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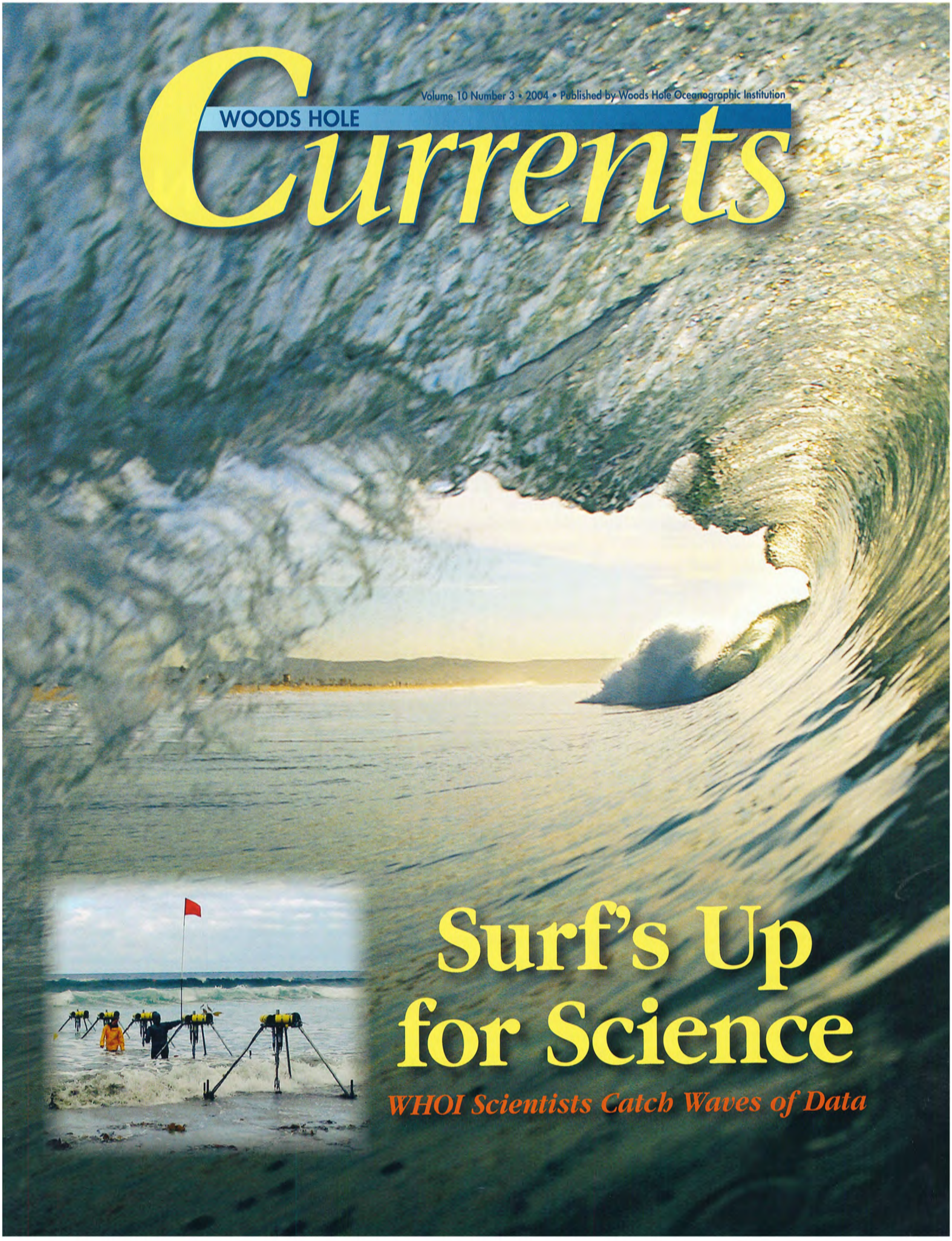
WOODS HOLE Currents



Surf's Up for Science

WHOI Scientists Catch Waves of Data

WOODS HOLE Currents

COVER: Researchers from WHOI and ten other institutions spent the autumn of 2003 on the beach in Southern California to study how the seafloor shapes and gets shaped by waves near the shore. Wave photo © DigitalVision. Inset photo by Tim Maddux.

