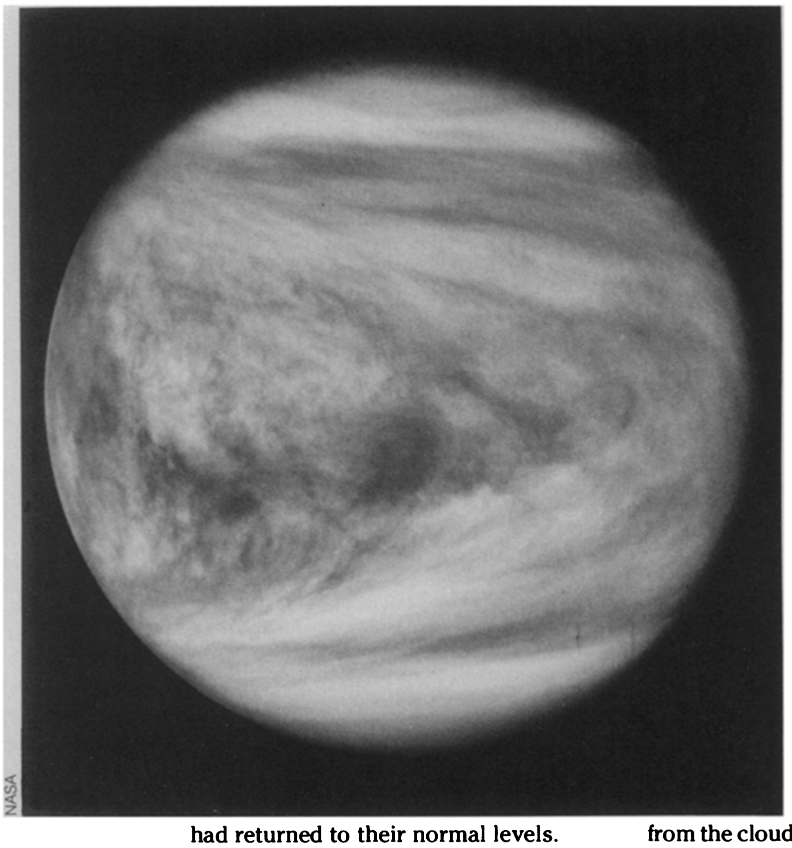
Venus: The Waters of Yesteryear

Of all of the other planets in the solar system, Venus is most like the earth in size, mass and distance from the sun. Yet the temperature at its surface is above the melting point of lead, and the atmospheric surface pressure is some 90 times earth's, equivalent to that about a kilometer below the waves of a terrestrial ocean. How can such fundamental similarities coexist with such radical differences? A key factor is water — or the lack of it. Both Venus and earth exuded large amounts of carbon dioxide in their early years, but on earth, water combined with most of the CO_2 and locked it into carbonate rocks, while on bone-dry Venus, the CO_2 remains free as the primary constituent of the atmosphere.

Yet Venus does have those earthlike credentials. So, was it always dry, or did it once give forth the equivalent of all the water in earth's oceans, only to lose it in the escalating heat? For years, the answer has eluded scientists. One theory holds that Venus must have been born dry, since the greater heat at its distance from the sun would have driven off any water before it could be incorporated into the forming world. Other scientists argue that mixing caused by collisions among the particles that ultimately formed both planets would have made it impossible for such an extreme difference in water content to develop.

It has been one of the great mysteries of earth's veiled neighbor. "I regard it as a major question, and perhaps *the* major question, regarding the formation of Venus," says Thomas M. Donahue of the University of Michigan. And now, according to Donahue, a belated reevaluation of some data originally written off as little more than evidence of a mishap has provided the first direct evidence of substantial amounts of water on the early Venus.

