VENUS: A Global View

Magellan's radar maps most of Earth's beclouded 'twin'

By RON COWEN

NASA/JPL

A series of dramatic images stole the show at a Washington, D.C., press briefing two months ago: portraits of a terrain marked by volcanic domes and web-like fractures; stereo views that render towering mountains and long, sinuous channels in three dimensions; maps that depict with unprecedented clarity a planet-wide view of occasional craters and splotchy lava flows.

Photographs of Earth? Guess again. These images, unveiled by NASA on Oct. 29, provide the highest-resolution map ever made of Venus, the planet often called Earth's twin because of its similarity in mass and size. Indeed, the images constitute the sharpest global view of any planet in the solar system.

Magellan, a U.S. spacecraft launched in May 1989, has pierced the cloudy Venusian atmosphere with radar to probe the surface below. The thousands of images it has sent back since September 1990 record features as small as 100 meters across — roughly the length of a football field. Scientists have now pieced together those images, which cover about 80 percent of the planet, to construct the first global view of Venus.

"We probably have a better global map of Venus now than we have of Earth," says Magellan project scientist R. Stephen Saunders of the Jet Propulsion Laboratory (JPL) in Pasadena, Calif. He notes that no map of Earth has completely traced the hidden ridges and other topography beneath the oceans. Adds NASA's Wesley T. Huntress Jr.: "We've sent missions to Venus since 1962. But in all that time, we've never seen what the planet really looked like."

Astronomers and geologists have only begun to puzzle over the wealth of information from Magellan's first 3,000 orbits around the planet. (NASA hopes to continue Magellan's mapping, which includes information about Venus' gravitational field, through 1995.) But the global maps already mark a turning point in our knowledge of Venus.

Resurfacing redux

The maps have heated up an ongoing debate about how and when the relatively blemish-free face of Venus took on its youthful appearance. Magellan data indicate that volcanic eruptions must have resurfaced the planet, since Venus has relatively few craters or other pockmarks created by asteroid impacts (SN: 5/4/91, p.280).

In fact, although asteroids sporadically bombard all planets, Magellan's maps reveal that Venus' surface averages only about two craters wider than 2 kilometers within every million square kilometers, says Gerald G. Schaber of the U.S. Geological Survey in Flagstaff, Ariz. In comparison, the moon's surface has an average crater density 1,000 times higher. The relatively few craters on Venus suggest that the planet got a facelift about 500 million years ago, erasing all previous craters.

Several members of the Magellan team suspect the planetary makeover occurred during a time when volcanoes erupted virtually everywhere on the Venusian surface, belching thick lava that repaved the planet over a period of about 100 million years.

But other researchers analyzing the Magellan images believe they can explain the planet's youthful looks without resorting to such a catastrophic upheaval. Geologist James W. Head of Brown University in Providence, R.I., and his colleagues argue that the volcanism that transformed the face of Venus occurred gradually. Various regions may have experienced upheavals at different times, he suggests, until enough lava had spewed out to bury most ancient craters.

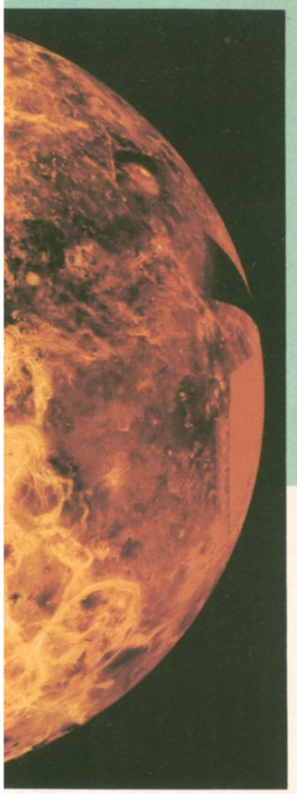
Head has now taken that notion a step farther. At the annual meeting of the American Astronomical Society's Division for Planetary Sciences, held last month in Palo Alto, Calif., he proposed that large-scale volcanic activity on Venus has proceeded intermittently for the last 2 billion years. Moreover, he suggested that the rate of volcanic activity roughly matches the rate at which asteroids hit the planet, thereby burying old craters about as fast as new ones form. Like a movie star that never seems to age, Venus may have maintained its youthful facade — a surface that seems no more than a few hundred million years old — for about half of the solar system's 4.5-billion-year history, he asserted.

