# New Evidence of Ancient Sea on Venus

Born in the same part of the solar system as our own planet, Venus has a mass, chemical composition, and size similar to Earth's. But the planet known as Earth's twin differs in at least one important respect. Venus is as dry as a bone. So could the two planets truly have a common origin?

A new analysis of spacecraft data suggests that in the distant past, Venus was all wet. The planet may have had an ocean as deep as 25 meters, according to a reexamination of data gathered by the Pioneer Venus satellite, which burned up in the Venusian atmosphere last fall after a 14-year mission (SN: 10/17/92, p.263). The ocean on Venus might have lasted long enough—about a billion years—to support primitive life, says Thomas M. Donahue of the University of Michigan in Ann Arbor. He reported the findings last week at a press conference in Pasadena, Calif.

Donahue and his colleagues base their report on the chemical evidence that water molecules leave behind when they split apart and leave the atmosphere of a planet. This chemical signature comes from the abundance of two atoms—hydrogen and its less abundant isotope deuterium, which has twice hydrogen's mass. From 1978 through 1980, Pioneer Venus recorded the ratio of deuterium to hydrogen in the planet's upper atmosphere.

The craft's early measurements revealed that this deuterium-to-hydrogen ratio is at least 150 times greater on Venus than in any other known place in the solar system. That unusual ratio presumably came about over billions of years during which atmospheric conditions on Venus prompted ionized hydrogen to escape, while gravity kept the heavier deuterium on the planet. Thus, Venus once had at least 150 times as much hydrogen as it does now. And since hydrogen readily bonds with oxygen to produce water, this suggests that Venus once had a minimum of 150 times as much water as it does now.

Those early data would make any ocean on the young Venus only 0.5 meter deep, notes Donahue. But in reexamining the data, two of his collaborators — Richard E. Hartle and Joseph M. Grebowsky of NASA's Goddard Space Flight Center in Greenbelt, Md. — calculated that deuterium on Venus might exit more easily, compared with hydrogen, than estimated.

If Donahue's team is correct, then Venus once had much more deuterium than previously calculated. This means that the planet must also have had more hydrogen in the past, in order to come up with the ratio of deuterium to hydrogen measured by Pioneer Venus. In fact, Donahue says, hydrogen was about 3.5 times more abundant than believed. And since more hydrogen implies more water, he asserts that Venus may once have had an ocean 8 to 25 meters deep. "The data indicate that Venus was a pretty wet planet," he says.

Donahue cautions that Venus' early water supply might have been steam, not liquid. But scientists generally believe that the sun's luminosity was 30 percent lower several billion years ago, and it may have been cool enough on Venus to permit an ocean. Later on, as carbon dioxide and other greenhouse gases — including water vapor itself — rapidly accumulated in the planet's atmosphere, the surface heated up and the proposed ocean disappeared.

A comparison of data collected by Pioneer Venus during its first few and last few years in orbit shows that the Venusian ionosphere is much lower and less dense when the sun is near a minimum in its 11-year sunspot cycle, Donahue notes. This indicates that if Venus had an ocean, it probably did not exist beyond the first billion or so years of the planet's existence, he says.

Climate modeler James Kasting of Pennsylvania State University in University Park says the new analysis hasn't yet convinced him that Venus once had a deep ocean. "It's not clear to me that we are understanding all the processes important for hydrogen escape; it's messier than we used to think," Kasting says.

Victor R. Baker of the University of Arizona in Tucson, who has proposed that Mars once harbored an ocean, says the Venus findings support the view that all of the inner solar system planets were formed from the collision of similar material and once had an abundance of water.

*— R. Cowen*

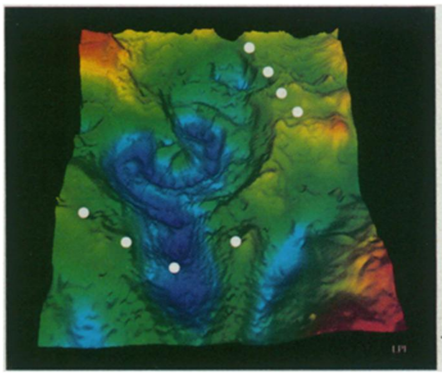
## Cretaceous die-offs: A tale of two comets?