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THE WOODS HOLE OCEANOGRAPHIC INSTITUTION is a private, independent, not-for-profit corporation dedicated to research and higher education at the frontiers of ocean science. WHOI's primary mission is to develop and communicate a basic understanding of how the oceans function and how they interact with the earth as a whole. The Institution strives to be a world leader in advancing knowledge about the oceans and explaining their critical role in the global environment.

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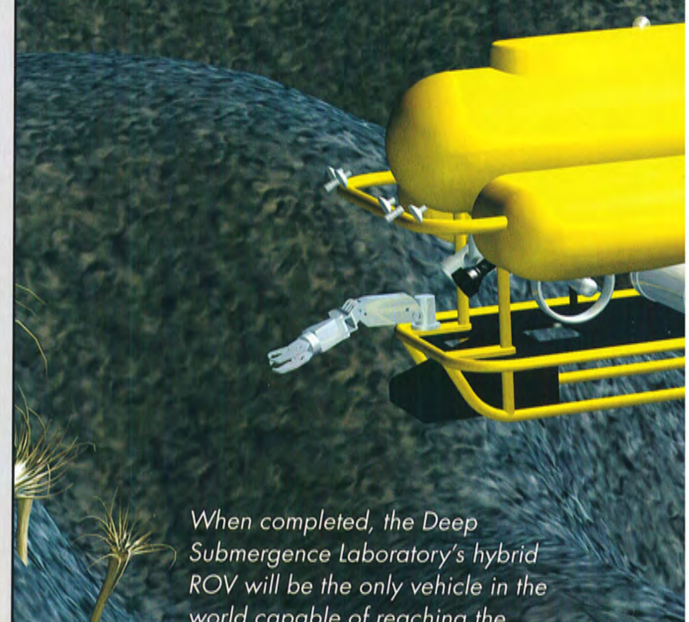
A New Robot for the Deep Frontier



When completed, the Deep Submergence Laboratory's hybrid ROV will be the only vehicle in the world capable of reaching the deepest parts of the ocean.

Illustration by Jack Cook.

If the engineers of WHOI's Deep Submergence Laboratory have their way, Americans will soon return to a remote environment they have not visited since the 1960s: the deepest trenches of the world's oceans.

Associate Scientist Dana Yoerger and Research Specialist Andy Bowen, along with Johns Hopkins University Associate Professor Louis Whitcomb, are developing a "hybrid" remotely operated vehicle (HROV), a battery-powered robot that will take scientists as deep as 11,000 meters (nearly 7 miles) below the ocean's surface. The National Science Foundation, U.S. Navy, and the National Oceanic and Atmospheric Administration recently awarded the team $5.5 million to build the novel vehicle, which will be part autonomous, free-swimming robot and part tethered ROV.

Though the oceans average two miles in depth—well within the range of several ROVs, including WHOI's *Jason II*—the deepest reaches such as the Mariana Trench in the Western Pacific can plunge almost 36,000 feet. These regions comprise just a few percent of the ocean floor, but they contain some of the most active earthquake zones.

Americans have visited the deepest seafloor only once, when Lieutenant Don Walsh and Jacques Piccard descended to the Challenger Deep in 1960 in the Navy bathyscaphe *Trieste*. The Japan Agency for Marine-Earth Science and Technology sent its ROV *Kaiko* to the bottom of that trench in 1995. But *Kaiko* was lost during a storm in 2003, so today there are no operational vehicles that can reach the deepest parts of the ocean.

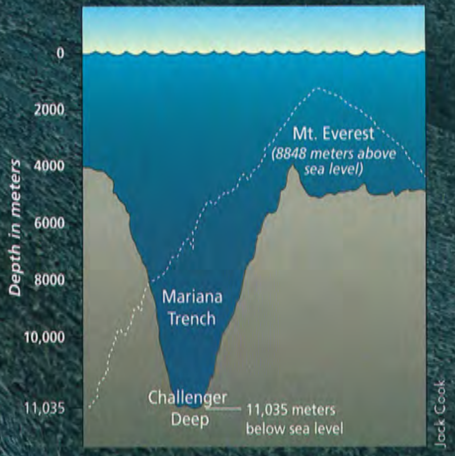
"Having access to these very deep and remote areas will open up whole worlds to the scientific community," said seafloor geologist Patty Fryer of the University of Hawaii. "We will be able to ask questions we never could ask before, and we will be able to go collect the evidence to answer them."