On Dec. 9, 1978, a U. S. spacecraft known as the Pioneer Venus Multiprobe arrived at the planet to conduct the most elaborate study ever undertaken of the "air" of another world. Approximately the scientific equivalent of a multiple-warhead missile, the device dispatched four instrumented capsules that descended through the atmosphere, measuring its properties all the way to the bottom. Aboard the largest of the probes was a neutral mass spectrometer, designed to analyze the composition of the lower atmosphere by scanning samples taken in through a tiny aperture, or "leak," in the capsule's spherical shell. But with about 50 km to go, just as it was beginning to penetrate the lower Venusian cloud deck, the instrument's reading of the dominant CO_2 suddenly dropped almost to zero, while the water count shot up 1,000 percent and sulfur dioxide showed a similar increase. About 25 km later, the readings had returned to their normal levels.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Principal investigator John Hoffman of the University of Texas and his co-workers (including Donahue, who is also chairman of the Pioneer Venus science steering group) concluded that the leak had been clogged by a droplet of sulfuric acid, common in the clouds, and confirmed their belief with laboratory tests using a copy of the probe's instrument. "But as far as providing information concerning the atmosphere of Venus was concerned," Donahue says, "apart from the note that, well, here is good, strong evidence that there's a lot of sulfuric acid in the clouds, we didn't look at those data between 50 and 25 kilometers in any detail until that night in Palo Alto."

"That night" fell this past Nov. 3, at an international conference on the Venus environment, nearly three years after the probe's descent. In a talk on the origin and evolution of the Venus atmosphere, Donahue was noting that a key to the water mystery might lie in the detection of deuterium, or "heavy hydrogen," a hydrogen isotope with twice the mass of regular hydrogen, and which is incorporated in about one ten-thousandth of the water molecules in earth's oceans. If the early Venus had quantities of water that were then dissociated into their component atoms, the hydrogen would presumably have escaped into space, while the heavier deuterium atoms would have remained behind. Hence, an excess, compared with the terrestrial value, in the present Venus ratio of deuterium to hydrogen could reveal how much water used to be there — if the ratio could be measured. The problem had been that, since water in today's Venus atmosphere is so rare, most of whatever water the Pioneer probe's spectrometer saw would have been contamination from earth, and the hydrogen from methane samples sent along to provide calibration for the instrument.

Listening to his colleague speak, it occurred to Hoffman that there might in fact have been one brief period when enough Venus water was present to yield a measurable deuterium-to-hydrogen ratio: the period when the leak was clogged by a droplet of sulfuric acid from the clouds. "I don't know why it never occurred to us — or anybody else — before," Donahue says. "It's been known to the entire [planetary science] community that our leak was stopped up with sulfuric acid, and that the evidence we presented was that we saw a large increase in water. But nobody tumbled to the idea that, hey, here is a time when you're really sampling Venus hydrogen, and if you ever had an opportunity to measure D-over-H, you had it then. We had all sat around for a couple of years, trying to figure out how to get D-over-H out these data, and hadn't tumbled on it till this time."

Looking that night at the data, which they carried with them in the form of computer printouts, Hoffman and Donahue indeed found a measurable D:H ratio. Refined over subsequent weeks, it appears to be about 1.5 percent — roughly 100 times that on earth. Figuring backward in time from measurements of the present amount of water in the atmosphere (the $H_2O:CO_2$ ratio), says Donahue, indicates that at one time there was at least 1.5 percent (the similarity with the D:H ratio is coincidence), the equivalent of adding nearly one and a half times the total atmospheric pressure of the earth, all of it in the form of water.

There could well have been far more, in fact, Donahue notes, without the D:H measurement being able to reveal its presence. Any more water than 1.5 percent, he says, would have so increased the greenhouse effect that hydrogen from the dissociated water would have escaped into space at supersonic speed, carrying the telltale deuterium with it. The similar amounts of carbon and nitrogen on Venus and earth, however, have suggested to some researchers that Venus could have "outgassed" as much as 300 bars of water in its early days, for a total atmospheric pressure equal to that nearly 4 km down in an earthly sea. The carbon-nitrogen argument is only circumstantial evidence, but it becomes considerably more persuasive in the light of the D:H result.

