Resurrecting Interest in a “Dead” Planet

New research suggests that the surface of Venus is busy, but it may take new missions to our “sibling” planet to confirm this.

By Damond Benningfield

In the past few years, though, planetary scientists have looked at Magellan’s observations in new ways, leading them to develop a more nuanced picture of the planet’s history. The Magellan images, combined with observations by more recent orbiters, have provided hints that Venus could be quite active today.

The new findings have whetted the appetites of many researchers for new Venus missions—perhaps a “Magellan 2.0” orbiter to snap higher-resolution pictures of the surface and make better maps of the planet’s topography or a long-duration balloon that would measure volcanic eruptions through ripples in the planet’s atmosphere.

Such missions would teach us more not just about Venus, the scientists say, but also about Earth and a whole class of exoplanets.

“Venus is an Earth-sized planet and now—who knew?!—there are Earth-sized planets all over the galaxy,” said Martha Gilmore, a professor of geology at Wesleyan University in Middletown, Conn. “So now, Venus is even more relevant for that reason.”

Catastrophe Strikes Venus

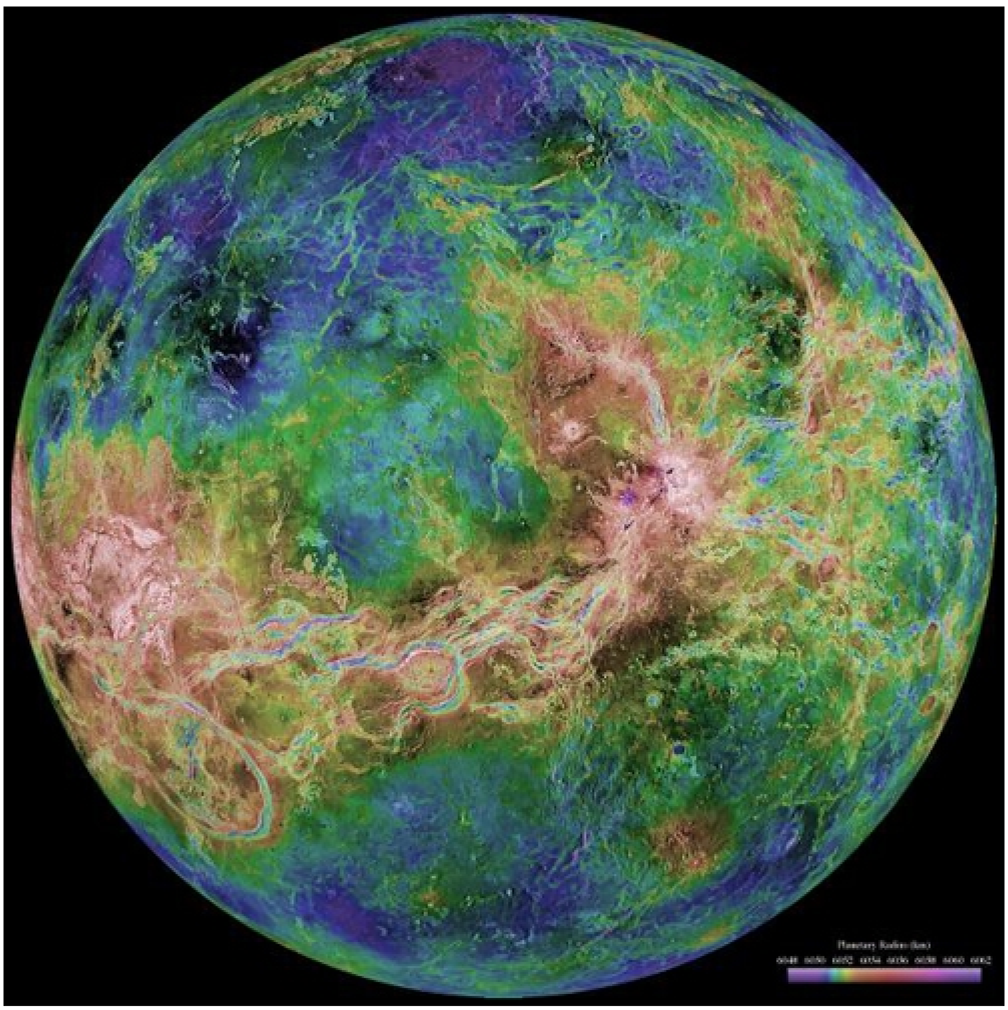
Venus is described as Earth’s sibling world. The two planets are about the same size and mass and probably were made from the same mixture of raw ingredients.