Unlike other remotely operated vehicles, the HROV can be reconfigured in the midst of a scientific expedition to operate in different modes: a free-swimming vehicle for mapping and broad surveys, and a tethered ROV for close-up sampling and imaging. By design, the HROV will be compact enough (roughly 10 feet by 7 feet by 7 feet) for quick deployment from virtually any ship in the world, allowing rapid response to interesting geophysical events such as volcanic eruptions or earthquakes.

"We are going to investigate an environment that is essentially unexplored," said Yoerger, head of the Deep Submergence Lab. "We often talk about surveying the seafloor with various tools in a methodical manner—we call it 'mowing the lawn.' In this case, we will be mowing the lawn where the grass has never been cut. We don't even know if there is grass!"

HROV will require several novel technologies to reach its goals. To overcome the tremendous pressure at extreme depths, the engineering team must work with special ceramic housings for their equipment. "In very simple terms, it's strength versus weight," said Bowen. Titanium has generally been used for pressure housings, but it would be about five times heavier than a ceramic housing. They must fend off 16,000 pounds per square inch of pressure without creating a vehicle that is too large to handle and too expensive to build.

The engineering team needs to not only reach the deepest seafloor, but maneuver when they get there. Traditional ROV cables and winches—which transmit both information and electricity—are thick and heavy, and they are likely to become restrictive at such great depth. Instead, the HROV



The Challenger Deep in the Pacific's Mariana Trench is more than a mile deeper than Mount Everest is high.

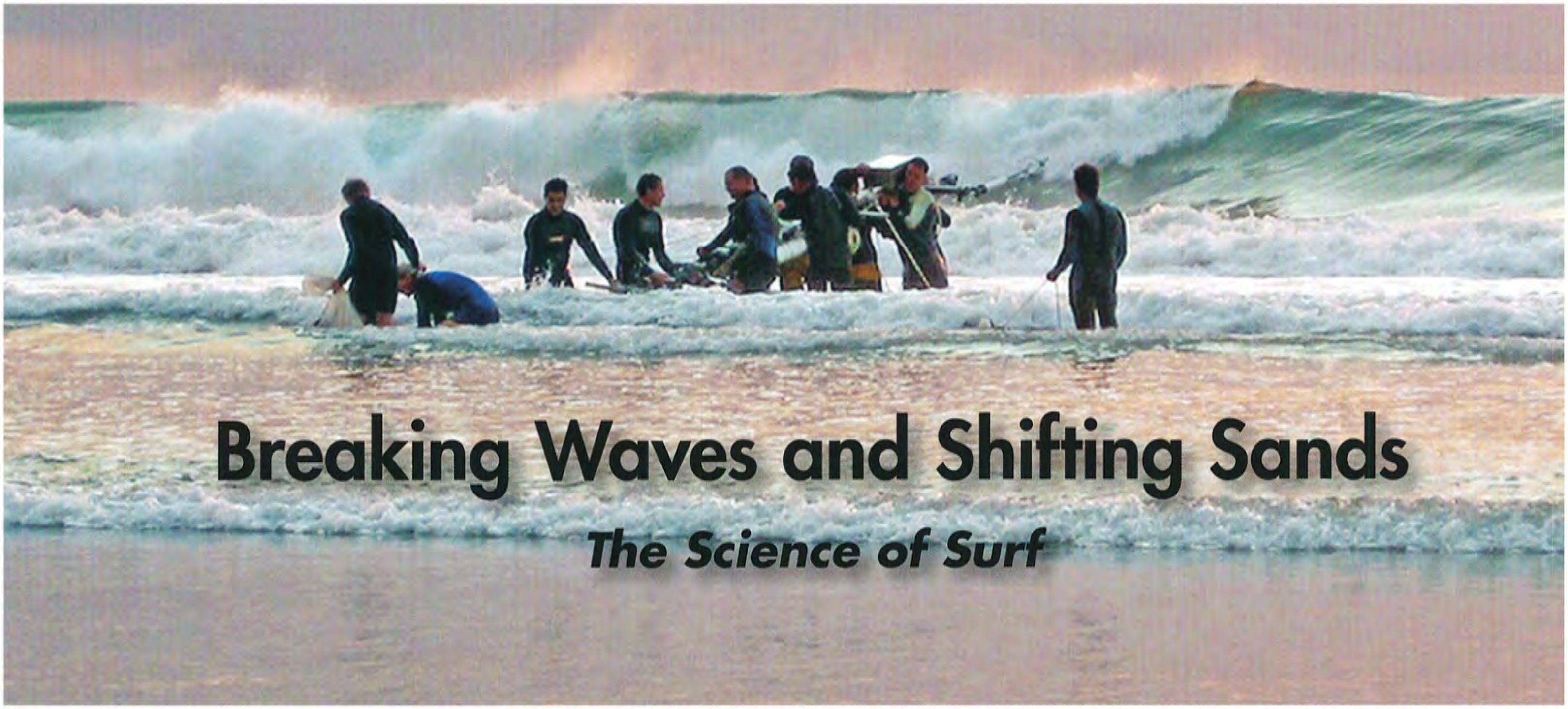
will draw power from special onboard batteries and will communicate with its operator through a fiber-optic cable less than 1/32 of an inch thick, about the width of fishing line. The micro-cable has been used by the U.S. Navy in torpedo guidance, but never in this kind of application.

