (see rock photograph above), which also shows a similar 1-µm feature, and placed it in a hot furnace at 600 or 900 Celsius (**°C**) in Earth's atmosphere between 12 minutes to about 26 days. Although these temperatures and atmospheric compositions are different from Venus, we expected the experimental weathering rates at 600 °C in Earth's atmosphere are comparable to weathering rates on Venus. These minerals were exposed to high heat, then the olivine crystals were removed from the furnace and measured in visible to near-infrared reflectance bands to examine the strength of the 1-µm absorptions in relation to exposure time to high heat.

After removing the olivine crystals from the furnace set at 900 °C, we noticed reddish-brownish coatings began to cover the mineral after 12 minutes. After 5 hours, the olivine appears to be completely coated with the oxidation minerals (see photo-insets in the figure below). In comparison, the olivine crystals from the 600 °C experiments show similar results, but progressed at a slower rate. Even after 26 days, the reddish-brownish coating did not completely cover the entire mineral. From a visible to near-infrared perspective, the 1-µm absorption from the olivine crystals exposed to 900 °C weakened and disappeared after 25 hours and converted to hematite by the end of the 26 days of exposure. Again, the olivine crystals exposed to 600 °C showed similar trends, but at a slower pace, but never made it to the stage where it was completely covered with hematite after 26 days. Extrapolating the results, if the experiments were to continue, we would suspect that the olivine crystals would be completely coated with hematite after several months to a few years.



Comparison of two spectra. The green line is the reflectance spectrum showing the 1-μm absorption (wide dip) in the unweathered olivine. The black line is the reflectance spectrum of the weathered olivine, which developed a coating of reddish-brown hematite and magnetite after heating at 900 °C in a furnace for 26 days. The experimentally-weathered olivine no longer shows the 1-μm absorption and looks more like a spectrum of hematite.

Active Volcanism on Venus

These experimental findings are very important to understanding volcanic processes on Venus. The results support the idea that after the emplacement of lava on the surface of Venus, magnetite and hematite completely coat these lava flows within years causing the 1-μm absorption feature to no longer be observable. However, because we do observe 1-μm absorptions in some lava flows, this would indicate that these lava flows are not thousands or millions of years old, as previously guessed, instead they are likely several years old. In other words, it is likely that Venus is currently volcanically active and is emplacing lava on the surface today.

To verify that lava flows on Venus are several years old, the next set of experiments are planned to put basalt, instead of olivine, into the furnaces to determine if the weathering rates are similar. On the other hand, to confirm that Venus is currently spewing lava as we speak, the planetary science community could emphasize the need to send a new and much-needed mission to our sister planet and see it happening directly. Three Venus mission concepts are in the works. NASA has selected two Discovery-class missions to Venus for Phase A concept studies, which means these are not official missions yet, but may be chosen in the future to move forward. One of these concepts is DAVINCI+: Deep Atmosphere Venus Investigation of Noble gases,

Chemistry, and Imaging Plus. It is designed to analyze the planet's atmosphere and image the surface at optical wavelengths. James Garvin of NASA's Goddard Space Flight Center is the principal investigator. The other concept is VERITAS: Venus Emissivity, Radio Science, InSAR, Topography, and Spectroscopy. It is designed to use radar and infrared spectroscopy to map the surface. Suzanne Smrekar of NASA's Jet Propulsion Laboratory is the principal investigator. The European Space Agency is looking at the M-class orbiter mission study called EnVision. It is designed, in collaboration with NASA, to use radar, InSAR, and a suite of spectrometers to analyze the planet. Caroline Dumoulin of Laboratoire de Planétologie et Géodynamique de Nantes, France is the principal investigator. These missions, if selected, will help determine the nature and current state of geological activity on Venus. Onward to Venus!

Additional Resources

Links open in a new window.

- **PSRDpresents:** Greatest Show on Venus: Lavas are Hot and Fresh Out of the Mantle --**Short Slide Summary** (with accompanying notes).

- Filiberto, J., Trang, D., Treiman, A. H., and Gilmore, M. S. (2020) Present-day Volcanism on Venus as Evidenced from Weathering Rates of Olivine, *Science Advances,* v. 6(1), eaax7445, doi: 10.1126/sciadv.aax7445. [**article**]

- Lunar and Planetary Science Conference 2020 Program Session, **Venus: Investigating Why Earth's Sister is Not its Twin**, links to abstracts of current research.

- NASA Selects Four Possible Missions to Study the Secrets of the Solar System (Feb. 13, 2020) **NASA Press Release**.

- Smrekar,S. E., Stofan, E. R., Mueller, N., Treiman, A., Elkins-Tanton, L., Helbert, J., Piccioni, G., and Drossart, P. (2010) Recent Hotspot Volcanism on Venus from VIRTIS Emissivity Data, *Science,* v. 328, p. 605-608, doi: 10.1126/science.1186785. [**abstract**]

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