improving the chances of avoiding coral whose apparent age is altered by chemical degradation.

The first mass spectrometry dates are in, and the oceanographers have reason to smile. While working at the California Institute of Technology, Lawrence Edwards, who is now at the University of Minnesota, and his colleagues got interglacial ages between 122,000 and 130,000 years at Barbados. In papers now in press, James Chen and his associates at Caltech and Edouard Bard and his colleagues at Lamont found comparable ages for Barbados coral. The true age, says Richard Fairbanks of the Lamont group, is "not 140,000 years, that's for sure."

As if all this weren't enough, the Devil's Hole age of 147,000 years or more has come under attack from other quarters. Wang-Xing Li, Joyce Lundberg, and their colleagues at McMaster University in Hamilton, Ontario, have gone spelunking themselves, using mass spectrometry to date carbonate in a coastal cave in the Bahamas where the deposition has been interrupted only when high sea levels flooded the cave. They find that the hiatus caused by the previous interglacial came about 125,000 years ago.

And P. van den Bogaard of the University of the Ruhr in Bochum, West Germany, and his colleagues have dated a volcanic ash deposit sandwiched between glacial and interglacial soils formed not one but two glacial cycles back. Their exceptionally precise argon-argon dating technique provided an age that is "distinctly younger than" Winograd's for the same interglacial.

Winograd has no explanation for the failure of the newest studies to support his contention that the last interglacial was 147,000 years ago. "We're new to this game," he says. "We certainly don't have all the answers." But he isn't giving in yet. He is looking forward to the answers that are expected soon from studies of the ancient New Guinea reefs, where some of the older dates have been reported. New samples from those reefs are being dated by mass spectrometry. And he has a longer record from Devil's Hole in the works.

The oceanographers aren't waiting; they are confident that these studies will vindicate their orbital variations hypothesis once again. Says Imbrie: "I'm not going to worry too much about it." ■ RICHARD A. KERR

ADDITIONAL READING

I. J. Winograd, B. J. Szabo, T. B. Coplen, A. C. Riggs, "A 250,000-year climatic record from Great Basin vein calcite: Implications for Milankovitch Theory," *Science* **242**, 1275 (1988).

What's the Sound of One Ocean Warming?

Oceanographers will make a noise in the Indian Ocean that may be "heard" in Bermuda—and used to measure global warming

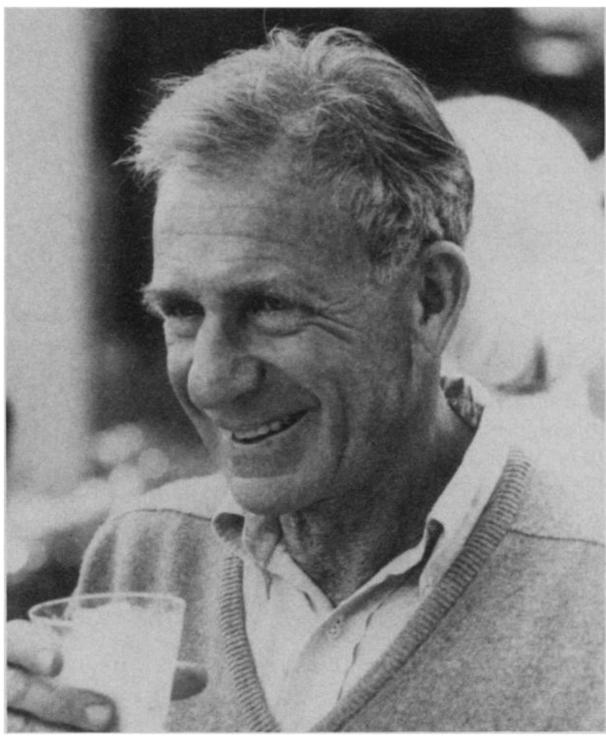
IF ALL GOES ACCORDING TO PLAN, a team of oceanographers will set sail early next year to a remote, desolate island in the Indian Ocean. On arriving, they will lower a complex piece of equipment 150 meters beneath the sea and fire a "shot" that may be heard halfway around the world—underwater.

A lot is riding on that big undersea bang. If the sound waves are successfully detected off Bermuda and northern California, this test will be the forerunner of a decade-long attempt to measure global warming in the world's oceans. And at the same time it would open up a whole new bag of technological tricks for studying the ocean's large-scale structure.

