Will Magellan Find a Half-Sister of Earth's?

Detailed radar maps of Venus will decide whether Venus and Earth, once viewed as twin planets, are at all closely related

As MAGELLAN SETTLES INTO ORBIT around the shrouded planet Venus, planetary scientists are looking for it to settle a long-running dispute: Will the spacecraft's cloud-penetrating radar discover an Earth sibling—a comfortably familiar planet with somewhat modified plate tectonics—or a totally alien Venus, a planet shaped by processes rare or unknown on Earth? Most planetary scientists are betting on a rendezvous with an alien. They are confident enough that they have been flooding scientific journals with predictions of what Magellan will find. But then there's planetary geologist James Head and a band of like-minded individuals who are bolder still. They are betting against the house.

Magellan's long-awaited arrival at Venus marks the end of a decade-long data drought endured by planetary scientists studying the four rocky planets of the inner solar system. By the late 1970s, the last probes to Mercury and Mars had returned clear images of unearthly planets whose outer shells had been frozen in place shortly after the solar system formed 4.5 billion years ago.

Only Venus held out any prospect of an outer shell broken into still drifting plates like Earth's. Venus is almost the same size as Earth and has a similar composition, which raised the possibility that it forms its surface through the drifting of plates the way Earth does. But the 1979 mapping of the Venusian surface by the radar of Pioneer Venus failed to support that preconception. Pioneer found no globe-circling system of ridges like the one that wends through Earth's oceans and produces new crustal plates.

And yet Head, who leads a group at Brown University, has been reluctant to concede that Venus and Earth are geologically dissimilar. He staunchly argued in the early 1980s that Pioneer Venus was too myopic to rule out plate tectonics just yet. Some version of plate tectonics could be operating undetected by Pioneer Venus' crude radar mapper, he said.

Ten years later, planetary scientists are still debating the question of how the surface of Venus has been formed. Most researchers still have trouble seeing anything like plate tectonics on Venus. The closest thing to a consensus in the community holds that the volcanoes identified by radar mapping—ranging from huge ones like Hawaii-size Beta Regio down to tens of thousands of domes several kilometers across—probably spewed all the magma needed to form a crust. And the crust is most likely being dragged about and deformed by the underlying mantle—a most un–Earth-like way of shaping a planet.

Head is not convinced, however. He believes that his detailed analyses of the less than optimal observations in hand make a good case for some plate tectonic processes on Venus that are quite similar to those on Earth. He believes, for example, that he has spotted a good candidate for the Venusian equivalent of a mid-ocean ridge where new crust may be forming and an area where crustal plates are colliding.

Although Head is clearly in a small minority, his views are being taken seriously in part because he has put together what is perhaps the most massive data analysis effort in the Venus geology business. In the 1980s, he recalls, "people said there wasn't a lot of data at hand; we should wait for Magellan. But I thought there was."

Rather than wait, Head forged cooperative relations with the Vernadsky Institute in Moscow, where Venera radar data would be processed, and Arecibo Observatory in Puerto Rico, which would produce most of the Earth-based radar maps. Then he gathered a group of students and postdocs at Brown that expanded until almost a dozen were working on Venus during the past year or so. Together they produced more than 30 papers in the past 2 to 3 years.

Catching Venus in the Act

Is Venus dead or alive? Throughout the 1980s, planetary scientists went back and forth on that question, but an increasing mass of data on sulfur dioxide in Venusian clouds now has most of them convinced that the planet has active volcanoes that erupted on a massive scale as recently as the 1970s. Researchers are hoping that the Magellan spacecraft will catch at least one of these volcanoes in the act.

The arrival at a consensus was aided, curiously enough, by a recent announcement that controversial observations of Venusian lightning, which were purported to imply active volcanism, had been misinterpreted. Debate over the connection between lightning and volcanoes had long diverted attention from sulfur dioxide measurements, compiled since the early 1980s by planetary scientist Larry Esposito of the University of Colorado.

The measurements indicate that a sharp decline has occurred in the amount of sulfur dioxide gas above the clouds of Venus. Presumably, it was first put there by volcanic eruptions, as happens on Earth. In Pioneer Venus observations, the concentration of sulfur dioxide droped from about 100 parts per billion in 1978 to about 10 parts per billion in 1986. A similar drop is supported by measurements from the Soviet Venera orbiter, rockets, and, as analyzed in recent months by Esposito and his colleagues at Colorado, the International Ultraviolet Explorer satellite orbiting Earth.

