says Peter Stang, who led the research effort. The Utah team has yet to test the squares' unique recognition abilities, but their architecture bodes well, Olah says.

These chiral forms are not the first squares out of the box for the Utah team. The researchers have already made a variety of nonchiral squares in hopes that their unique cavities and configurations of atomic components will allow them to act as catalysts, filters, or traps for molecules that only fit in square corners. The earlier models were formed by creating two different sets of building blocks: corners and straight connecting arms. A metal atom such as platinum, which has four possible binding sites extending out like the arms of a cross, often serves to create the corners. The researchers block off two adjacent sites with chemical groups known as phosphines, leaving the other pair—which forms a right angle—free.

To connect these 90-degree corners, the researchers use arms made from organic compounds, such as bipyridine, which have a pair of nitrogen atoms on each end. When the scientists add the corners and arms to an organic solvent, the squares spontaneously assemble as the electron-rich nitrogen atoms in the arms bond to the electron-hungry metals in the corners.

But while these squares can trap molecules, they cannot distinguish between the mirror-image structures of chiral twins. To give their squares this extra ability, the group replaced the bipyridine arms with compounds such as 2,6-diazaanthracene-9,10-dione (DAAD). The nitrogen atoms at the ends of these molecules are slightly offset from the molecules' long axis. As a result, the DAAD arms have to twist when they bind to the corners, giving an overall asymmetrical twist to the square (see photo).

To ensure that all of the squares twist in the same way—essential if they are to find just one chiral species in a sea of molecular variety—the researchers replaced the phosphine units at the corners with bulky chiral compounds commonly abbreviated as BINAPs. The BINAPs hem in the attachment sites for the DAAD arms, leaving only one way for the DAADs to fit into the corners. The result is formation of just one consistent chiral architecture, or enantiomer, explains Stang. "We don't fully understand why we get one particular enantiomer," says Stang. But, he adds, that enantiomer should only recognize one molecular species.

The Utah team now plans to test the squares for this selective recognition. If the chiral squares pass the test, the next step will be to design squares that catalyze reactions between chiral molecules, such as unsaturated amines, and hydrogen to create products which are used in drug synthesis. That could make it very hip to make squares.

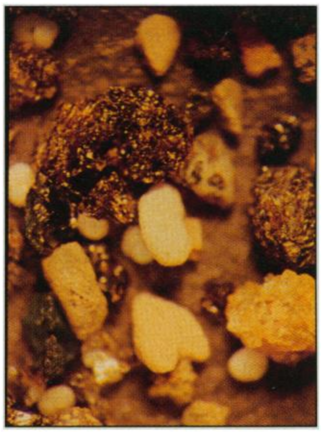
–**Robert F. Service**

CLIMATE

Millennial Climate Oscillation Spied

For climate researchers, figuring out how much Earth's climate is being warmed by the release of greenhouse gases has become a major growth industry. But from studies of past climates comes a reminder that the greenhouse effect isn't the only thing determining global climate. By analyzing climate records stored in sediments and glacial ice, researchers have detected a slow climate oscillation that has alternately warmed and cooled the world every couple of thousand years for the past hundred thousand years, and perhaps for hundreds of millions of years.

Such millennial-scale oscillations had been spotted before, in the last ice age and even earlier in Earth's history. But the latest work firmly establishes them in the Holocene Epoch, the 10,000 years since the end of the last ice age. The climate oscillations in the Holocene are "not quite as wild as [in] the ice age," says ice core specialist Richard Alley of Pennsylvania State University, "but [the epoch] is certainly not boring."



G. BOND

Marking the climate beat. Ice-borne grit records an extra chill.

Indeed, the oscillation's latest dip to the cold side may have been the Little Ice Age of 300 years ago. "Because this oscillation runs through the Holocene, it means that it is operating independent of glacial ice and that it is running now," says paleoceanographer Gerard Bond of Columbia University's Lamont-Doherty Earth Observatory, whose lab is contributing to the work. Understanding what drives the oscillation—still a mystery—might help predict how much—or if—natural warming will boost greenhouse warming.

