PALEOCLIMATOLOGY

Viable But Variable Ancient El Niño Spied

A climate record preserved in the bottoms of now-vanished lakes in New England shows traces of El Niño as far back as 17,500 years ago. The findings, reported on page 1039 of this issue, indicate that the tempo of tropical Pacific warmings remained roughly constant, but the beat strengthened and weakened for thousands of years at a time.

Muddy message. Varying thickness of lake sediment layers tells of a variable El Niño.

CREDIT: T. M. RITTENOUR/UNIV. OF NEBRASKA, LINCOLN

"It's nifty stuff," says paleoclimatologist David Rea of the University of Michigan, Ann Arbor. "This is new information—how long does a climate mode last, and when does it switch to the next mode?" The results fit well with new climate models that suggest that periods of weakened El Niños rhythmically alternate with the current mode of strong El Niños. Driving these swings, at least in the models, are periodic variations of solar heating as Earth wobbles on its spin axis. The record of these orbitally induced climate shifts over past millennia may help researchers understand how climate oscillations like El Niño will respond to future greenhouse warming.

The latest record of ancient El Niño is a byproduct of century-old geologic work. Early in the 20th century, Swedish geologist Ernst Antevs came to New England to sort out the history of the great ice sheets' retreat northward beginning 20,000 years ago. He could map the sequence of sediments washed out from the ice sheet and deposited in a lake at the ice's edge, such as Glacial Lake Hitchcock, which filled the Connecticut River valley. But to trace the ice front's position in New York, Vermont, and New Hampshire at a given time, Antevs needed a time marker that would tell him that sediments in widely separated lakes were laid down at the same time.

Antevs found such a marker in the seasonal layering of glacial sediments. Each summer, glacial meltwater would carry a heavy load of coarse sediment into the lakes, and each winter, meltwater would slow to a trickle, laying down a thinner, finer-grained layer. Antevs could tell which year, out of thousands, one of these layers or varves was laid down, because climate changes from year to year and decade to decade influenced the amount of melting across New England, creating unique patterns of varve thickness.

Geologists Tammy M. Rittenour and Julie Brigham-Grette of the University of Massachusetts, Amherst, which sits on Glacial Lake Hitchcock deposits, shared Antevs's interest in glacial history. They took a digitized version of his thickness records of more than 4000 summer-winter varve pairs published in the 1920s, filled a few gaps by adding some new thickness measurements (including some from a core they drilled on campus), and verified a 4000-year varve chronology spanning the glacial retreat from 17,500 to 13,500 years ago.

But the varve record offered tantalizing hints about climate as well. Rittenour (who is now at the University of Nebraska, Lincoln) and Brigham-Grette teamed with statistical climatologist Michael Mann of the University of Virginia in Charlottesville to extract a history of climate variability over that same 4000-year period. The thicker a varve, the warmer the weather in New England that year. They found that New England climate varied with the same 2.5- to 5-year beat that El Niño currently follows in the Pacific. Apparently, then as now, El Niño's influence reached into New England.

That came as a bit of a surprise, because a 12,000-year climate record retrieved from an Ecuadorian lake, close by the tropical Pacific, shows no sign of El Niño's torrential rains in that period (*Science*, 22 January 1999, p. 467). But the New England varves hold a clue to reconciling the two records. The Ecuadorian record may contain only the strongest El Niños, the ones whose heavy rains could wash sediment into the lake, while the New England record may contain both large and small El Niños. In New England, the apparently larger El Niños steadily faded until they were more or less gone 13,500 years ago. If those were indeed the larger ones, their absence left the Ecuadorian record with nothing big enough to record from the end of the ice age until strong El Niños returned in the past 5000 years.

Climate modelers using two very different paleoclimate models think they see how El Niños might have waxed and waned this way over the millennia. Amy Clement and her colleagues at the Lamont-Doherty Earth Observatory in Palisades, New York, used a simple model of the tropical Pacific, and Zhengyu Liu of the University of Wisconsin, Madison, and his colleagues used a complex global model. Both groups find that Earth's wobbling could be responsible. Today, Earth's spin axis is tilted so that the planet is closest to the sun in January, during Northern Hemisphere winter, giving the planet a little extra solar heating then. But Earth wobbles like a top, taking 21,000 years for one wobble, so that 11,000 years ago its spin axis pointed in the opposite direction, putting Earth closest to the sun in Northern Hemisphere summer. In the models, that extra summer heat is enough to strengthen winds over the tropical Pacific at a time of the year critical to initiating a new El Niño, discouraging it from forming, says Clement.