Hot on the trail of a prehistoric killer, geologists have used the chemical equivalent of fingerprints to exonerate one suspect while shoring up the case against another in Earth's greatest murder mystery — the mass extinction that ended the Cretaceous period and wiped out the last living dinosaurs.

At the Lunar and Planetary Science Conference in Houston last month, several teams of researchers reported on studies concerning two impact craters that date to the boundary between the Cretaceous (K) and Tertiary (T) periods 65 million years ago. Analysis of a crater buried near Manson, Iowa, suggests that the impact there left no widespread trace in the sediments of the time and therefore did not cause any of the global havoc. Instead, mounting evidence links the Chicxulub crater beneath Mexico's Yucatán Peninsula with the K-T catastrophe.

"I think people who have been supporters of Manson have realized that Manson is probably not responsible for virtually anything we see in the K-T boundary sediments and that everything is fitting into place for Chicxulub," says Joel D. Blum of Dartmouth College in Hanover, N.H.

Scientists first raised the idea of K-T impacts in 1979, after finding a thin layer of clay containing high concentrations of the element iridium in 65-million-year-old sediments. Because iridium is much more abundant in comets and asteroids than in Earth's crust, the scientists proposed that the clay layer represents the fallout from a thick dust cloud created when an extraterrestrial body walloped Earth at the end of the Cretaceous.



Sharpton

*Gravity data from Chicxulub show the buried crater. White dots indicate proposed outer rim, which would make the crater nearly 300 km across.*

Further impact evidence came when researchers studying the K-T boundary sediments found slivers of quartz bearing fractures created by a severe shock wave. The K-T sediments also yielded pieces of "tektite" glass, which forms when an impact sends up a spray of molten rock droplets that solidify as they fall.

When geologists went searching for the crater left after the K-T crash, they focused first on the Manson structure. At 35 kilometers wide, Manson is one of the biggest impact craters on Earth, though most scientists have considered it too puny to account for the amount of iridium present in K-T boundary sediments. In the last two years, geologists have drilled into the Manson crater to obtain samples that would resolve its age and relationship with the K-T event.

Blum and his colleagues used the isotopic ratios of several elements to compare drill samples from Manson with pieces of tektite glass found in K-T boundary sediments from Haiti. This chemical fingerprinting technique revealed that the Manson impact could not have created the Haitian glass. "The Manson samples are about as different as you can get," Blum says.

The same technique shows a "striking similarity" between the Haitian glass and rocks from Mexico's Chicxulub crater, suggesting that the Haitian samples formed from the Yucatán rock, says Blum. Although oil company geologists discovered the Chicxulub structure in the late 1970s, only within the last two years have researchers recognized the formation as a K-T crater.

After the identification of Chicxulub, some geologists who had previously worked on the Manson crater wondered whether K-T boundary sediments contain evidence of both impacts. Indeed, in the Rocky Mountains, sediments dating to this time show two distinct clay layers, possibly from the two impacts.

New evidence, however, argues against the idea that Manson left a widespread imprint. Wayne R. Premo and Glen A. Izett of the U.S. Geological Survey in Denver came to this conclusion by dating zircon crystals found in K-T sediments from Colorado, a technique first used last year by another team. These crystals – remnants of the rock originally hit by the impactor – are roughly 550 million and 330 million years old. Because the rocks at Manson are much older, the zircons suggest that the Iowa impact left no appreciable mark in the Colorado sediments, says Premo.

Maureen B. Steiner of the University of Wyoming in Laramie reports that early analysis of the magnetic orientation in the Manson drill samples indicates the Manson crash occurred roughly 200,000 years before or after the Chicxulub impact. On the basis of this evidence, Eugene M. Shoemaker of the USGS in Flagstaff, Ariz., suggests the two strikes most likely came from comets, perhaps knocked loose from the Oort cloud at the edge of the solar system.

In terms of global effects, geologists believe the Chicxulub crash did almost all of the damage because it was so much larger than the Manson hit. Early analysis of the buried Mexican crater indicated it was 180 km across, which would make it the largest known crater on Earth. But Virgil L. Sharpton of the Lunar and Planetary Institute in Houston reports that a new study of gravity measurements hints that the Chicxulub crater spans almost 300 km, making it one of the largest in the solar system. Scientists think such a crash blocked out sunlight and chilled Earth for several years before spawning a global heat wave that lasted perhaps a millennium. *– R. Monastersky*

# Using light to focus chilled chromium atoms

To fabricate microscopic circuits on silicon chips, semiconductor manufacturers typically shine light through a mask onto a photosensitive surface to create the necessary patterns. But the width of the mask's lines limits the fineness of features that can be etched on a chip.