The surface of Venus, though, is quite different from that of its planetary sibling.

“You’re not in Kansas anymore—it’s the Oz of the two planets,” said James Head, a professor of geological sciences at Brown University in Providence, R.I., and a member of the Magellan radar team.

Instead of yellow brick roads and poppy fields, however, Magellan revealed that this planetary Oz is paved with volcanic rock. Although other craft had used radar to peek through the obscuring clouds, none did so in such high resolution or for so long. Magellan orbited Venus for more than 4 years; during the first two, its synthetic aperture radar mapped almost all of the planet’s surface, most of it at resolutions of 100–250 meters per pixel.

Radar images revealed that more than 80% of the surface is volcanic, more than two thirds is covered by volcanic plains, and much of the rest is dominated by tesserae (regions of rugged, deformed terrain that are higher than the average elevation). The images also showed shield volcanoes up to 9 kilometers tall, pancake-shaped domes, arachnoids—concentric rings surrounded by fractures that look like spider webs—and other intriguing features.



The images contained a surprising dearth of impact craters, though. Scientists counted fewer than 1,000 of them, relatively evenly distributed across the planet and all looking fairly fresh.

“So people hypothesized, ‘Gee, most of the craters aren’t modified, they’re evenly distributed, that would argue that there was some catastrophic resurfacing,’” said Head, who also served as a guest investigator on two earlier Soviet radar missions, Venera 15 and 16. “The idea was that all of this volcanic activity came out at the same time, then it stopped.”

Catastrophic resurfacing about 500 million years ago (give or take 250 million years) reigned as the leading description of Venus’s geologic history (or at least the idea that got the most attention) for years. And Head still said that although the repaving might not have happened in as short a time as originally supposed, it didn’t take long in geological terms.

“The hypothesis was modified to say that the crust itself was highly deformed, then the volcanic activity came out,” he said. “It’s got to be within tens to a hundred million years between each other. We need to go with a new radar mission to see the rate of volcanism and where the volcanism is to test that hypothesis.”

Or Does It?

Many scientists, though, have reinterpreted the surface in a less dramatic way. New maps of Venus have allowed scientists to study the landforms and their relationships to each other in more detail. These new views favor a more “steady state” interpretation, in which different areas of the planet were resurfaced at different times, over a much longer period.

“I think the general view is that rather than this catastrophic resurfacing event, which sounds amazingly dramatic and kind of science fictiony, it’s much more piecemeal or episodic,” said Paul Byrne, an assistant professor of planetary geology at North Carolina State University in Raleigh. “You have this process where a bit gets resurfaced, then another bit gets resurfaced, then another bit gets resurfaced. At a given time, the resurfacing is still formidable, but it’s not necessarily that the whole planet is overturning and vomiting out its guts at one time.”

“We can show beyond a shadow of a doubt that there was no catastrophic resurfacing,” added Vicki Hansen, a professor of geology at the University of Minnesota Duluth. “You can absolutely re-create the crater database without catastrophic resurfacing.” Her detailed mapping of roughly a quarter of the surface, Hansen said, demonstrates that it could have been sculpted over a period of up to a few billion years.

Most of the steady state models posit an era in which the tesserae formed, followed by creation of the vast volcanic plains, followed by an era of activity that built the volcanoes and related structures. And the same models agree that Venus is likely to be active today, which would support the idea of a resurfacing process that has played out gradually instead of catastrophically.

There’s little or no evidence, though, of Earth-like plate tectonics on present-day Venus. “We certainly don’t see an interconnected system of plate boundaries like on Earth,” said Smrekar.

That apparent lack of plate boundaries provides insights into Venus’s interior, said Robert Herrick, a research professor at the University of Alaska Fairbanks. It suggests that there’s little water in the lithosphere to help lubricate the motion of tectonic plates, for example. (On the other hand, recent studies have suggested that Venus’s interior may retain 75% of the water it was born with, compared with just 50% for Earth.)