That Earth's orbital variations may be fiddling with El Niño's vigor has climate researchers excited. "This is a real opportunity to look at El Niño under other climatic base states," says paleoclimate modeler John Kutzbach, a collaborator of Liu's at Wisconsin. By seeing how El Niño reacts when prodded by changes in the rest of the climate system, he notes, researchers should get a better idea of how El Niño will behave in the future. The recent results "say, yes, if we have a different base state, we get a different El Niño," he says. "And the greenhouse will obviously be a different base state." –**RICHARD A. KERR**

HUMAN GENOME

Mapping a Subtext in Our Genetic Book

PARIS—As scientists race to finish a rough draft of the human genome, a European consortium is about to launch an effort to pinpoint every key spot in our genetic code where cells turn genes on and off by adding a methyl group to cytosine, one of the four nucleotides that make up DNA. Variations in methylation between healthy and ailing tissues "might give us a better understanding of what goes wrong" in some diseases, says Alexander Olek of Epigenomics, a biotech start-up in Berlin. The consortium announced at the Genomes 2000 meeting here last month that they have won initial funding for the project, which aims to grind out methylation maps for every kind of tissue.

Since the 1960s, researchers have accumulated more and more evidence suggesting that methylation plays many roles, including silencing the extra X chromosome in females. And methylation gone awry is linked to cancer and rare inherited diseases such as ICF syndrome, an immune disorder distinguished by facial abnormalities such as low-set ears.

The mysterious instructions on where and when a cell ought to add methyls are somehow transmitted to daughter cells during cell division. Many scientists believe the resulting "epigenetic" variations are "a way of regulating genes in a hereditary manner without changing the genetic code," says Olek. "There are hundreds of thousands of methylation signals in the human genome, and the methylation pattern pretty much reflects the pattern of gene [activity]."

For now these patterns are as inscrutable as hieroglyphics were before the discovery of the Rosetta stone. "We would like to find out what different methylation patterns mean," says Stephan Beck of the Sanger Centre in Cambridge, U.K. Sanger—along with Epigenomics, the Max Planck Institute for Molecular Genetics in Berlin, the French National Genotyping Center in Paris, and others—formed the Human Epigenome Consortium (HEC) last December to undertake the twin Herculean tasks of compiling methylation patterns for every tissue and raising an undetermined wad of cash to get going. To provide insights into biological processes, Olek estimates that HEC must identify about 400,000 cytosines that undergo methylation. HEC will use several tools to hunt down these cytosines, including a DNA chip developed by Epigenomics that maps methylation patterns. The effort will be a slog: Multiply the number of target cytosines by roughly 100 tissue types, Olek says, and "you've got almost the same amount of work as the entire human genome."

HEC met its first milestone last month, when the European Union gave it $1.1 million for a pilot project in a small region—about 4 million base pairs, or 1/1000 of the human genome—containing the genes for the major histocompatibility complex (MHC), proteins that present snippets of pathogens to immune cells. Researchers will look at MHC regions in about 20 tissues, mainly various classes of immune cells, and they will compare methylation patterns of inactive cells with ones riled up by pathogens or by autoimmune disease.

Although HEC will make its pilot data freely available to the scientific community—along with methylation patterns in healthy tissues once the full project gets under way—Epigenomics plans to set up a proprietary database on differences between healthy and diseased tissues to flag, for example, patterns associated with tumors. "If they can develop assays for the early detection of tumors, that's going to be key for cancer treatment," says Adrian Bird, a molecular geneticist at the University of Edinburgh.

Some experts are less enthusiastic. "Whether it will be as revelatory as assumed remains to be seen," says Aravinda Chakravarti, a human geneticist at Case Western Reserve University in Cleveland. He thinks the project should also probe other regulatory processes, such as how DNA is packaged into chromatin. "This might tell us how valuable a methylation map really is."