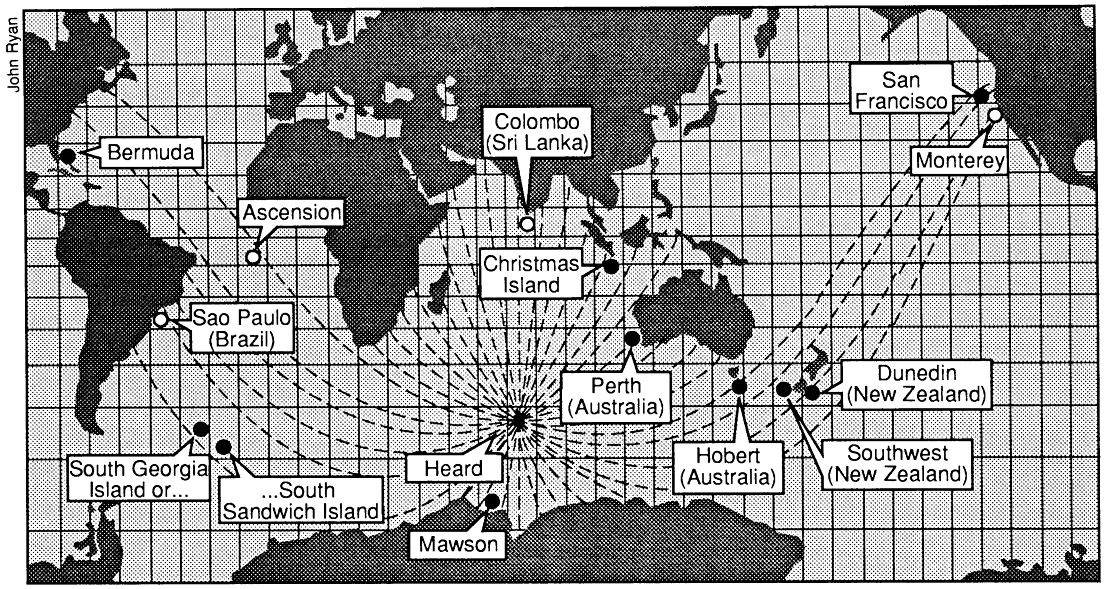
The specific technical trick at hand is acoustic tomography. In that technique, sound waves are generated, then detected, and their motion is computed to yield a picture of the intervening water—much as radioactive particles are used in computerized axial tomography (CAT) scanning to yield a three-dimensional picture of the brain. Since it was pioneered a decade ago by oceanographers Carl Wunsch of Massachusetts Institute of Technology and Walter Munk of the Scripps Institution of Oceanography, acoustic tomography has been employed to study local ocean regions, but this would be the first test across five oceans at once—and one addressing a seminal question of our day: Is the earth heating up? "If this works, tomography will have been shown to be useful on a global scale," says Wunsch.

There are many pitfalls, however. So many that Munk, the father of the $1.7-million project, concedes many think it is a "slightly mad scheme." Critics point to the remote location and to technical problems in interpreting data. "We might flop terribly," Munk admits, "but the fact is, we have our money and we have our ship." The ship comes from the Navy and the money from four federal agencies (the Office of Naval Research, the National Science Foundation, the Department of Energy, and the National Oceanic and Atmospheric Administration) that think the potential payoff—the first accurate measurements of ocean temperatures—are worth the gamble.

The reason measuring the speed of sound waves underwater can indicate global warming is that sound travels faster in warm water than in cold water. Therefore the speed of sound waves traveling through the ocean can provide a gauge of temperature. Of course, there already are large amounts of data on ocean temperatures, gathered largely from ships. But ocean temperatures are notoriously tricky to measure, and Munk


Scripps Institution of Oceanography

Toast to a "mad scheme." *Walter Munk of the Scripps Institution of Oceanography fathered the plan to fire the underwater shot.*



Straight shot. *Sound waves generated at Heard Island may be detected by hydrophones at Bermuda and San Francisco, as well as other sites, some definite (filled circles), some probable (open circles).*

and his team are hoping this initial test of tomography will provide the first reliable baseline—a baseline that could later be used to check temperature increases.

