MEETING BRIEFS

Ancient Tropical Climates Warm San Francisco Gathering

Climate records preserved in the Greenland ice sheet got a lot of the attention at the fall meeting of the American Geophysical Union (AGU) in San Francisco last month (*Science*, 24 December 1993, p. 1972), but ancient tropical records were a rival attraction. In talks scattered in unrelated sessions, researchers reported a possible role for the tropics in driving the last ice age, a link between high latitudes and the tropics that may have redirected human evolution, and a tropical climate periodicity that may help fill a gap in the understanding of climate variability.

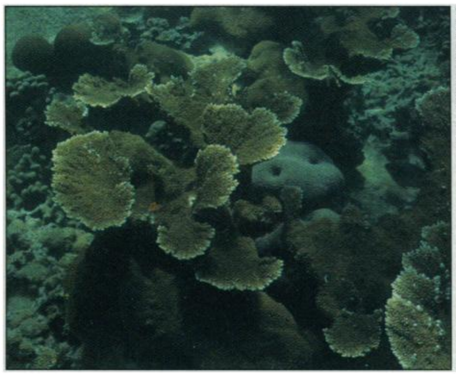
In Tropical Coral, Signs of an Ice Age Chill

In Earth's turbulent climate history, the tropics once seemed strangely uneventful. A landmark study of ocean sediments in the early 1970s showed that when the rest of the world cooled by 5°C at the height of the last ice age 18,000 years ago, the tropical oceans experienced only the mildest of chills: 2°C or less. Climate modelers never could satisfactorily explain how the tropics could have remained aloof from the drastic temperature changes seen at higher latitudes. Now, if climate records preserved in an ancient reef can be trusted, they won't have to.

At the meeting, paleoceanographers Thomas Guilderson, Richard Fairbanks, and James Rubenstone of Columbia University's Lamont-Doherty Earth Observatory presented their analysis of two different temperature-sensitive records from coral formed off Barbados during the depths of the last ice age. "They both came out to be about the same answer," says Guilderson: The tropical Atlantic 18,000 years ago was about 5°C colder than today, just like the rest of the world. Although other records on land had already raised doubts about the tropical warmth during the ice age, the coral result carries particular weight because it comes from the tropical ocean, which provided the first evidence of tropical climate stability.

"It's a really good study," concedes Thomas Crowley of Texas A & M University, who worked on the 1976 CLIMAP study that suggested warm ice age tropics. "But one data point from one region is not going to be enough to convince everyone. Nature is full of surprises; I would like to see further testing." Many climate modelers, on the other hand, may be delighted, because trying to keep the tropics immune from temperature changes in the rest of the world had hamstrung efforts to reconstruct past climates and predict greenhouse warming.

The original evidence for tropical warmth during the ice age relied on the temperature sensitivity of particular species of single-celled plankton called foraminifera, whose skeletons are found in sea-floor sediments. When warmth-loving species dominate a sedimentary layer, the inferred temperature is high—and that's what CLIMAP workers saw in sediments from the ice age ocean. Since then, however, land-based climate records such as pollen deposits had raised doubts. These data seemed to show that land masses, if not oceans, in the tropics cooled with the rest of the world. To resolve the issue, Guilderson and his colleagues applied two additional paleothermometers to their ancient coral.



A climate record in the making. In the last ice age, coral like this recorded a distinct chill.

One was a traditional isotopic method, in which researchers measure the ratio of two stable isotopes of oxygen in the coral's calcium carbonate—a ratio that changes depending on the temperature of the water in which the coral is growing. The other, newer method relies on traces of strontium found in the carbonate. Strontium atoms get into the carbonate by taking the place of calcium, which is chemically similar. The substitution rate varies with water temperature, and over the past 2 years an extremely sensitive technique called thermal ionization mass spectrometry has opened the way to strontium measurements precise enough to yield a practical paleothermometer.

Comparing results from the two methods, Guilderson and his colleagues found that they tracked each other fairly closely through the coral record, from 19,500 to 8000 years ago. "We have two independent temperature proxies that are both saying the western tropical Atlantic was 5°C colder [than it is now] during the last glacial maximum," says Guilderson.