To create much finer features, some researchers have been exploring the possibility of using light itself as a lens to guide atoms to particular positions on a surface. Last year, Gregory L. Timp of AT&T Bell Laboratories in Holmdel, N.J., and his collaborators demonstrated the effect with sodium atoms (SN: 3/14/92, p.166). Now, Robert J. Celotta and his colleagues at the National Institute of Standards and Technology (NIST) in Gaithersburg, Md., have shown that light can also be used to position chromium atoms.

"The work that Celotta has done is really a big step forward," Timp says. "He has moved atomic physics to the center of the periodic table. He has proved . . . that you can, in principle, use any element that you want."

In separate reports, Timp and Celotta described their findings at last week's American Physical Society meeting, held in Seattle.

To deposit parallel lines of sodium atoms on a silicon surface, Timp and his co-workers first cool a beam of sodium atoms to temperatures of less than 1 millikelvin. The cooled beam then passes through a standing wave of laser light, which nudges the atoms into certain paths in the same way that a pattern of ripples on the surface of a pond focuses sunlight into a comparable pattern of bright and dark areas on the pond's bottom.

The researchers have obtained indirect evidence that their technique deposits evenly spaced lines of sodium atoms about 300 nanometers apart and probably less than 100 nanometers wide. But because sodium reacts readily with stray atoms and molecules still roaming the ultrahigh vacuum in which the experiment is done, the pattern deteriorates too quickly to be imaged.

Chromium reacts far less readily than sodium, but it takes a much higher temperature to create a beam of chromium atoms. The NIST team had to go to great lengths to produce the beam and then cool the atoms to temperatures low enough for a standing light wave to focus the beam into narrow lines.

"We were pleased just before the meeting . . . to come up with images of the chromium lines," Celotta says. "They look to be quite high resolution." *– I. Peterson*

# Revealing the sun's solitary vibrations

The sun rises, its face warm, placid, reassuring. But on closer inspection, our home star actually behaves like a bubbling cauldron, with heat-driven convection currents setting vibrations ringing throughout its interior.

Astronomers began tuning in to these vibrations in the 1970s and have since learned a great deal about the sun's dynamics (SN: 7/2/88, p.8). Now, researchers have hit upon a new way of extracting information from this solar symphony. The technique, developed by NASA solar physicist Thomas L. Duvall Jr. and his colleagues at the National Solar Observatory (NSO) in Tucson, Ariz., may enable astronomers to use individual acoustic waves traveling through the sun to study its interior, much as seismologists use the echoes of earthquakes to probe geologic structures deep within the planet.

"This really brings us a little closer to what's being done in terrestrial seismology," says Duvall. The researchers report their findings in the April 1 NATURE.

Usually, helioseismologists observe the entire spectrum of solar vibrations simultaneously. The sun, they have discovered, resonates most strongly at specific frequencies, or pitches, much like an enormous pipe organ. The new technique enables researchers to track the motion of individual acoustic waves, which emanate from a relatively thin, active layer near the sun's surface.

These waves travel downward into the sun, where changes in density bend them back up toward the surface. The waves deflect off the underside of the surface, creating ripples that astronomers can observe from Earth. Each wave can repeat this process 50 or more times.

"This is a major advance," declares John W. Leibacher, director of the NSO and an early practitioner of helioseismology. The technique, says Leibacher, may help researchers probe smaller regions of the sun, perhaps illuminating the mysterious subsolarian processes that generate sunspots.

However, the proof of the new method will be in the doing, comments solar physicist Timothy M. Brown of the National Center for Atmospheric Research in Boulder, Colo. As it stands, the technique may prove somewhat insensitive to low-frequency vibrations, Brown says. This may hobble efforts to chart relatively slow, albeit massive, flows of material far below the sun's surface, he explains. Nonetheless, he adds, the technique represents "an important move in the right direction." *– D. Pendick*