In addition, the planet’s high surface temperature (about 740 kelvins) may prevent surface layers from cooling enough to become dense enough to sink into the mantle, which is a key tectonic process on Earth. “That makes plate tectonics very difficult on Venus,” Herrick said.

“Pack Ice” on a Hot World

Even without crustal plates, “Venus has tectonism all over [its] surface—folds, faults, fractures, and other features,” said Hansen. But its tectonic activity appears to be more small scale and regional. Work published last year by Byrne and his colleagues, for example, found evidence of “blocky” structures across much of the planet’s lowlands.

“A lot of those regions have a distinctive pattern of intersecting little mountain belts and rift zones—smaller than the ones on Earth,” Byrne said. “If you start mapping these things, you can convince yourself that there are low-lying discrete portions of the Venus crust that are physically independent from the areas around them.”

Byrne compares the behavior of these areas to pack ice. “Most of the tectonic activity—most of the deformation that affects the ice—goes into the edges of these rafts, these blocks,” he said. “So some parts pull apart, some parts push together, and some parts go side by side. And we think we’re seeing the comparable mechanism of behavior from much of the Venus lowlands.”

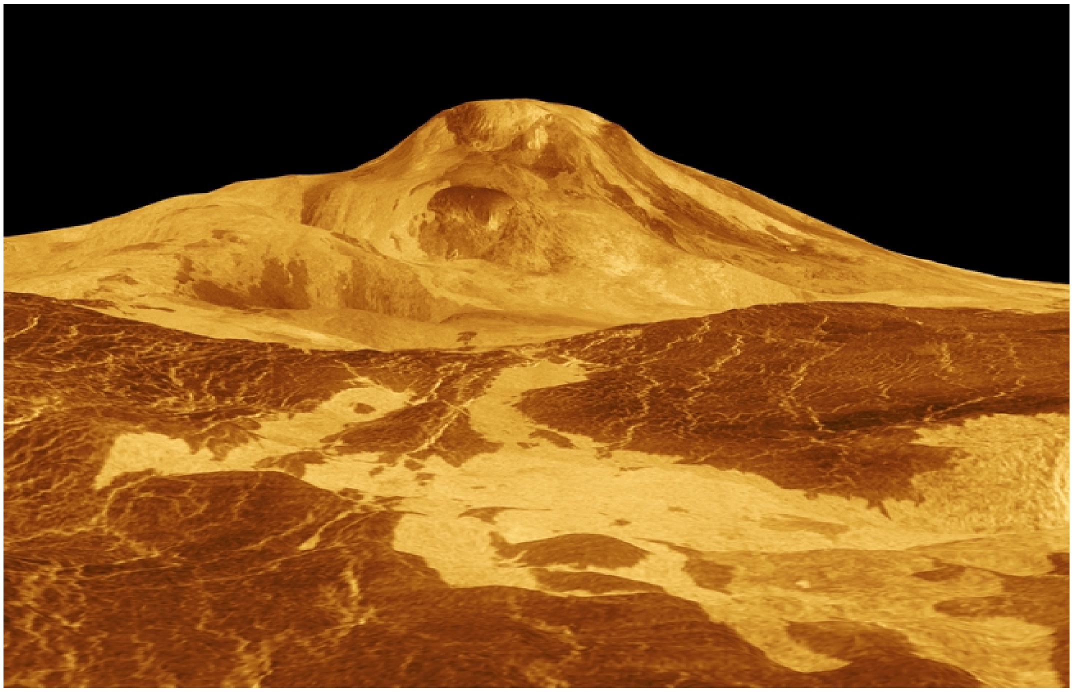
The studies have identified dozens of blocks, which range from a few hundred to about 1,500 kilometers wide, distributed across much of the planet. They show relative horizontal motions of up to tens of kilometers. They are found in plains that are thought to be some of the youngest regions on Venus, so it’s possible the blocks are continuing to move today.

Byrne said that the motions could be driven by plumes in the mantle below relatively thin portions of the lithosphere. Roiling convection in the mantle could crack weak layers of crust at depths of 10–15 kilometers, with that deformation propagating to the surface.

“We don’t see anything like this on any of the other solar system worlds,” Byrne said. “Understanding this isn’t just about understanding Venus. It’s also [about] looking to understand the rules that govern how rocky planets such as Venus and Earth behave in general.”