If so, what's wrong with the CLIMAP analysis? Guilderson can't prove anything yet, but he suspects the forams don't faithfully record extremes of temperature. He and his colleagues will be studying warm-water forams to see whether they are as sensitive to cooling as the CLIMAP workers had assumed. And just to be sure their Barbados result isn't an anomaly, they will be repeating the analysis on coral from the Pacific.

If the ocean and terrestrial evidence that the tropics do respond to climate shifts holds up, researchers trying to predict greenhouse warming will have an easier task. They will be able to distribute the predicted warming more evenly between the poles and equator, which might help explain why high-latitude temperatures so far haven't risen as much as existing models predict. Modelers of ice age climate, meanwhile, will no longer face the problem of explaining how the middle and high latitudes of both hemispheres could have cooled simultaneously while separated by a perennially warm tropics.

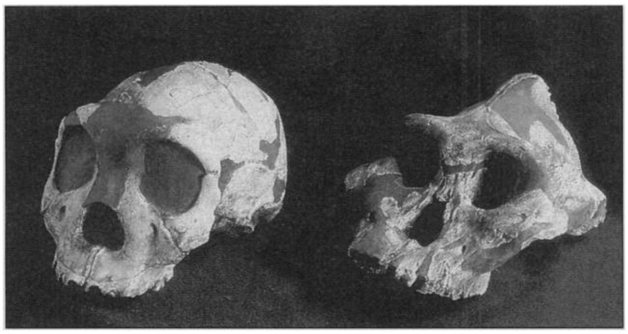
Indeed, the new evidence from the coral suggests that the tropical oceans could actually have helped transmit the ice-age climate signal from the Northern Hemisphere to the Southern, says Guilderson. Because the high latitudes in both hemispheres import some of their heat from the tropics, tropical oceans cooled by the growth of northern ice sheets—perhaps as the ice drove sun-shielding clouds toward the equator—might in turn have cooled the southern latitudes. Thus a bit of coral might yet drag a detached tropics into the climatic fray.

An Ice Age Nudge for Human Evolution in Africa?

Earth scientists are used to thinking about the connectedness of things. Meteorologists, with only a bit of hyperbole, talk about the "butterfly effect" that transforms the flutter of a Brazilian insect's wing into a Texas twister. Oceanographers trace currents that warm Europe back to straits between Indonesian islands. But perhaps the grandest chain of causation earth scientists are tracing—one that still has many missing links—connects the collision of Asia and India 43 million years ago to the appearance of the genus *Homo* in Africa 40 million years later. Now, Peter deMenocal of Columbia University's Lamont-Doherty Earth Observatory says he has put the finishing touches on one crucial link in the chain.

By drawing on records of African climate preserved in offshore sediments, deMenocal reported at the AGU meeting, he found that the intensifying cycles of cooling and drying in tropical Africa around 2.8 million years ago—about the time of a pivotal branching in the human family tree—were driven by a climate signal from the high northern latitudes. That's the same time major ice sheets appeared in North American and northern Europe, culminating a gradual cooling that may have begun when India plowed into Asia. The ice sheets, it seems, somehow drove the climate shift in Africa—and perhaps the evolutionary fate of the hominids living there.

FRANCIS H. BROWN/COLLEGE OF MINES, UNIV. OF UTAH



A climatic split? Cooling and drying may have induced the evolutionary split that led to *Homo erectus*, an ancestor of modern humans, and *A. Boisei (right).*

Paleontologists have long known that tropical Africa turned cooler and drier 2 million to 3 million years ago, and climate modelers had suspected a link with the Northern Hemisphere ice sheets. But the existing climate record for Africa, from lake sediments and other sites on land, "just isn't detailed enough to nail down what was happening," says deMenocal. The exact timing of the dry spells could yield clues to their driving force. And, as a bonus, a better record could help test an idea championed by some anthropologists: that a drying climate drove hominids out of the shrinking forests and into the savanna, where the demands of gathering food from a variety of sources triggered the explosive mental development of future humans.