"Fiber-optic tethers, ceramic pressure housings, 11,000 meter vehicles, and autonomous vehicles have each been developed and deployed previously," said Whitcomb, a visiting investigator at WHOI. " But the HROV will be the first vehicle to marry these technologies for access to extreme depths. The scientific need has existed for decades. We are taking advantage of recently developed technologies to provide a novel and cost-effective vehicle to meet this need."

"The real challenge is to build a vehicle that is actually useful at 36,000 feet," added Yoerger, who expects the project to take three to four years. "This is a combination of science and adventure, and we can't use the same old methods. We need tools and sensors that match the scale of what we are trying to achieve, while allowing us the freedom to explore."

To learn more, visit www.whoi.edu/marops/vehicles/

—Shelley Dawicki



Breaking Waves and Shifting Sands

The Science of Surf

Researchers carry an instrument tower into the surf near La Jolla, CA, to measure the movement of water beneath the breaking waves.

By Michael Carlowicz

Black's Beach, near San Diego, is renowned to surfers for its tasty waves. Blue-green waters swirl in a jumble of rip currents, whirling eddies, and powerful crossing swells. It is not a beach for novice surfer dudes and dudettes.

But less than three kilometers down the coast, toddlers, scuba divers, and sea kayakers frolic in the gentle waves of La Jolla Shores, where the surf seldom rises more than a half meter.

It's the same Pacific coastline, the same weather and wind patterns. So how can a surfer's paradise lie so close to a parent's dream beach? WHOI scientists Britt Raubenheimer, Steve Elgar, and two dozen colleagues from the Nearshore Canyon Experiment spent the autumn of 2003 trying to find out.

Steve Elgar, a senior scientist in the Applied Ocean Physics and Engineering (AOPE) Department, studies the surf zone, where the water covers his head and the waves start to rise and break toward the shore. Britt Raubenheimer, an associate scientist in AOPE, works in the swash zone, the part of the beach alternately covered and uncovered by the foamy white water that wets your ankles and wipes out sand castles.

Britt Raubenheimer

Research Associate Peter Schultz conducts one of the daily surveys of the shoreline using a dolly mounted with a global positioning system receiver.

They both work in the waves, with a knack for building experiments and collecting observations that few others have the patience or moxie to attempt. They share an interest in using their measurements to improve the mathematical models of coastal processes. And they love getting their feet wet in the surf. Their science is better off for the partnership.

A mess of physics

Nearly all theoretical models that explain the physics of the deep ocean break down and go haywire near the shore. The coast is a puzzle with a thousand moving pieces.

Even when the ocean looks still, everything is in motion. Waves shape beaches, and beaches shape the waves. Winds blow from ever-shifting directions. Waves come in at different periods and angles. Waters rush toward the beach and back out, while sloshing sideways too. Some waves are born in storms thousands of kilometers away; others are whipped up by nearby winds.

The slope of the beach, the shape and size of its sand grains, the position of offshore islands, canyons, shoals, and sandbars—even the level of the local groundwater table—all play a role in coastline dynamics. All told, the beach is a mess, a mathematical nightmare.

Britt Raubenheimer

WHOI Research Assistant Amy Kukulya carries a stalk of kelp that was entangled in the current-measuring instruments of the Nearshore Canyon Experiment. The vast kelp beds off Southern California posed a persistent threat to the experiment.