Bond originally spotted a millennial climate oscillation during the last ice age by analyzing the rock grains in marine sediments older than 10,000 years. When icebergs that split off from the ice sheets on North America and Iceland began to melt, they dropped sand- and pebble-size rocks to the bottom of the deep North Atlantic that are so large and angular that they could not have washed there from rivers. And as Hartmut Heinrich of Germany's Federal Office for Marine Navigation and Hydrography in Hamburg had reported in 1988, the abundance of this ice-rafted debris in sediment cores jumps every 7000 to 10,000 years, reflecting gushes of bergs from the ice sheets that sailed across the North Atlantic. But when Bond and his Lamont colleague Rusty Lotti looked more closely at the sediment cores, they also found smaller but more frequent surges in ice-rafted debris every 2000 to 3000 years.

Early on, all these North Atlantic iceberg surges were assumed to be driven by processes intrinsic to the ice sheets. The idea was that the North American ice sheet periodically grew until it collapsed under its own weight, spewing out an iceberg armada. But a year ago, Bond and Lotti seemed to rule out that idea, at least for the ice sheets around the northwestern North Atlantic, when they showed that the little Icelandic ice sheet was discharging icebergs on roughly the same schedule as its larger neighbor. If the internal dynamics of the ice sheets were responsible for the surges, the two ice sheets should have been following quite different schedules (*Science*, 6 January 1995, p. 27). Some oscillation in global climate, not the internal dynamics of the ice sheets, seemed to be driving the iceberg surges.

If so, the oscillations would also be expected in the Holocene, after the great ice sheets had largely melted. Indeed, Suzanne O'Brien of the University of New Hampshire and her colleagues had already found a clue that the oscillations didn't end with the ice age in an analysis of sea salt in Greenland ice during the Holocene. In results just published in the 22 December issue of *Science*, these researchers found that, starting 11,300 years ago, the flux of fine particles of sea salt falling on the core site of the Greenland Ice Sheet Project jumped five times at intervals averaging 2600 years. Apparently, more intensely winterlike, stormy weather was periodically lofting more than the usual amount of seawater droplets off the Atlantic and onto Greenland.

O'Brien had passed her unpublished results on to Bond, who decided to look for a matching oscillation in a Holocene-age sediment core drilled between Greenland and Iceland. There, as Bond reported at last month's meeting of the American Geophysical Union, he found increases in ice-rafted debris—albeit a tenth the size of ice-age ones—at 1000- to 2400-year intervals. These surges tended to coincide with the sea-salt peaks on Greenland, suggesting that periodic spells of unusual cold were creating more icebergs or letting ice travel farther than usual before dropping its load of debris.

What the ultimate driver of this millennial climate oscillation is, no one can say, but Bond, O'Brien, and some others are intrigued by the possibility that the driver is not within the climate system itself, but is instead the sun. "I think there's increasing evidence of solar variability playing a significant role on century and millennial time scales," says paleoclimate modeler Thomas Crowley of Texas A & M University.

Supporters of this idea point to a variety of evidence suggesting that solar activity varies on a time scale similar to their climate oscillations. There is, for example, an approximate 2700-year cycle in salt deposition recorded in a now-dry saline arm of the ocean. The cycle is so old—more than 250 million years—that the sun is about the only thing whose behavior has been consistent enough over time to have caused it. If so, then the climate variations that caused the iceberg surges might also date back that far.

Still, says Alley, "I don't believe that anyone has a convincing story" about what's causing the oscillations. To convince him that the sun is indeed behind them, Alley wants to see variations in a uniquely solar signature in the ice cores. An approximate 2500-year oscillation has been reported in the amount of carbon-14 in tree rings, which could be reflecting the sun's influence on carbon-14 production in the atmosphere, but changes in the amount of carbon-14 returned from the deep ocean by varying currents could mimic the effects of solar variations. So Alley looks to ice core analyses of beryllium-10, an isotope whose abundance is solely dependent on solar activity. A search for beryllium-10 variations is under way, another factor that will keep climatologists' interest in the recent past high even as they try to predict the future.

–Richard A. Kerr

ANTIMATTER

Physicists Produce First Antiatom

European physicists revealed their first glimpse into the shadowy world of antimatter last week, with the announcement by the CERN particle physics center in Geneva that researchers there had created the first few antiatoms. An international team used CERN's Low-Energy Antiproton Ring (LEAR) to create a total of 11 atoms of antihydrogen, the simplest complete atom in the antiworld. "The CERN measurements are a milestone in the progress that physicists have made in producing exotic atoms," says theorist Stan Brodsky of the Stanford Linear Accelerator Center (SLAC) in California.