For a detailed picture of what was happening in the African cradle of our species, deMenocal went to the ocean. Long sediment cores retrieved by deep-sea drilling ships off West Africa and in the Arabian Sea and the Gulf of Aden off East Africa preserve at least two indicators of terrestrial dryness—dust from arid areas and tiny silica granules from tough savanna grasses—blown out to sea from the continent. By studying how these indicators vary over 8 million years of the sediment record, deMenocal chronicled in unprecedented detail the bursts of dryness that afflicted the African continent; he also linked their intensification to climate change at higher latitudes.

The cooling and drying at that time, deMenocal found, was marked by a change in timing of the periodic dry spells. Like climate elsewhere on Earth, African climate feels the influence of cyclical orbital variations, among them the wobbling of Earth's axis and its changing tilt, which change the distribution of sunlight over the planet. Before 2.8 million years ago, according to the sediments, African dryness varied with Earth's 21,000-year wobble. But after a transition period of a few hundred thousand years, the high-latitude tilt signal came booming through in the form of more intense periods of cooling and drying at intervals of 41,000 years.

That timing change means that a climate link must have developed between the tropics and the high northern latitudes, deMenocal argues, because unlike the wobble—which affects sunlight in the tropics—the tilt cycle has its strongest impact on high-latitude sunlight. Some change in conditions at high latitudes must have enabled the tilt cycle to exert a tropical effect. And the most obvious change, he says, was the growth of the ice sheets.

Just how the ice influenced African climate may have differed for East and West Africa, says deMenocal. A computer climate model run by David Rind of the Goddard Institute for Space Studies in New York City and deMenocal shows that the cold North Atlantic of the ice age would have generated high atmospheric pressure over the North Atlantic. That high pressure would tend to dry West Africa by opposing the monsoon circulation of the atmosphere that brings moisture to West Africa today. East Africa, in contrast, would owe its dry spells to the high mounds of ice in northern Europe and Scandinavia, which would have diverted cold, dry air over the Arabian Peninsula and part of East Africa. As the North Atlantic cold and the amount of ice waxed and waned in step with the tilt cycle, Africa experienced repeated cycles of aridity.

Still, that's just one link in a longer chain of causation that some researchers trace back to the collision of India and Asia, which pushed up the Himalayas and the Tibetan Plateau. According to one hypothesis, this uplift gradually diverted the atmosphere's circulation, driving the long cooling that led to glaciation. Meanwhile, others, mainly paleontologists, are wrangling over the other end of the chain: the possibility of a connection between African drying and the emergence of human ancestors.

Paleontologist Elizabeth Vrba of Yale University has argued in favor of a climate-evolution connection based on the rough coincidence of bursts of evolution among many African animals, including the hominids, about 2.5 million years ago and the cooling and drying. But many paleontologists would agree with David Pilbeam of Harvard University, who says, "I don't think the fossil record is yet good enough to say with confidence that this is what's happening." Getting human ancestors into the picture may be the hardest part of all.

Milankovitch Plays Climate in Double-Time in the Tropics

Climate researchers, like early geographers, have their terra incognita, but it lies in the realm of time rather than space. To explain climate variations on short time scales, of a few years to a few decades, they can invoke volcanic eruptions and changes in ocean circulation; for shifts lasting tens of thousands to millions of years, they can call on Earth's rhythmic orbital variations—so-called Milankovitch cycles—or the slow shufflings of continents. But climate also changes on time scales of between 1000 and 15,000 years, and climate researchers have mostly been at a loss as to why. Now, paleoclimatologist Teresa Hagelberg of the University of Rhode Island thinks she can fill in some of the features of that terra incognita.

At the AGU meeting, she presented evidence that in the tropics, the shortest Milankovitch cycle—a periodic wobble, or precession, of Earth's spin axis that changes the intensity of the seasons—may drive climate change at twice the cycle's usual frequency: 10,500 instead of 21,000 years. Her analysis of marine climate records shows, moreover, that climatic echoes of this "double-time" precession can be found as far poleward as 50°N. Besides giving researchers an explanation for at least some of the puzzling middle-range climate periodicity, the results also suggest that on those time scales, tropical climate may put its stamp on a broader area. "Most of our attention has been focused on high latitudes," where ice ages get started, says paleoceanographer Steven D'Hondt of Rhode Island. "But here's a real hint of a strong tropical [role]."