"It all fits together," says Esposito. "It's absolutely well established. There are not only active volcanoes but also volcanoes with enough heat energy output" to drive the gas into the upper atmosphere. The eruption or eruptions that apparently peaked in the 1970s would have had to have been as powerful as the eruption of Krakatoa in 1883, Esposito estimates.

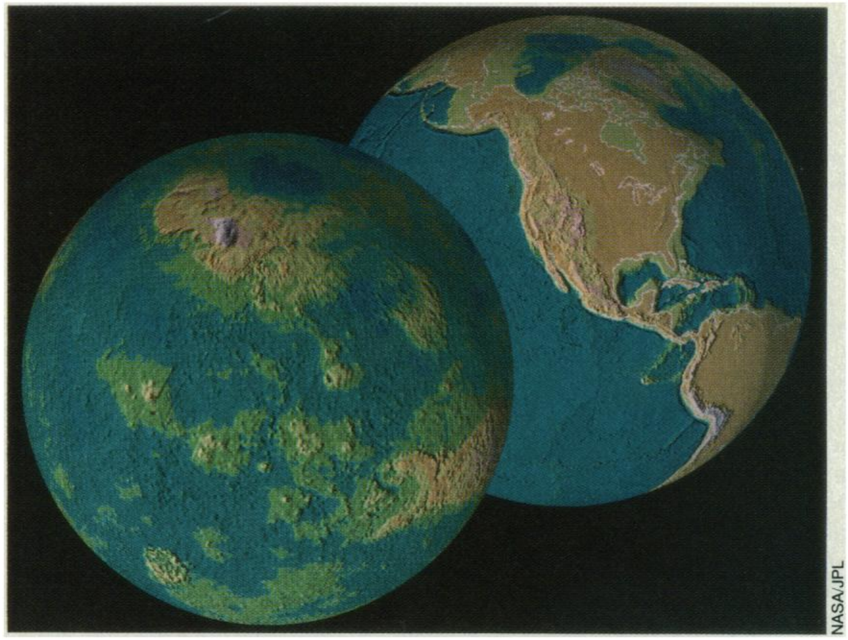
As for the lightning controversy, though it led debate over Venus's volcanic activity onto a side track, it has taken an interesting turn. The controversy was kicked off in the early 1980s when the late Frederick Scarf, who was a plasma physicist at TRW Space and Technology Group in Redondo Beach, proposed that radio noise picked up by Pioneer Venus was caused by Venusian lightning. And that lightning, Scarf argued, was clustered over a region of volcanic highlands along the equator of Venus. The presumption was that the volcanic ash billowing from erupting volcanoes was generating the lightning, much as happens on Earth.

Harry Taylor soon attacked Scarf's hypothesis. Taylor, a planetary aeronomist who has retired from NASA's Goddard Space Flight Center in Greenbelt, Maryland, and Paul Cloutier of Rice University argued long and hard that the radio noise was either

The Brown geological effort is a huge one in a field in which only four or five U.S. groups of two to three members each are active. But quantity isn't everything. The final arbiter will be the Magellan spacecraft now being fine-tuned by its controllers.

The Magellan spacecraft that went into orbit around the planet last week is a lean probe, stripped of all non-geologic instruments to meet a $550-million budget. Its key hardware consists of a 3.7-meter antenna borrowed from Voyager project spares and a microwave transmitter-receiver. The microwave echoes collected by an ordinary radar yield the distance and reflectivity of the target, but Magellan's synthetic aperture radar will add the Doppler shift and target a myriad of points on the surface below. Merging of the three echo properties by computer processing will form the most detailed images of the surface of Venus ever made.

There was a synthetic aperture radar on Pioneer Venus, too, but that provided a resolution of only 25 kilometers at best—enough to identify Beta Regio as a gigantic volcano complex and map out the broad outlines of the two highlands (16,000-kilometer-long Aphrodite Terra near the equator and Ishtar Terra to the north). The instruments flown on the Soviet Venera 15 and 16 spacecraft in 1983 improved resolution to 1 to 2 kilometers, as did Earth-based radars. That allowed geologists to start detailed mapping of crumpled crust, lava flows, and impact craters, but together these radars covered little more than 40% of the surface. And a resolution of 1 to 2 kilometers was still marginal for geologists trying to decipher which processes are forming and shaping the crust. Now Magellan promises to provide 200-meter resolution over nearly the entire planet.