Hot Spots for a Hot Planet

Although there’s no eyewitness view of an erupting volcano, the circumstantial evidence of an active Venus is piling up, from possible activity around coronae to what appear to be recent deposits of volcanic ash atop Maat Mons, the planet’s tallest volcano

.

“How recent is recent?” asked Smrekar. “Some new lab work suggests that it’s quite recent—years, not millions of years.”

A study published in 2012 found that the floors of many of Venus’s craters are “radar dark,” suggesting they’ve been partially filled with volcanic rock.

“That could be telling you that craters are continuously being filled and covered over everywhere,” said Herrick, who led the study based on 3-D views of Venus he compiled from overlapping tracks of Magellan observations.

Another 2012 study reported spikes in the amount of sulfur dioxide (SO_2), a volcanic gas, in Venus’s upper atmosphere. Venus Express, a European Space Agency (ESA) satellite, detected a significant jump in the level of the compound above the clouds not long after it entered orbit in 2006. Since SO_2 is quickly destroyed by sunlight, any found at those altitudes must have just arrived. The SO_2 spike mimicked one detected by NASA’s Pioneer Venus orbiter in the early 1980s.

The researchers concluded that the most likely source of both spikes was the recent eruption of one or more volcanoes. Because of the vigorous rotation of the atmosphere, however, it was impossible to pinpoint the culprits.

Venus Express was more successful at isolating possible volcanic activity by discovering hot spots on the surface, reported in 2015. An infrared instrument detected the spots in Ganis Chasma, a rift valley that’s one of the youngest known regions on Venus. The four hot spots were consistent with the glow of lava hundreds of degrees warmer than the surrounding terrain, distributed in areas ranging from 1 to about 200 square kilometers.

“Everyone agrees, there is some volcanism on Venus,” said Herrick. “It could range from reasonably Earth-like to maybe a magnitude lower than Earth rates. I would tend to guess it’s toward the high end. I want it to be more active.”

Kick-Starting a New Era

Everyone agrees on one other point as well: We won't know the full answers to Venus's geologic past and present without more data.

"There's still a lot of life left in the Magellan data for us to explore," said Byrne. "But [Venus is] an almost criminally underexplored world….Why are we not sending legions of spacecraft to this thing to characterize its atmosphere, its surface, its interior?"