"Our goal is to understand and model waves, currents, and sand movement to better predict conditions along the shoreline," Elgar said. "We would love to reach a level of understanding where you could give us a map, some information about the sediments, tell us the direction and strength of the winds, and we could tell you what the waves will be like along the coast."

From a science perspective, understanding the nearshore region is critical because it is where the greatest quantity of sediment and suspended material moves through the ocean. Waves and currents deliver nourishing sediments to the beaches and nutrients to clams, crabs, and other shoreline organisms. Similarly, land-based sediments, chemicals, plants and animals, and fresh water must cross this region as they wash out to the deep ocean.

From a societal perspective, understanding the nearshore is vital to living wisely along the coast. "Studies of the nearshore will directly benefit beachside communities concerned with erosion and beach nourishment," said Tom Drake, program manager for the Coastal Geosciences Program at the Office of Naval Research. "They will give coastal planners an improved ability to predict how pollution from storm runoff moves through nearshore waters. And they will aid biologists attempting to trace the complex paths of larvae and other marine organisms in the surf zone."

Rachel Horwitz

Britt Raubenheimer (blue-purple), Steve Elgar (black, right), and colleagues set instrument tripods and cables. Each instrument was wired to a station on the beach, where investigators could monitor data collection in real time.

The nearshore is growing in importance, as the U.S. coastal population is estimated to grow by 3,600 people per day. Nearly 53 percent of Americans live in coastal counties.

Yet the surf and swash zones have typically been neglected. "There's a lot of tedious, physical work to be done, and it is labor-intensive, which makes it tough to fund," Raubenheimer said. Scientists and equipment are constantly pounded by waves and sandblasted by strong, sediment- and debris-laden currents. "But the difficulty," she said, "is part of what makes it interesting."

WHOI Research Assistant Amy Kukulya (orange) and Associate Scientist Britt Raubenheimer (black) check the stability of their instruments and supporting tripods, which were covered and uncovered by the rise and fall of the tides. They used pressure gauges to measure wave heights—derived from the weight of water above the instrument—and acoustic current meters to measure the direction of the flowing water in three dimensions.

California dreaming

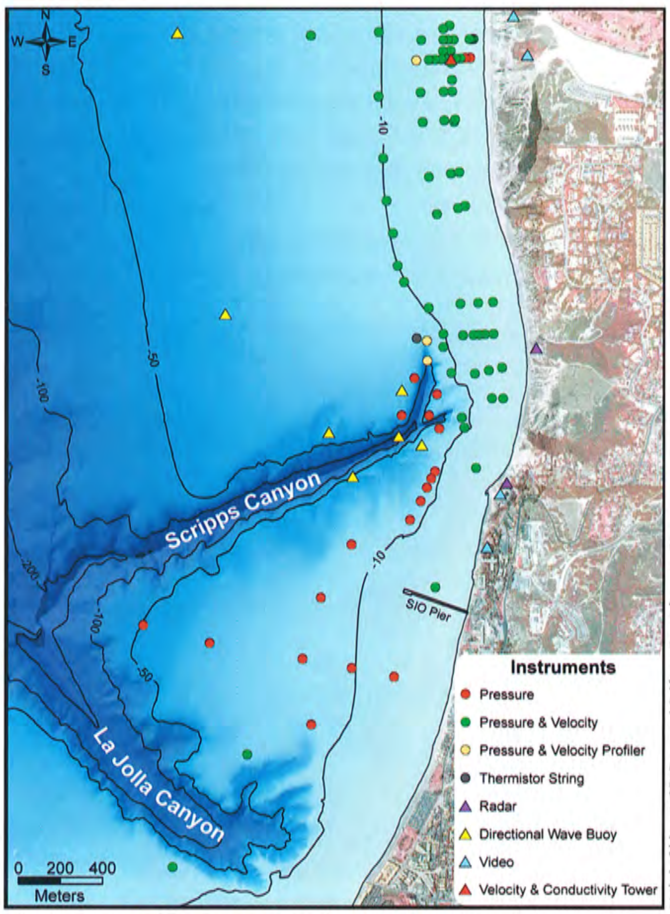
For much of the past 15 years, Elgar and Raubenheimer and other surf zone researchers have focused their surf and swash experiments on the East Coast of the United States, where the gently sloping, broad continental shelf allows waves and sediments to behave somewhat predictably. When researchers can make the right measurements in the Atlantic—they have been developing and refining their tools for a generation—then the physics problems are at least manageable.