Head notes that the gentle rate of surface eruptions he envisions — enough to generate 1 cubic kilometer of new volcanic deposits a year — roughly matches the rate at which new surface forms on Earth. In fact, the forces governing serial eruptions on Venus, as well as their intensity, may have much in common with a key type of volcanism on our planet, he says.

Earth's hard, outer shell, known as the lithosphere, consists of more than a dozen small and large "plates" that move about the globe. Most eruptions occur when a gap opens between two plates, allowing molten rock from Earth's interior to rise to the surface. The most recent Magellan images, like those beamed to Earth earlier in the year, continue to indicate that Venus at present has no such system of interconnecting plates.

However, surface upheavals on Earth also develop when a heat source deep within the mantle propels a plume of material through a plate to crack open the surface. One such "hot spot" formed the volcanic Hawaiian islands; others have generated submerged seamounts.

Venus' interior seems to vent its heat through a similar process, Head says.



This global view of Venus' surface, centered at a longitude of 270°E, shows volcanoes clustered near the equator. Orange hue simulates the color of light filtered through Venus' dense layer of carbon dioxide clouds.

He estimates that the rate at which hot spot activity on Earth generates new volcanic deposits "pretty much approximates the rate we think we see on Venus."

Nonetheless, Head's theory may have difficulty explaining recent observations. If large-scale surface eruptions indeed occur intermittently, then Magellan should have detected a substantial number of craters partially covered with lava, Schaber reasons. Such craters would represent a missing link: surface blemishes captured before another lava flow obliterates them.

But to date, Magellan has found no evidence of such a gradual resurfacing. Nearly all craters look remarkably pristine, Schaber says. Lava has flooded or partly covered only 4 percent of the nearly 830 craters Magellan has recorded, he reported at last month's planetary science meeting. Moreover, sporadic, localized volcanism cannot easily account for the remarkably uniform distribution of craters over the face of Venus, Schaber contends.

Head agrees that a close examination of Venusian craters should help researchers decide between the two styles of volcanism. It remains unclear, he adds, whether the small percentage of lava-covered craters found by Magellan contradicts his model of intermittent volcanism. "We haven't done the detailed calculations to suggest how many craters should be modified given a certain level of volcanism," says Head. "I figure we're at a point where each of us has a legitimate interpretation. I'm convinced that as we look at [the craters] in more detail, there are going to be different stages of degradation."

Memories of an old Earth

Venus' youthful looks intrigue astronomers. At the same time, several surface features on the planet resemble Earth as it may have appeared several billion years ago, Magellan researchers note. During that ancient terrestrial period, known as the Archaean era, Earth's crust had not yet divided into distinct plates and life forms were extremely primitive.

Some land forms near the Venusian equator hint that the planet's crust has the potential to eventually form tectonic plates, says Ellen R. Stofan, Magellan deputy project scientist at JPL. For instance, some surface areas show signs of horizontal motion that might resemble rift zones, regions where plates separate, while others bear some similarity to subduction zones, places where one plate dives beneath another.

"We don't know if Venus is [temporarily] stuck in a stage of pre-plate-tectonics or if the crust might be too weak to break up into rigid plates like those on Earth," she says. Stofan notes that the surface temperature on Venus — around 470°C — may render its surface akin to Silly Putty over millions of years, making it difficult for rigid plates to form — or for such structures as mountains to hold their shape against the relentless tug of gravity.

Indeed, says Stofan, several mountains on Venus shows signs of slumping due to surface gravity. Magellan's images of large cracks or troughs in mountain ranges suggest that such elevated areas are "literally trying to rip themselves apart so they can flatten out," she says. On the other hand, the long-term survival of Maxwell Montes, Venus' largest known mountain, indicates that rising plumes of material from the interior may counterbalance the downward pull of gravity, keeping some high-altitude areas intact.

"Venus is providing a test of almost everything we assume about [geological processes] on Earth," Stofan says.

Where's the action?

Unlike a television camera, a radar detector can't record steam plumes, the blur of flying rocks or other real-time indications of an active volcano. But researchers can search for signs of recent activity on Venus by comparing images of the same region taken months apart, or by examining the relative radar brightness of a group of similar landforms.

