PALEOCEANOGRAPHY

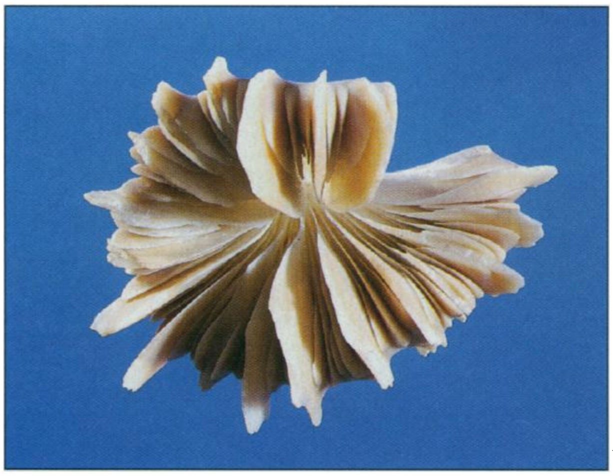
Deep-Sea Coral Records Quick Response to Climate

Paleoceanographers—the historians of Earth's oceans—have always been at a serious disadvantage compared to the physical oceanographers who document the present. They can't launch current meters to measure how water masses with different heat and salt content stirred past oceans. Instead they have had to content themselves with reading chemical and isotopic clues from sediment records, which hint at the location and depth of particular water masses in the past. These snapshots couldn't say how fast the water was moving and thus how it might interact with the atmosphere to form the climate system.

Now oceanographers have found that by analyzing deep-sea corals, they can replace those snapshots with a motion picture. By measuring a carbon isotope trapped in precisely dated corals, they can assemble a record of the currents flowing through the ancient ocean. And the first use of this new kind of record provides the best evidence to date for an idea long espoused by climate modelers: When climate changes, ocean circulation can suddenly shift and perhaps feed back to affect climate.

On page 725 of this issue of *Science*, paleoceanographer Jess Adkins of Columbia University's Lamont-Doherty Earth Observatory in Palisades, New York, and his colleagues report that coral dredged from thousands of meters down shows that as the last Ice Age began to wane 15,000 years ago, the deep currents bathing the western North Atlantic changed in less than 160 years. Besides demonstrating that the deep ocean can respond quickly to climate change, the finding shows that deep-sea coral—much of which is now gathering dust in storage—"is a stupendous archive," says paleoceanographer Scott Lehman of the University of Colorado, Boulder. Given enough samples from around the world, "you'd be doing real physical oceanography in the past, something we've never been able to do."

Opening a new field to paleoceanographers required a bit of luck and some perseverance. Researchers have been hauling up rocks from the sea floor for decades to study the ocean crust, but the centimeter-sized, solitary-living deep-sea corals that came along for the ride were often ignored and even discarded when storage space got tight. But after hearing a 1993 talk by coral expert Michael Risk of McMaster University in Hamilton, Ontario, oceanographer Edward Boyle of the Massachusetts Institute of Technology (MIT) and Adkins, then his student, also began to consider the potential of deep-sea coral to serve as a paleoceanographic record. Unlike sediments, the traditional paleoceanographic record keepers, corals are relatively easy to date precisely with isotopic methods, and they aren't stirred by burrowing animals, so they have finer time resolution.



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Coralline current meter. Deep-sea corals only a few centimeters across reveal circulation changes in the ancient ocean.

Starting with hundreds of samples from several collections, Boyle and Adkins first had to find a way to quickly and inexpensively identify coral that grew at a time of particular interest. They roughly dated more than 100 corals by counting the radioactive decay products of uranium-238 with an economical mass-spectrometry method. They identified four corals that grew about 15,000 years ago, about 1800 meters down on the slope of Kelvin seamount in the western North Atlantic. Then they used a second, more precise mass-spectrometry method on uranium decay products to date these four with a precision of 200 years or less.

Adkins and his colleagues also measured the amount of radioactive carbon-14 remaining in the coral. Carbon-14 is often used for dating corals, but in deep-sea samples it holds clues to ocean circulation. Cosmic rays create carbon-14 in the atmosphere, so this isotope's abundance in seawater begins to decline as soon as the water sinks below the surface. Adkins could use the carbon-14 "clock" to estimate the interval from the time the water sank to the time it delivered carbon to the coral—a measure of how fast deep water masses were forming.

The carbon-14 levels showed that the four corals lived through a major circulation shift 15,400 years ago. By tracing isotopes along the growth layers of the corals, the team saw a decline in carbon-14 abundance from their oldest parts to their youngest—a period of less than 160 years, according to estimates from living deep-sea coral. That decline signals a switch in ocean circulation, implying that the corals were exposed to "older" water—water that had last seen the surface a relatively long time before. Adkins thinks the lower carbon-14 level is a signature of so-called Antarctic Bottom Water, which sinks in Antarctica and so had traveled the globe before reaching the corals. In less than 160 years, he thinks, it had replaced another mass that had sunk nearby in the North Atlantic.

Other indicators are consistent with that idea. They suggest that warmer, more saline surface waters were shifting northward—early signs that the ice age was losing its grip, although no one is sure whether climate or circulation changed first. Saline water is denser and more prone to sink, so the changes at the surface may have let the North Atlantic water sink below the 1800-meter depth of the corals, allowing the Antarctic water mass to move in.

"The corals are some of the first proof that the deep ocean can change very quickly," says Adkins. "The deep ocean can readjust itself almost as quickly as the atmosphere and ice." For years, ocean modelers have been warning that in a warmer, nonglacial world, deep-water formation in the North Atlantic might abruptly grind to a halt. That would have serious consequences for climate, because the sinking draws warm surface water northward, warming Europe and starting a circulation that affects climate worldwide. But this is the first time researchers have actually gathered evidence of such dramatic, rapid changes in the real ocean. "The importance of these corals as climate recorders can't be overemphasized," says Risk.

The study also opens a window on the rates of ancient ocean circulation. For example, Adkins suggests, on the basis of both the isotopic and chemical properties of the corals, that the Antarctic water took 500 years to travel to Kelvin seamount, about 400 years longer than today. That implies more sluggish deep-water formation. If Antarctic samples confirm that finding, researchers might be able to gauge how fast heat was being pumped through the oceans, a vital clue to the ancient climate system. For the thousands of ancient deep-sea corals hidden away in dusty storage rooms, this study offers a new lease on life.

–Richard A. Kerr