For climate modelers, a double-time Milankovitch beat in the tropics isn't wholly unexpected. In 1991 David Short of Goddard Space Flight Center in Greenbelt, Maryland, and his colleagues published results showing that the precession cycle of summer temperatures—in which summer warmth peaks in the Northern Hemisphere, then in the Southern Hemisphere, and again in the north over a cycle of 21,000 years—should be expressed at twice that rate in the tropics. Geography is what converts the cycle into double time, the model suggested. Land masses straddling the tropics but extending well north and south could, in effect, capture both the Northern and Southern Hemisphere maxima, pushing up tropical temperatures every 10,500 years.

Some confirmation came last September, when Jeffrey Park of Yale University, D'Hondt, and their colleagues published evidence of a strong double-time climate beat 75 million years ago, from a site in the Atlantic (*Science*, 10 September, p. 1431). But until Hagelberg's work, nobody had found a double time beat in recent climate.

Hagelberg searched for evidence of the double-time cycle in three deep-sea cores of sediment laid down during the past 1 million years in the eastern tropical Pacific, the eastern tropical Atlantic, and the North Atlantic at 50°N. All three cores record climate in the form of the varying amount of carbonate from plankton that lived in the overlying waters. The population of plankton—and hence the amount of carbonate—should vary with climate factors such as the intensity of wind-driven upwelling of deep, nutrient-rich waters. Hagelberg found not only that the carbonate content varied over periods of 10,000 to 12,000 years, but also that much of the periodicity was in step with the precession cycle. At the tropical sites perhaps 50% of the climate variability having periods of 10,000 to 12,000 years was Milankovitch-related, says Hagelberg.

That's a nice confirmation of the model prediction, but the results from the North Atlantic site are perhaps more intriguing. Though the site lies far from the tropics, as much as 30% of the sediment core's 10,000 to 12,000 year variability was still coupled to the double-time precession cycle. Perhaps tropical Milankovitch forcing unsettles mid-latitude weather patterns by influencing heat transport throught the ocean, Hagelberg says. Fill in one blank space on the map, it seems, and another gap is sure to beckon.

–Richard A. Kerr

POPULATION GENETICS

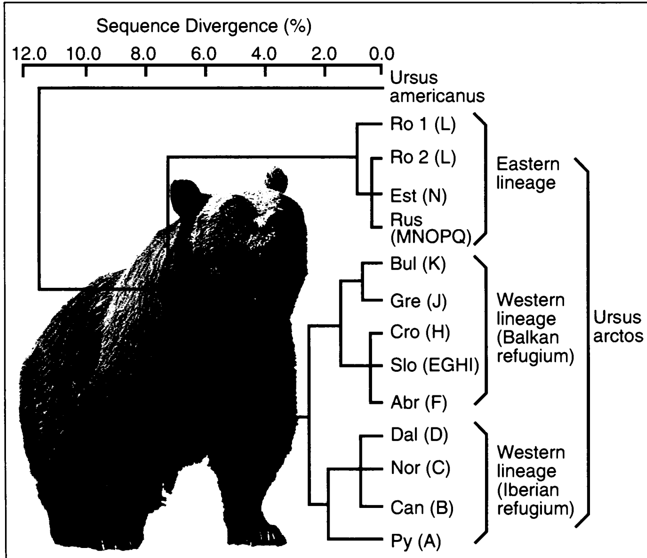
A Family Tree of European Bears

PARIS—The French Ministry of the Environment recently found itself playing matchmaker, desperately looking for consorts with acceptable family backgrounds. Its task: to preserve a population of European brown bears living in the Pyrenees, which has shrunk to just 10 animals and is facing extinction. The obvious solution would be to bring in some bears from other regions, but the imported animals would have to be genetically similar to the threatened bears—otherwise, the mixing could lead to an irretrievable loss of the genetic heritage of the Pyrenean brown bear. Likely candidates would be nearby populations, but the only remaining bears in western Europe are isolated groups in France, Spain, and Italy that total less than 100 animals. So the ministry wondered if members of the large populations of brown bears in Russia and Romania would be genetically acceptable.