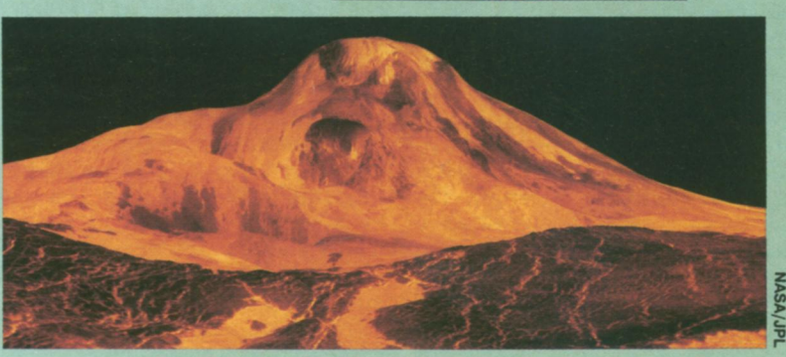
However, with the flood of Magellan data only partly analyzed and the inherent difficulty in comparing radar maps taken at different viewing angles, scientists can make mistakes. Twice now, researchers have announced the likely discovery of very recent geologic activity on Venus, only to retract their statements a month or two later.

In August, scientists at JPL spotted a mismatch between a pair of radar photographs, taken eight months apart, depicting an equatorial highland called Aphrodite Terra. A bright line in a November 1990 picture, thought to be a fracture, seemed to have evolved into a bright, rocky patch in the later image. At a

The false-color image below shows Magellan's view of Venus' northern hemisphere, centered on the North Pole. Data from the earlier Pioneer-Venus spacecraft fill in some regions not yet mapped by Magellan.

This computer-generated, false-color perspective of the volcano Maat Mons (below) initially led researchers to suggest that Maat Mons had erupted within the past 10 years. They now suspect it last erupted millions of years ago.

NASA/JPL



NASA/JPL

hastily called press conference, the researchers reported that the differences between the two images indicated the region had suffered a landslide in the intervening eight months (SN: 9/7/91, p.149). But members of the JPL team later admitted they had erred: Distortions in the radar maps – due to differing viewing angles – had fooled them into thinking a landslide had occurred (SN: 10/26/91, p.269).

At the Oct. 29 press briefing, researchers announced a far more dramatic finding. New images of Maat Mons, one of the largest volcanoes detected on Venus, suggested that the 8-kilometer-high structure had spewed lava within the past 10 years – and might still be active. Scientists based their speculation on radar pictures of the volcano, which rises higher than Mt. Everest. Maat Mons' peak appears dark in radar images, even though all other known volcanoes on the planet appear bright, notes planetary scientist John A. Wood of the Smithsonian Astrophysical Observatory in Cambridge, Mass.

He and other researchers agree that the dark regions indicate that Maat Mons is a youngster among Venusian volcanoes; unlike older structures, its lava hasn't had time to chemically mix with the thick atmosphere to form metal-rich minerals that reflect radar beams well. But just how long does it take for lava on Venus to react with the atmosphere?

In October, Wood said he believed such chemical mixing could occur in a matter of years. If true, this would suggest that Maat Mons erupted within the past decade. He based his tentative dating on the planet's hot temperatures and two chemical studies: measurements of sulfur dioxide in the Venusian atmosphere – an indicator of volcanic activity – made in 1982 by the Pioneer-Venus spacecraft, and soil surface analyses by Venera 15 and 16, two Soviet craft that landed on the planet in 1984.

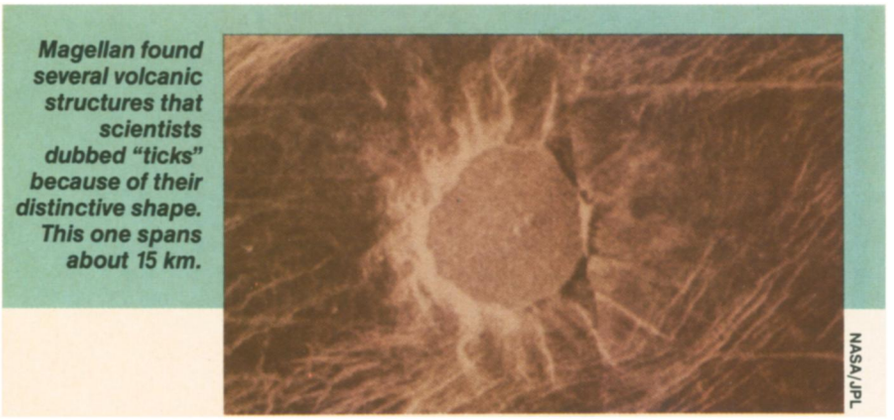
Wood told SCIENCE NEWS that he has altered his thinking since the briefing and now agrees with several other scientists that weathering on Venus occurs far more slowly. As a result, he has drastically revised his estimate: Maat Mons may have last erupted a few million years ago.