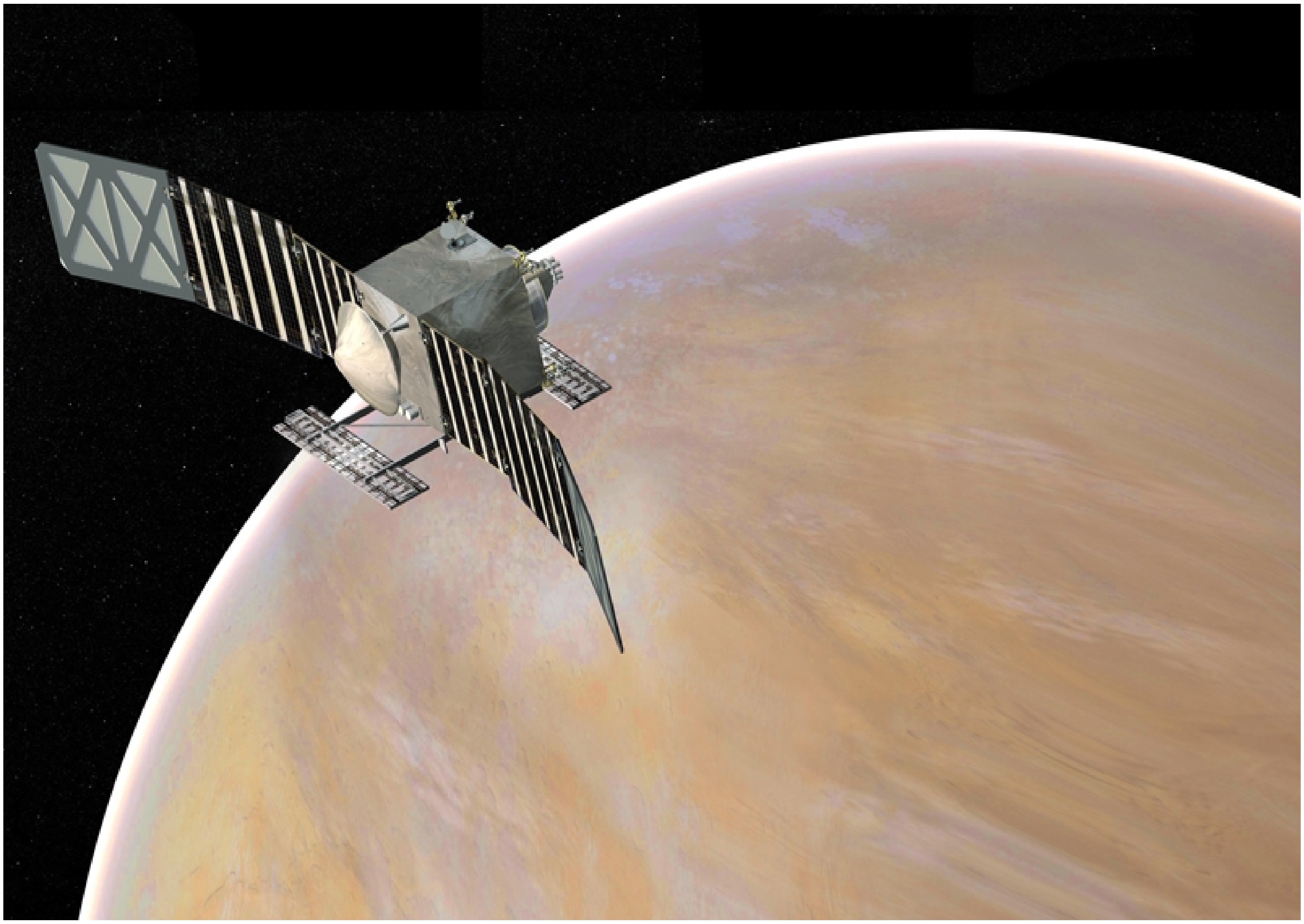
A new radar orbiter could provide higher resolution than Magellan and produce much better topographic maps. (The horizontal scale of maps produced with Magellan's altimeter is in the tens of kilometers.) It would allow scientists to look for changes on the surface during the 25 years since Magellan's demise, such as lava flows or ash deposits. And it could obtain more detailed observations of possible volcanic gases.

Yet only two Venus orbiters—the only dedicated missions since the end of Magellan—have arrived at the planet since then: ESA's Venus Express and Japan's Akatsuki. Venus Express was a major success, and Akatsuki continues to operate today.

For the future, ESA is considering a Venus orbiter, EnVision, that would detect minute changes in the planet's surface and probe up to 100 meters below the surface. A decision is expected in 2021. India also has announced plans to launch an orbiter in 2023.

NASA has shown little interest in Venus, concentrating instead on Mars and many of our solar system's smaller bodies. It has pondered several proposed Venus missions over the past decade but has rejected them all.

Smrekar has served as principal investigator for several of the proposals to NASA and reprises the role this year. Venus Emissivity, Radio Science, InSAR, Topography, and Spectroscopy (VERITAS), an orbiter with a radar system and an infrared instrument to look for volcanic activity and measure surface composition, was submitted to the Discovery program on 1 July. It (and a similar mission proposed to the New Frontiers program) was selected as a finalist in earlier reviews but failed to make the cut.



Scientists have proposed Venus landers as well, although the challenges of surviving the high temperature and intense surface pressure make them more daunting.

Other scientists have proposed balloons that would float through and below the clouds. Among other instruments, they could carry seismometers that would detect the vibrations of venusquakes or volcanic eruptions transmitted through the dense atmosphere. In the more benign conditions well above the surface, they might operate for weeks or longer, providing a broader look at geologic activity than any lander.

Any proposal still faces stiff competition from other priorities. But Venus scientists say the discovery of possible Venus-like worlds in other star systems may stimulate new interest in the original.

“I have astronomer colleagues who come to me and say, ‘I’m studying these exoplanets and I’ve got 50 Venuses. What do we know?’” said Head. “This is great!…You’re not looking at the surface, but there’s a new perspective on things, and that’s really critical. That’s another dimension. The more we understand about Venus, the more we’re able to place these Venus-like exoplanets into context, and that will be really incredible.”

“We only need one mission to spark that interest in other researchers, in policy makers, and [in] the public,” said Byrne. “That might be all we need to kick-start a new golden age in Venus exploration.”

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