In the wake of several research campaigns at an Army Corps of Engineers facility in Duck, North Carolina, scientists including Elgar developed a nearshore processes model, a testable mathematical hypothesis of how the beach works. That model has been built, tested, and refined repeatedly with field observations from Duck and other facilities where the seafloor geometry is relatively simple and the variables are few.

But researchers have known all along that most coasts are not as simple as North Carolina. Many continental shelves have abrupt, irregular seafloors that cause large gradients in the waves and currents. Scripps Canyon and La Jolla Canyon in Southern California provide one of the more dramatic extremes, with wild changes in wave energy over distances of just a few hundred meters.

"Our present theories for how waves move over an irregular seafloor are best suited to smooth or gently rolling underwater hills," Drake said. Elgar, Raubenheimer, and longtime collaborator Robert Guza of the Scripps Institution of Oceanography (SIO) decided it was time to try modeling a more complex environment.

Situated just a few hundred meters off Torrey Pines State Beach near San Diego—and close to a research pier operated by SIO—the Scripps and La Jolla canyons are the poster children for unusual seafloor geometry. The two canyons start as one, several kilometers offshore, and cut as much as 300 meters into



Michele Okihiro, NCEX Team, and California Data Information Project

The location of instruments and sensors deployed during the three-month NCEX campaign near San Diego.

the seafloor. The chasm forks, with branches running perpendicular to the coast and coming as close as 100 meters to the shoreline.

"As waves pass over the canyons, the steep topography may act like a magnifying glass and concentrate ocean wave energy in hot spots, creating large waves," Raubenheimer said. The canyon acts like a circus mirror as well, distorting, reflecting and trapping ocean waves along the shore to make legendary rip currents.

But just how the canyon affects the direction and speed of nearshore currents is poorly understood. "The currents there are the most complex I've seen anywhere," said Guza.

Like surfers itching for a challenge, the trio took on the waves of Scripps Canyon from September through November 2003. In the Nearshore Canyon Experiment (NCEX), they collaborated with more than 20 scientists from 10 institutions to measure how the underwater topography of submarine canyons affects wave propagation and nearshore currents.

Attacking the shore

Before NCEX, little real-life data had been collected to support theories and models of how the surf and swash zones behave on complicated coasts. The focus of the 2003 experiment was to collect field measurements that could stretch and validate the numerical models.

In the oceanographic equivalent of the Normandy invasion, they attacked the shore from water, land, and air. They set up tripods and frames of instruments with sensors to measure wave heights, water speed and direction, and the movement of sediment on the bottom. They launched jellyfish-like drifters with global positioning system (GPS) sensors to follow the currents up, down, and along the coast. From airplanes and from cliffs above the beach, they collected video

National Security in the Surf Zone

There is an obvious but often unspoken reason for studying how waves and currents behave on different coasts with different seafloor profiles: national security.

In the World War II era, the Navy and Marines were desperate for knowledge of how to make amphibious landings, and some novel coastal research was conducted as a result. Then the Cold War moved most naval research to the deep, where submarines and big ships played acoustic cat-and-mouse in the blue water.

As global threats and approaches to combat changes again, the Navy has renewed its interest in the coastline. In fact, the U.S. Office of Naval Research was one of the major sponsors of the Nearshore Canyon Experiment (NCEX). The experiment itself is pure, fundamental coastal research. But the lessons will surely have military applications.

Special forces such as the Navy Seals need to understand and predict the dynamics of waves and currents because any operation that involves crossing the surf zone is dangerous. Equipment used for reaching and crossing the beach may not operate safely, and landing troops slowed by the surf are more vulnerable. The price of misunderstanding waves or water depth is paid in human lives.

"If you were to invade La Jolla, for example, where would you want to land?" Elgar said of the divergent surf conditions in the region. "The Pacific Rim is chockablock with deep submarine canyons like the one in La Jolla. North Korea, for instance, has an offshore canyon system that is quite similar. If researchers can improve their knowledge of how the shape of the seafloor influences wave dynamics, it could be possible to predict the waves and currents along coasts in other countries, where field experiments like NCEX are impossible."