But was it ever an actual liquid ocean? Perhaps, Donahue says, though it would have lasted for no more than the planet's first few hundred million years. As the sun's heat evaporated some of the water, the greenhouse effect would increase, evaporating more water and further raising the temperature until most of the water had dissociated out of existence. If there was once 300 bars of water, in fact, the temperature could have reached 1,500 K (more than 2,700°F), says Donahue, which would also help explain another problem that has bothered advocates of a once-wet Venus: While the hydrogen from the water escaped into space over the eons, where did the heavier oxygen go? It, too, is rare in the present Venusian atmosphere, but 1,500 K, the Michigan scientist notes, happens to be about the melting point of basalt, a likely major component in the planet's rocky crust. A molten surface would have made the rocks ready candidates for oxidation, stealing the oxygen back out of the atmosphere.

Support for the probe's D:H measurement, meanwhile, may also exist in data from another source, an ion mass spectrometer aboard the Pioneer Venus orbiter that accompanied the Multiprobe vehicle to the planet and now looks down on the atmosphere from above. Several researchers have interpreted that instrument's measurements at atomic mass 2 as representing molecular hydrogen ions (H_2^+), but Harvard's Michael B. McElroy and colleagues believe the cited abundance to be incompatible with the observed amount of atomic hydrogen, or H_1. Instead, they suggest, the mass 2 reading could be indicating deuterium, leading to a calculated D:H ratio of about 1 percent, in the same range as the number from the probe. —*J. Eberhart*

Real-time computer-enhanced microscopy

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Standard video display of the phase-contrast microscopic image of a cultured kangaroo-rat cell (A). Clarity improves with computer: edge enhancement (D), same with background blackened (G), and contrast heightened by intensity transformations (J). Bottom is standard DIC-*microscopy image (K).*

Those who peer into the microscopic world are limited by the resolution of their magnifying instruments. Michael Berns, for example, found he was able to focus laser light beamed through a microscope into a point smaller than the diffraction limits of the best light microscope available. For one who studies subcellular — often molecular-level — changes wrought by such laser irradiation, this was a serious obstacle. But he and Robert Walter have made headway in overcoming the problem by borrowing from the space program those computer-enhancement techniques used to sharpen the focus of video images beamed back from space.

What the University of California at Irvine team has done is to couple a highly light-sensitive video camera and an image processor (originally designed for analysis of LANDSAT satellite images) to a Zeiss Axiomat microscope. Video display often provides viewers better-quality detail than would be possible using a microscope alone, Walter says. But by adding a digital image-processing computer, the researchers further enhanced data by reducing signal "noise," subtracting out background media, highlighting the edges of selected features, or arbitrarily altering image contrast — all in real time. And switching between alternate imaging techniques can be achieved at practically the push of a button, Walter says. A report on the system appears in the November PROCEEDINGS OF THE NATIONAL ACADEMY OF SCIENCES.

There has been a virtual explosion in video microscopy, Berns notes, with people using TV cameras to get good images from microscopes. "I think we've taken the next step," he told SCIENCE NEWS, "by running those good TV images through the computer for enhancement. I don't know if anyone else is doing what we're doing, but I suspect not."

Built for the laser-microbeam program, a national biotechnology-research facility, the system Berns and Walter developed was costly, roughly $500,000. But a more moderately priced system might be assembled for roughly $100,000, Walter says. Computer software is the critical component, but the university team is willing to share programs they've developed.

Some traditional techniques, such as differential interference contrast (DIC) microscopy, offer the level of detail and contrast achieved with computer enhancement (compare at left the DIC-image, K, with computer-enhanced version, J). However, the computer system develops images more quickly, offers greater flexibility in customizing enhancements, and requires less light to view objects. The last is notable, Berns points out, since the light required for DIC microscopy can damage or kill some living systems. —*J. Raloff*