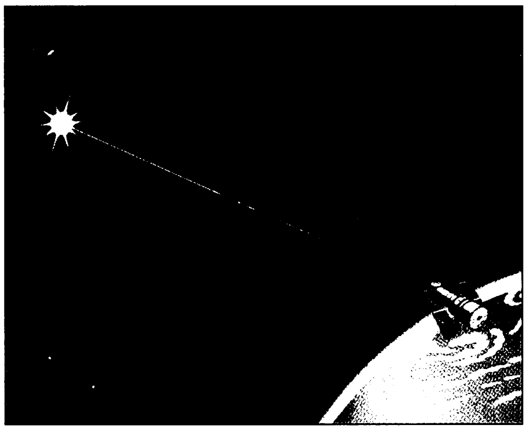
Others say the time is ripe to bring the heavy guns of sequencing to bear on methylation. "For much too long people have ignored the fact that DNA consists of five bases instead of four," says Beck. Olek hopes the fifth base will entice other major sequencing centers to joint the HEC. "They'll have to find other projects to keep them busy after the human genome is finished," he says.

–MICHAEL HAGMANN

ASTRONOMY

Astronomers Detect More Missing Matter

Forget about dark matter, the mysterious invisible stuff that scientists say holds the galaxies together. The plain old ordinary matter that makes up stars, planets, and you and me presents puzzles of its own. The early universe contained up to 10 times more of it than would fit into all of today's galaxies, and no one knows where it all went. Now new data from the Hubble Space Telescope suggest that much of it may be hiding out in the open, in enormous clouds of ionized gas stretching between galaxies.



Through a gas, darkly. Ionized oxygen absorbs quasar light.

CREDIT: J. GODFREY/STSCI

Astrophysicist Todd Tripp and astronomer Edward Jenkins of Princeton University in Princeton, New Jersey, and astrophysicist Blair Savage of the University of Wisconsin, Madison, found a clue to the missing matter's whereabouts when they pointed the Hubble at a particularly bright, young quasar and dissected its light. In the ultraviolet region of the quasar's spectrum, the researchers found pairs of absorption lines, wavelengths at which the intensity of the light dipped. The lines indicated that oxygen VI, oxygen stripped of five of its eight electrons, lay between the quasar and Earth, soaking up some of the light. And where there's oxygen, there's sure to be hydrogen, as hydrogen is by far the most abundant element in creation. So, as the researchers report in the 1 May issue of *Astrophysical Journal Letters,* they concluded that intergalactic space is filled with clouds of invisible ionized hydrogen. "This brings us toward a census of all the matter in the universe," says Jane Charlton, an astronomer at Pennsylvanina State University, University Park.

Such a census is necessary because most of the ordinary matter in the universe has gone missing over the past 10 billion or 12 billion years. When astronomers peer at very distant quasars, they see a forest of absorption lines due to hydrogen atoms. The lines indicate that, when the universe was just a couple of billion years old, it was filled with enormous clouds of hydrogen. But when they look at younger, not-quite-so-distant quasars (say, 5 billion years old), researchers find far fewer lines. Apparently, a few billion years ago, as galaxies swarmed into clusters and the universe generally grew lumpier, most of the hydrogen atoms disappeared.

Or maybe they just became invisible. To absorb light, a hydrogen atom must be whole; a raw nucleus, stripped of its electron, can't do the trick. In the original hydrogen clouds, perhaps one atom in a million retained its intact, light-hungry form. According to a theory developed over the past decade, the clouds collapsed into a network of denser filaments. During the collapse, the gas heated to temperatures between 100,000 and 10 million kelvin—hot enough to pop the electrons off the remaining neutral hydrogen atoms, but cool enough to prevent ricocheting hydrogen nuclei from giving off copious x-rays. "Most of the matter today, if it's in this form, is very difficult to observe," says Renyue Cen, a theoretical astrophysicist at Princeton University, who predicts that half of all ordinary matter exists as such intergalactic "warm hot gas." If that is true, then like a set of misplaced keys, the missing hydrogen may be hiding more or less where it's been all along.

The new Hubble observation supports the theory and suggests that ionized gas clouds may contain as much matter as all the galaxies combined. But Tripp and colleagues say it's too early to tell precisely how much matter the clouds account for. The oxygen VI measurement reveals only the gas at the lower end of the expected temperature range. Moreover, the researchers must estimate the ratio of oxygen to hydrogen. "By far that's the biggest uncertainty here," Savage says. "And figuring that out is not going to be easy."

–ADRIAN CHO