To find out, it called in geneticists Pierre Taberlet and Jean Bouvet from the Laboratory of the Biology of High Altitude Populations of the Université Joseph Fourier at Grenoble in the French Alps. Their work has produced a remarkable offshoot: a unique family tree of bears. Taberlet and Bouvet set about their matchmaking by collecting samples of DNA (mostly from hair) from 60 European bears (*Ursus arctos*), from Spain to Russia, and from Greece to Norway. For comparison, they threw in samples from one American black bear (*Ursus americanus*) and DNA extracted from bones of the long-extinct European cave bear.

The researchers compared changes in a variable stretch of the bears' mitochondrial DNA containing 280 base pairs and found a clear-cut difference between eastern European bears and the isolated populations in western Europe: More than 7% of the DNA was different. The American black bear was even further removed, with 12% of the DNA sequence differing from its European cousins. Using the rate for evolutionary change in a homologous sequence of human mitochondrial DNA as a molecular clock, Taberlet and Bouvet estimate that the two European lines diverged about 850,000 years ago during the first ice age.

The western bears were themselves split into two groups when the animals were pushed southward and one branch took refuge in the Iberian peninsula, the other in the Balkans. After the thaw, the populations spread out again but did not mix, and some of the eastern bears crossed the land bridge between Siberia and Alaska into the New World, where they gave rise to the Montana and Rocky Mountain grizzly (an American brown bear, also *U. arctos*). Alaska's Kodiak bear (again *U. arctos*) is thought to have appeared later and this line also spawned the closely related polar bear (*Ursus maritimus*).



Ro 1 & Ro 2 (L)=Romania; Est (N)=Estonia; Rus (MNOPQ)=Slovakia, Estonia, Lapland (Sweden), Finland & Karelia (Russia); Bul (K)=Bulgaria; Gre (J)=Greece; Cro (H)=Croatia; Slo (EGHI)=Slovenia, Trentino (Italy) and Bosnia; Abr (F)=Abruzzo (Italy); Dal (D)=Dalarna, Sweden; Nor (C)=Norway; Can (B)=Cantabrian mountains (Spain); Py A=Pyrenees, France

Family portrait. *U. arctos* genealogy based on mtDNA analysis.

SOURCE: P. TABERLET AND J. BOUVET PHOTO: PETER NORMAN/ANIMALS ANIMALS

Paleontologist Oliver Ryder of the Center for Reproduction of Endangered Species at the Zoological Society of San Diego says that fossil records confirm the French findings that the brown bear and polar bear have their origins in Europe in the early Pliocene. "The 0.85 million year date is perfectly consistent with the fossil record," he says. But he cautions that bear DNA may mutate at a different rate from human DNA so some correction in the dating may be needed. Ryder adds that his own, unpublished work with mitochondrial DNA suggests that the American black bear did not evolve from the brown bear but from an earlier common ancestor, which explains the 12% difference in their DNA.

The French researchers also acquired some 30,000-year-old bones of cave bears (*Ursus spaeleus*) that were excavated from the Pré-l'Etang cave at the foot of the Alps near Grenoble. The huge 700-kilogram, 3-meter cave bear was a vegetarian that became extinct at the end of the last Ice Age. Catherine Hänni of the Pasteur Institute in Lille, an up-and-coming specialist in ancient DNA, managed to extract and amplify a 140 base-pair fragment of mitochondrial DNA from the bones. Her analyses indicated that the cave bear appeared at about the same time as *U. arctos*, 850,000 years ago. But Ryder warns that the smallness of this fragment could again lead to errors in dating.

Taberlet and Bouvet concluded from their genealogy that eastern bears would not be suitable consorts for their threatened western cousins. The Ministry of the Environment has accepted their advice and it is now assessing bears from nearer to home, such as southern Scandinavia and Bulgaria.

–Alexander Dorozynski

Alexander Dorozynski is a journalist based in Paris.