—Mike Carlowicz

Britt Raubenheimer

Recovery of drifters from the surf near Scripps Canyon. Drifters are GPS receivers and radio beacons that float with currents, giving scientists a picture of surface flows.

and radar images of the surf zone. They drove Waverunner personal watercraft headlong into the surf, with GPS receivers and bottom-finding sonar strapped on the back.

A crew of 25 people—many of them outstanding athletes—struggled to keep the equipment free of kelp and sand, not to mention keeping it upright. "It was the hardest place we've ever worked, and there were few easy days," Elgar said. "We've never run an experiment in a place where the circulation was so crazy."

Divers dropped off from boats 100 meters north of the equipment would often drift so fast that they could not reach the instruments. Other times they would walk or swim out from the beach into strong shoreward currents, get themselves into two or three meters of water, and then find there were no currents at all...or currents pulling out to sea.

The effort was worth it. "We gathered a spectacular data set," Elgar said after they achieved a 98 percent data return. Critical to their success were many practice runs and equipment trials leading up to the experiment.

They also monitored the performance of their instruments in real time, connecting their equipment in the surf zone with their battery-powered computers on the beach via cables.

Awash in data

With the field experiment completed, Elgar and Raubenheimer have months of data processing and sorting to do. They are probably years from presenting conclusions to scientific colleagues. But they already have some tantalizing preliminary insights.

As predicted, the direction and strength of waves are definitely altered by the shape of the Scripps and La Jolla canyons, just as winds are focused and directed by mountains and valleys. In some places, the offshore ridges reflect waves in divergent directions. In other places, waves are focused, causing hotspots for erosion along the beach.

Breaking waves cause an increase in the mean water level, piling up water along the beach as you might pile up water at one end of a bathtub. They found evidence that changes in the water levels caused by changes in wave heights might be important for driving the wildly divergent surf along the coast.

"Breaking waves transfer their energy into the water column, and that momentum lifts the water up," Raubenheimer said. The funhouse bouncing and focusing of waves near La Jolla create extreme gradients between water

Tim Maddux

From a cliff above Black's Beach, Joe Calantoni of the Naval Research Laboratory reviews video of the surf conditions around the swash instruments. Researchers remotely sensed fluid motions in the surf and swash zones, made estimates of current velocities, and compared them with observations made in the water.


Britt Raubenheimer

Steve Elgar adjusts a set of current meters, which had to be kept within centimeters of the shifting sands and pointed at the ocean bottom.

levels—similar to high- and low-pressure systems in the atmosphere. "With all the waves breaking at different angles, the water column is lifted unevenly, which might be what is driving the strong currents."

So now it is time to go back to the computers and models, new observations in hand. "This data set comes from an environment completely different from anywhere the models have been tested," said Elgar. "The question now is: can our models work in a complicated situation? It is an iterative, evolutionary process, and it will take two to three years for the modelers to integrate these data and adjust. But ultimately, we have to let the observations guide us and figure out the important physics that is missing."

To learn more about surf zone and swash zone research, visit http://science.whoi.edu/PVLAB

— Christina Johnson contributed to this story.

Public Science, Public Service

Steve Elgar

Britt Raubenheimer talks to a surfer about the research being conducted on Black's Beach, a world-famous surfing spot. Below: Raubenheimer and colleagues spent a lot of time reaching out to beach visitors when a sewage spill contaminated the waters.

Three months of field work in Southern California brought its share of unexpected and extracurricular developments for scientists in the Nearshore Canyon Experiment.

"Putting 25 instrument tripods in the middle of a world-famous surfing spot created a PR need," Elgar said. The NCEX team hired off-duty lifeguards to make surfers and beach visitors aware of—and keep them away from—the science instruments. The NCEXers also left a gap in their array to give surfers some space to enjoy one of their favorite spots. "We told the surfers we're interested in healthy beaches, too," Raubenheimer said. "That seemed to resonate because many surfers are environmentally conscious."

Tom Kleindinst

Steve Elgar and Britt Raubenheimer in Truro, MA, where they conducted beach surveys and tested their instrument-laden Waverunner watercraft.

Early in the project, a harmful algal bloom, or "red tide," developed along the Pacific Coast from Mexico to Santa Barbara. While the bloom was not harmful to humans, it killed fish and left the water murky. Installing the science gear in the midst of a bloom "was like changing a flat tire with your eyes closed," Elgar said.