Hardly two peas in a pod. *As these computer-generated globes of Venus and Earth reveal, the surfaces of the two planets have little in common at first glance. Magellan data should allow researchers to decide whether Venus has any vestige of Earth-like plate tectonics.*

But it is not just lack of fine detail that has prevented researchers from reaching a consensus. Another problem is that two cultures—those of geology and geophysics—have been involved. Head is a geologist. Geologists tend to look for clues in the radar images and in the details of the surface topography, as measured by the altimeters carried by spacecraft. To geologists, the skin of the planet will reveal the deeper play of forces. Geophysicists, on the other hand, dwell on the subtle variations in the gravitational pull of Venus, as detected by precise tracking of the spacecraft, and the broad contours of the topography. These and the way they correlate with each other tell geophysicists something about what is going on beneath the surface.

So far, the geophysicists say that rather than plate tectonics they see signs of a mantle plume rising beneath the volcanic center of Beta Regio, just as plumes are thought to rise beneath hot spots on Earth like Iceland and Hawaii. But this is no ordinary hot spot plume.

Indeed, in the view of many geophysicists, such as Roger Phillips of Southern Methodist University, and even some geologists, the unusual behavior of Venusian hot spots can explain much of what is known about the surface of Venus. Unlike the plumes of terrestrial hot spots, the plume beneath Beta Regio seems to be driving the crust upward into a broad dome. Similar if less energetic plumes may be driving up beneath the highlands of Aphrodite and Ishtar to give them much of their height. Plumes of various sizes could also build volcanic edifices and pave the entire surface with their lava to form crust. Volcanic repaving is an insignificant process on Earth. The heat from hot spots, along with conduction through the crust, seems to account for all the heat that needs to escape from the interior of Venus. On Earth, plate tectonics dominates heat loss.

Indirectly, mantle plumes could deform the crust in ways impossible on Earth. The 475°C surface temperature of Venus could weaken the base of the crust and let gravity deform the crust as it falls off plume domes and piles up at the dome fringes. And the apparent absence of a deep weak zone, called the asthenosphere on Earth, would allow plumes and other parts of the mantle to drag crust along to produce deformation as well, according to work by Phillips.

Head does not deny that some alien Venusian processes may be going on, but he and Larry S. Crumpler of Brown have developed a rather complete model with familiar elements from plate tectonics. In it, the several-kilometer-high Aphrodite Terra is analogous to Earth's mid-ocean ridges, at least in its western portions. They find that the shape and surface features of Aphrodite resemble those of terrestrial spreading centers.

If Aphrodite is a spreading center creating crust, is crust also being destroyed? The Brown group sees evidence of crust converging on the western end of Australia-size Ishtar, bending and crumpling to form linear mountain ranges as it collides. Some crust may be thrust beneath the Ishtar high-

emissions from the ionosphere unrelated to lightning or mere telemetry noise.

Space physicist Christopher Russell of the University of California, Los Angeles, now appears to have settled the matter, at least as far as volcanoes are concerned. Russell, who coauthored with Scarf some of the first work making the connection between Venusian lightning and volcanoes, has reanalyzed the observations. His conclusion: neither Scarf nor Taylor was entirely correct. Instead of clustering over volcanic regions of the surface, the reanalyzed lightning events cluster with respect to the time of day, being most abundant in the late afternoon and evening. That is just when the buildup of the sun's heat on Earth produces thunderstorms. This temporal correlation and the character of some of the radio noise suggest to Russell that he is seeing the effects of lightning among the clouds 60 kilometers above the surface, not over a few volcanoes.

■ R.A.K.

land to be destroyed in the mantle, as happens at deep-sea trenches on Earth.

Over in eastern Ishtar, the Brown group finds a situation reminiscent of the northern Pacific Ocean and Alaska. On Venus, several high-riding blocks of crust marked by a distinctive cross hatched pattern called tessera seem to have converged and docked against preexisting highlands, just as the Pacific plate has swept up bits and pieces of crust to form the geologic patchwork of southern Alaska.

In the Head and Crumpler model of Ishtar, the accreted blocks may have formed when plumes rising from the mantle beneath a spreading center like Aphrodite spewed extra lava to thicken the growing crust, the way Iceland has formed perched on the Mid-Atlantic Ridge. Head and Crumpler added such mantle plumes to their model of Aphrodite in order to explain some thicker-than-average crust there.

Despite all the effort, the Brown workers have yet to win many converts outside their own ranks. Elsewhere in geology, some still wonder whether Head has pushed the data too far. And interpretations of the same observations can vary immensely. When Soviet geologist A. A. Pronin of the Vernadsky Institute looks at the data from Ishtar, he sees a mantle plume rising beneath it that is dragging the crust outward to form mountain belts as the plume spreads away. The Brown model, however, has crust converging on Ishtar to make the mountains.

