VENUS, AN ACTIVE PLANET: EVIDENCE FOR RECENT VOLCANIC AND TECTONIC ACTIVITY

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DOI: 10.2138/gselements.17.1.67

Similar in size to the Earth, Venus differs from our planet by its extreme surface temperature (470 °C), suffocating atmospheric pressure (about 92 times that of the Earth’s), and caustic atmosphere (mostly CO₂, with sulfuric acid rain). Venus is Earth’s hellish twin sister. However, there are some similarities. As for the Earth, Venus has also had a very complex geologic history. During the early 1990s, NASA’s Magellan spacecraft imaged the surface of Venus with radar and gave us a panorama of a volcanic wonderland (Fig. 1). The surface of Venus is dotted with some of the largest volcanoes in the solar system, complete with summit calderas and extensive lava flows. Volcanoes on Venus resemble many of those on Earth, particularly those formed from the eruption of basaltic magma, such as Mauna Kea (Hawaii, USA) and Mount Etna (Italy). One of the biggest unresolved scientific questions about Venus concerns its style and rate of volcanism during its geologic past. Did volcanic eruptions on Venus occur locally and constantly in time? Or did the planet undergo sporadic events of global and catastrophic volcanism which rejuvenated its entire crust in a short amount of time?

During the 2000s, the European Space Agency’s (ESA’s) Venus Express orbiter shed new light on the style and age of Venusian volcanism. Through the atmospheric measurements made by the VIRTIS (visible and infrared thermal imaging spectrometer) instrument mounted on the Venus Express spacecraft, it was possible to derive the amount of infrared light emitted from a part of Venus’ surface (during its nighttime) in the 1 µm spectral band. The signal from the 1 µm band correlates mainly with the oxidation state and amount of iron in surface rocks. Using the VIRTIS data, Smrekar et al. (2010) first reported that some lava flows at Idunn Mons emitted so little light (at 1 µm) as to suggest that these lavas had not been oxidized by Venus’ atmosphere. The implication was that these lavas were relatively fresh and young (Fig. 2). Other lava flows from the volcano (and the surrounding region) were more consistent with oxidized and altered basalt. Smrekar et al. (2010) suggested that the youngest lava flows were about 2.5 million years old or younger (possibly even as young as 250,000 years old). However, the ages of these fresh, basaltic lava flows at Idunn Mons could not be well constrained because the rate of alteration of fresh basalt and how that alteration might affect the spectral signal was not understood.

Basaltic rocks on Venus are in contact with a hot caustic environment and, because water is not stable on the surface to make clay minerals (Zolotov 2018), should alter quickly to form surface coatings mainly of hematite and sulfates. These coatings could, in theory, be used to date different lava flows, because the amount of alteration should correlate with the age of the rock exposed to the atmosphere. Recently, experimental laboratory studies investigated exactly this—how quickly alteration minerals would coat the surface of basaltic rocks and minerals in contact with a Venus-simulated atmosphere (Berger et al. 2019; Cutler et al. 2020; Filiberto et al. 2020). In order to constrain the age of the freshest lava flows at Idunn Mons, Filiberto et al. (2020) and Cutler et al. (2020) investigated how the oxidation coatings would affect the spectral signals of the basalt. The experimental results showed that alteration and oxidation minerals form on the rock and mineral surfaces on laboratory timescales—olivine, basaltic glass, and alkali-basalt alter with timescales of weeks to months (Fig. 3). Pyroxene alters much more...
slowly. The spectral signal of oxidized basalt, glass, and olivine become dominated by hematite even before a full coating forms on the surface of the sample (Cutler et al. 2020; Filiberto et al. 2020). Applying these experimental results to Venus’ lava flows suggests that any lava flow on the surface of Venus with an infrared signature of fresh lava may only be a few years old. However, the exact age of the lava flow (whether they are years or decades old) will depend on the exact mineralogy, specifically the amount of pyroxene versus olivine or glass in the flow.

Lava flows at other Venusian volcanoes (e.g., Maat Mons, Theia Mons, Rhea Mons) have radar properties consistent with being young, but their emissivity signatures have not yet been measured (Brossier et al. 2020). Some of these geologically young volcanic structures are also associated with extensional rift zones, based on their radar images and physical properties (Fig. 4). Similar volcano–rift settings are fairly common on Earth: for example, the East African Rift system and the Rio Grande Rift in the USA. Geologic investigations of the volcanotectonic interrelationships between Idunn Mons and the rift system in which it sits also suggest that volcanic and tectonic activity have alternated in time during the recent geologic past. This implies that Venus could also be seismically active (D’Incecco et al. 2020). Further suggestions of a geologically active Venus come from a recent study on the geomorphology of corona structures (volcano-tectonic features formed by the interaction between mantle plumes and the lithosphere), which suggested at least 37 represent active mantle plumes (Gülcher et al. 2020).

However, in order to constrain the style and rate of volcanic resurfacing during Venus’ geologic history, new missions would be needed to study the surface, subsurface, and atmosphere of Venus. Such missions are currently under review: NASA’s DANVICI+ and VERITAS, ESA’s EnVision, and the Roscosmos-NASA Venera-D. Any one of these missions alone, or better yet in concert, would shed new light on the mysterious geologic evolution of Venus.

ACKNOWLEDGMENTS

AHT and JF received partial support from NASA SSW grant 80NSSC17K0766. PD thanks the European Union for financial support through the Programa Operativo Nazionale Attraction and International Mobility grant AIM1892731. This is Lunar and Planetary Institute (LPI) contribution no. 2597; LPI is operated by the Universities Space Research Association (Texas, USA) under a cooperative agreement with the Science Mission Directorate of the National Aeronautics and Space Administration.

REFERENCES


Figure 4 Magellan radar image of Beta Regio (Venus), which consists of Theia Mons (bright feature on the center bottom of the image) and Rhea Mons (the bright feature upper right of the image) and the associated Devana Chasma, a large central rift that runs through Rhea Mons and down to the south. North is to the top of the image. Image: NASA GODDARD SPACE FLIGHT CENTER, Image number: C3-14N300.