Even so, he notes, Maat Mons remains the youngest volcano known on Venus.

Craters and their secrets

Compared with the pockmarked faces worn by Mars and the moon, only a smattering of craters dimple the surface of Venus. Besides helping to fix an age for the planet's youthful appearance, the diverse features of the 830 or so craters mapped by Magellan offer insights into the Venusian atmosphere, Schaber says.

While the majority of features on Venus appear geologically young and unscarred, fractures crisscross one-third of the observed craters, which range from 2 to 275 kilometers in diameter. All of the most severely fractured craters and some of the more moderately fractured ones lie in highly disrupted, upland terrains, such as Aphrodite Terra and Beta Regio in the equatorial highlands.



Magellan found several volcanic structures that scientists dubbed "ticks" because of their distinctive shape. This one spans about 15 km.

This concentration of fracturing suggests that eruptions may continue to occur within these rugged regions, Schaber says. Molten rock seems to have squirted out of many of the craters – in some places, carving out channels that wind through as much as 500 kilometers of nearly flat terrain. Such lava-like flows apparently resulted from rock that melted when an asteroid slammed into the Venusian surface, Schaber says. The force with which an asteroid hits the surface creates fierce winds that may exceed the speed of sound on Venus, about 500 meters per second. Such gusts may spread out flows, accelerating channel formation.

Most of the widest craters, presumably formed by the most massive asteroids, display bigger flows. Craters created by asteroids that hit at a glancing angle also tend to have larger flows, possibly because these lopsided impacts produce a bigger deposit of molten material in the direction the asteroid was traveling, Schaber says.

The few craters less than 35 kilometers in diameter, and the complete absence of craters less than 2 kilometers across, tell yet another story, says Schaber. This scarcity of small craters suggests that tens of thousands of small asteroids burn up in the hot, dense Venusian atmosphere before they can strike the surface. At the planetary science meeting, Schaber speculated that dark blotches on the surface – sometimes surrounded by bright fractures – represent regions above which small asteroids have disintegrated. The dying asteroids create shock waves in the dense atmosphere, pulverizing surface rock into a fine dust. The dust reflects radar poorly, possibly accounting for the dark splotches, Schaber theorizes. The blast may also fracture surrounding areas, he notes.

Patterns of volcanism

Many volcanic features on Venus range in diameter from 100 to 500 kilometers and display a wide diversity of shapes. These include domes, mountains, highland plateaus, web-like fractures – even areas shaped like giant ticks.

To Head and his colleagues, the web-like fractures suggest that Venus contains large underground reservoirs of magma, or molten rock. As the magma solidifies and contracts, the surface above may crack in web-like patterns.

More than half the 1,400 volcanic clusters imaged by Magellan concentrate in a roughly circular region about 10,000 kilometers across, centered on the equator. This area, which covers about 20 percent of the planet, may indicate where hot spots congregate, Head says.

While it's tempting to think that the volcanic domes share an origin similar to those on Earth, the hotter temperatures and 90-fold higher atmospheric pressure on Venus suggest an alternate explanation, Head says.

Geologists believe that volcanic domes found near Taos, N.M., in the Mojave Desert and at other terrestrial locales formed when thick, silica- and aluminum-rich magmas rose to the surface. Possessing a consistency more like toothpaste than water, this hot rock tends to build domes once it cracks the surface, rather than spreading out into thin sheets.

On Venus, however, more primitive magmas – with a more fluid consistency – might sometimes evolve into domes, Head says. Under certain conditions, he theorizes, Venus' higher atmospheric pressure keeps gases dissolved within magma deposits. Upon reaching the surface, the gases bubble out of the molten material, leaving behind a viscous lava capable of forming domes.

This notion, like others about Venus' landforms, remains speculative. But with a global map of Venus only months old, perhaps that's to be expected.

"Keep in mind that in the last year we've looked at something that has the surface area of Earth, whereas humans have explored terrestrial features for thousands of years," Head says. The new data from Venus, he observes, may well yield a trove of discoveries to challenge scientists for decades to come. □