Among geophysicists, other types of data loom large. Geophysicist Walter Kiefer of NASA's Goddard Space Flight Center in Greenbelt, Maryland, calculates that Head's proposed spreading center in western Aphrodite could account for only 10 to 20% of its topography and gravity variations. "I don't think we can rule out spreading centers," he says, but from a geophysics point of view, "it must play a minor role."

Whether a Venusian version of plate tectonics, a terrain dominated by the motions of the underlying mantle, or something between the two turns out to be the case, both geologists and geophysicists are eager to settle the matter with Magellan data. "All the blind men are going to have to talk to each other just to describe this elephant," says Sean Solomon of Massachusetts Institute of Technology, "much less to understand how to make one."

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ADDITIONAL READING

J. W. Head and L. S. Crumpler, "Venus geology and tectonics," *Nature* **346**, 525 (1990).
W. M. Kaula, "Venus: A contrast in evolution to Earth," *Science* **247**, 1191 (1990).
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NF's Cancer Connection

Less than a month after the neurofibromatosis (NF) gene was isolated, investigators have their first solid clues about how the gene brings on this disease, which affects 100,000 people in the United States alone. And that discovery lands NF, which was virtually ignored by researchers until 6 years ago, in the middle of one of the hottest areas of cancer biology.

Ray White of the University of Utah has found that the protein coded for by the NF gene is a close cousin of a recently identified protein, GTPase-activating protein or GAP. Discovered just 3 years ago by Frank McCormick at Cetus, GAP is being furiously investigated in a number of labs, as it seems to play a pivotal role in many human cancers. NF, like cancer, is characterized by runaway cell growth, which gives rise to numerous benign tumors known as neurofibromas. White reported the discovery in the 10 August issue of *Cell*.

Not only does White's latest finding tell researchers how the gene might be working but it also makes it possible to at least envision therapeutic strategies. "This catapults us forward," says Peter Bellermann, executive director of the National Neurofibromatosis Foundation. "Do we have a cure? No. But we do know what avenues to pursue."

Perhaps the biggest payoff from this discovery is that some of the top guns in cancer research will now turn their sights to NF, says White, who adds, "and these guys are very good." Already, McCormick at Cetus and Michael Wigler at Cold Spring Harbor Laboratory, who calls White's discovery "riveting," are gearing up to study the new NF gene and what it might mean for cancer in general.

White discovered the family resemblance between the NF gene and the GAP gene when he compared the NF gene's sequence to that of nearly 20,000 proteins in computer databases. Such a comparison would normally be done as soon as a new gene is identified, but when White and another team led by Francis Collins of the University of Michigan rushed to publication last month, both groups had sequenced just a small chunk of this mammoth gene. Once White had more sequence in hand, he scanned the databases, looking for any similarity that might give some hint as to what the gene does.

The match he found was better than he could have hoped for: a stretch of 360 amino acids in the NF protein was remarkably similar to—in fact, it was 25% identical to—the catalytic region of GAP. What's more, the NF protein is even more closely related to the yeast equivalent of GAP, IRA1, not just in the catalytic region but extending 860–amino acids downstream and 350 in the other direction. Fascinating, says Wigler, who points out that, like GAP, the NF gene must be crucial to normal cellular functioning since it has been conserved throughout evolution.

But it will take some time to figure out what the NF gene is doing because, despite several years of intensive study, little is known about GAP except that it interacts with *ras*, a gene that, when mutated, is involved in perhaps 25% of human cancers. Exactly how GAP and the *ras* protein interact, however, is controversial, though one thing is clear: *ras* signals cells to grow, and when things are working normally, GAP down regulates or turns off the *ras* protein. In short, GAP keeps *ras* from running away with the cell. But GAP may have another role as well; in addition to acting upon the *ras* protein, GAP also seems to be a target for it, receiving and then transmitting signals down a still mysterious pathway.

This understanding, rudimentary as it is, suggests a couple of hypotheses for what the NF gene might be doing, both of which fit handily with White and Collins' initial speculation that NF is one of a small class of tumor suppressor genes. One possibility is that the NF gene ordinarily holds a *ras*-like protein in check, and when both copies of the NF gene are inactivated by a mutation, cell growth runs amok. The other model posits that the NF gene ordinarily plays an essential role in Schwann cells, the cells that give rise to neurofibromas, signaling them to differentiate. If the gene is knocked out, then the cells keep dividing relentlessly, massing into tumors. "Both models are simplistic and probably wrong," says White, but they are a place to start.

The next step is to figure out whether the NF protein interacts directly with *ras* or with a protein similar to it, which White is already setting out to do in collaboration with McCormick. McCormick predicts an answer in a couple of months.

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