Physicists are intensely excited at the prospect of being able to study this entirely new atom, because it will provide a fundamental test for physicists' understanding of matter. "Astrophysicists tell us that in the big bang we should have antimatter as well as matter, but ... in space they do not find antimatter, at least not in the amounts they see matter," says Walter Oelert of the Institute for Nuclear Physics, part of the German National Research Center at Jülich, who led the LEAR team. "A principal question for us is 'why is the amount of matter and antimatter different?' " says Oelert.

Antimatter is the mirror image of the matter that makes up our world. Its existence was suggested by British theorist Paul Dirac in 1931, whose famous quantum equation postulated the existence of an antiparticle counterpart of the electron. Dirac theorized that this particle, dubbed the positron, would have the same mass as the electron but opposite charge, and that the two would annihilate on contact.

The positron was found 2 years later, by Carl Anderson of the California Institute of Technology, while antiprotons were spotted at the University of California, Berkeley, in 1955. But until now, nobody has been able to combine a positron and an antiproton to create antihydrogen, because they are usually created in violent collisions, and slowing them down or closely matching their speeds is far from easy.

In 1992, however, Brodsky and colleagues Charles Munger and Ivan Schmidt suggested a possible method for making antihydrogen. Oelert and his team, which includes scientists from the University of Genoa in Italy and other German universities, were the first to get it to work last September. The team directed a jet of xenon gas across the path of LEAR's antiproton beam. Very occasionally an antiproton is scattered by the positive charge of a xenon nucleus, converting part of its energy into an electron-positron pair. In a small fraction of these cases, the positron's velocity was sufficiently close to that of the

Forge for antimatter. CERN's Low-Energy Antiproton Ring made the first atoms of antihydrogen.

CERN

scattered antiproton for the two particles to combine and create an antihydrogen atom. The process of combination is so rare that producing 11 antihydrogen atoms required 5×10^{12} antiprotons.

Initially, the antihydrogen atoms kept moving along with the antiproton beam, but as they have no net charge they evaded the magnets that bend the beam around LEAR's running track–shaped path. So at the first bend the atoms exited through a window into a custom-built silicon detector. Here, each antihydrogen atom broke up, only 40 billionths of a second after its creation, and the fragments produced a signal that enabled the researchers to identify the antihydrogen atoms. "We should have expected to see nine events and we saw 11 ± 2, which is extremely good agreement, better than we ever expected," says Oelert.

It will be a while, however, before physicists can start studying these intriguing new creatures, because they zip through the apparatus at close to the speed of light. "This is a problem," says fellow LEAR scientist John Eades. But physicists are very keen to solve it: All of the currently accepted theories for the four fundamental forces of nature depend on an absolute symmetry between matter and antimatter. Atoms of antihydrogen should emit light at exactly the same frequencies as hydrogen; any differences would be a huge jolt to the theories. "If we found a tiny discrepancy, that would have a tremendous influence on the way we look at the universe and the way we interpret the big bang," says Eades. Although it might provide some clues to why antimatter seems to be in short supply in the universe, "one would have to change essentially all of our ideas about the way the universe works and is constructed," Eades notes. Finding a break in the symmetry, he adds, "would shed new dark on everything."

Brodsky's colleague Munger will start a new experiment at SLAC later this year that will attempt simple spectroscopy on fast antihydrogen atoms produced in a similar way to Oelert's. Other researchers are taking a different route. "It's only a matter of time till slow antihydrogen will be available," predicts Harvard University's Gerald Gabrielse. His team hopes to produce antihydrogen using trapped antiprotons and separately trapped positrons, which would then be combined in a third trap.

While they wait for these new experiments, physicists find themselves confronting a different problem: dismissing popular reports that antimatter drives will soon be powering spaceships to the stars. Says Brodsky: "Rocket engines burning antimatter fuel will remain in the realm of fiction."

–Andrew Watson

Andrew Watson is a writer in Norwich, U.K.