Propelled by this notion, the oceanographic team is scheduled to sail on 23 January 1991 to Heard Island, a glaciated volcano at 53 degrees south between the Antarctic and Australia. On board with Munk will be Bob Spindel, an oceanographer at the University of Washington, and Andrew Forbes, an oceanographer at CSIRO Division of Oceanography in Tasmania, Australia. When they reach the frigid island (which has such foul weather and rough terrain that no human beings live there), they will probably have to battle 20-foot swells to lower their instruments.

Among the first instruments to go over the side will be three electrically powered acoustic "loudspeakers" known as HLF-4LL acoustic sources. When electric signals are fed into these circular instruments, they act much like diaphragms to produce underwater sound waves. For 12 days the loudspeakers will fire pulses of sound at 209 decibels with a center frequency of 57 hertz (to distinguish them from the 60-hertz noise of the U.S. power grid and the 50-hertz noise of the Soviet grid).

If the test works (and it is a test, rather than a full-dress tomographic experiment, because it relies on only a single source of sound rather than on triangulating among different sources), the waves will be detected 3½ hours later by hydrophones off San Francisco and Bermuda, monitored by Ted Birdsall and Kurt Metzger, oceanographers at the University of Michigan.

The reason the waves may be able to reach halfway around the world is that they should, according to Munk's reckoning, travel along a sound channel about 1 kilometer deep. At that depth the temperature and pressure will act as a kind of wave guide, keeping the waves intact and preventing them from reaching the surface or the bottom, where they would dissipate. Some of the waves will bump into landmasses, of course, but those that don't will run from the site of the underwater blast directly to the receivers.

The test team will then merely have to measure the time the signals take to arrive—shorter if they're traveling through warm water, longer if the passage is chilly. Not a trivial task, since the measurements must be extremely precise. Yet the team has already become remarkably skillful in detecting small changes in arrival time—they can gauge changes with a precision of 1 millisecond over distances of 1000 kilometers. This expertise will be put to use in detecting the infinitesimal delays that would accompany ocean warming. (The team estimates that travel time over the current travel path, which is about 15,000 kilometers long, should decrease by 0.1 to 0.2 second per year if global warming is indeed taking place.)

But sweeping answers to big questions—such as "Is global warming occurring?"—remain far in the future. For the moment, a debate is heating up over whether the Heard Island project will yield any usable data at all on climate change. Skeptic Russ Davis, a Scripps oceanographer who declined an invitation to get on board the Navy ship, doubts that Munk will be able to prove that the warming is global. "I think the world will be obviously warmer by the time they figure out how to use those measurements," Davis says. Specifically, Davis argues, it may be difficult to distinguish the effect of local phenomena such as eddies and gyres from global perturbations.

Munk responds that by measuring sound waves that have traveled 15,000 kilometers, he will be able to overcome the localized effects of eddies, which generally extend only 100 kilometers or so. Sound waves that have traveled across the ocean should reflect changes in temperature over the entire region, he argues.

He goes on to say that his data will have two great advantages over the controversial data—now dating back 100 years—that has been interpreted as showing increases in sea surface and atmospheric temperatures. It's better than terrestrial data, he says, because in the ocean there are no urban heat islands, which bedevil land measurements. And it's better than previous ocean measurements, which were done using different techniques and are not comparable.

Munk hasn't silenced the skeptics, however. Even his old collaborator Wunsch says he is worried about the cost and wisdom of using a site as hostile as Heard Island for the test site. Only an oceanographer with Munk's clout could have sold such a risky venture, Wunsch says.

But for Munk, Heard Island had great charm: it gave him a shot across five ocean basins. In theory, a blast there could be detected off Brazil, Africa, New Zealand, Tasmania, Perth, Indonesia, Antarctica, and Hawaii in addition to both U.S. coasts. Says Munk: "I thought it was intriguing—the idea that you could be on both sides of North America and hear a source of sound on the other side of the world."

If January's experiment works out, a permanent sound source will be installed at Heard Island. Then the next step would be to expand to full tomography, with half a dozen or more sound sources, which would give an even better picture of temperatures across the ocean basins. And that prospect excites even the skeptics. "The acoustic part by itself is interesting," says Davis. "Every time you look at the ocean in a new way, you find something out. Every time you get a new instrument, you discover new phenomena." ■ ANN GIBBONS

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