In October, the wildfires that raged through San Diego County occasionally rained ash on the NCEX team, though the experiment was never in jeopardy. The crew, however, spent several weeks fretting about family, friends, and their homes.

When 130,000 gallons of sewage spilled into the ocean just a few hundred meters from where the NCEX team was working, scientists detected it before the city did. Researchers informed beachgoers of the pollution more than 24 hours before the city started closing beaches. The NCEXers tracked the plume as it washed along the coast and dissipated. In fact, by the time the city managers posted signs to keep citizens out of the water, the scientists knew the hazard had passed. "Like many coastal managers, they have very little information about how the water flows, and had no solid idea about what would happen after the spill," Elgar said. "Some of our work could help answer those questions. In the future, a city official might use a model of waves and currents to project how sewage might flow along the coast."

In the final weeks of the project, Britt Raubenheimer and Steve Elgar got married after a nine-year engagement. On November 22, following a day of diving and recovering equipment, the crew came in, took showers, and then witnessed the vows of their science leaders. "It was sorta crazy, and I guess we could have picked a less busy time," Raubenheimer said. But it was certainly a happy ending to the experiment.

—Mike Carlowicz

Ocean Science in the Jungle

The pristine lagoons, mangroves, and tropical forests of Isla Canales de Tierra provide a bountiful research reserve.

During a vacation cruise in 1999, a conservation-minded European businessman moored his yacht for the night in a quiet cove off the Pacific coast of Panama. What he saw at dawn dazzled him.

"I saw this incredible bay," Jean Pigozzi recalled. "I heard howler monkeys. I saw dolphins jumping around the boat. I saw red crabs running around the mountains." He also spotted evidence of trouble in paradise: burned forests and damaged reefs.

Smitten by the natural beauty and concerned about its ruin, Pigozzi began buying acreage near the Panamanian coast. He now owns about 3,500 hectares (8,600 acres) of sandy beach, rocky shore, and jungle. "I am interested not only in conserving the sea and forest, but in bringing science and high technology to conservation," said Pigozzi. "That's my dream."

Liquid Jungle Lab occupies a small Pacific island about 250 kilometers (150 miles) from Panama City. It borders Coiba National Park, slated to become one of the world's largest marine reserves.

In 2001, he heard a talk by Dave Gallo, WHOI director of special projects, at a California technology conference. Pigozzi then approached the Institution for guidance on developing a program for scientific research on his land. He also contacted the Smithsonian Tropical Research Institute and the Royal Botanical Garden of Madrid. By 2001, he started building—not a beachfront resort but a scientific laboratory.

He named his project the Liquid Jungle Lab.

An opportunity for science

The hilly green island known as Isla Canales de Tierra could be mistaken for an out-of-the-way tropical resort. "It looked like paradise, but within all this beauty we saw a terrific opportunity," said Jesús Pineda, an associate scientist in the WHOI Biology Department who helped scout the site for its research potential.

The isolated area offers researchers a chance to study ecosystems relatively untouched by pollution and development. The lab sits 250 km (150 miles) southwest of Panama City and is accessible only by boat or small plane.

Impressed by the pristine environment and Pigozzi's commitment to science and conservation, the WHOI Ocean Life Institute (OLI) agreed to participate in the project. The lab will operate under a scientific cooperative agreement between OLI, Smithsonian, the Botanical Garden, and a foundation established by Pigozzi. Researchers will provide scientific and technical advice on the operation of the field station and use it for research.

"I am excited by the opportunity to see environments that no one has worked on before," said Larry Madin, senior scientist in the WHOI Biology Department and Director of OLI. "We can launch small boats, study or collect drifting plankton or jellyfish, and then come back to the lab to work. Other researchers working on everything from viruses to dolphins are going to find similar opportunities."

Research begins spring 2004

In March 2004, Madin led a team of nine biologists, ecologists, and chemists to the lab to begin developing research plans. Within a few years, Madin anticipates that dozens of scientists could be visiting to conduct basic and applied scientific research projects.

The lab is designed like a village, complete with modern laboratory and storage space, workshops, dormitories, an infirmary, a library, and conference rooms.

Future plans call for a shore lab with running seawater for experiments, a marina, a helicopter pad, and an airstrip.

"I fell in love with this place, and it turns out that it's extremely fascinating for scientific reasons," said Pigozzi, an independent venture capitalist. Pigozzi graduated from Harvard University in the 1970s and has since explored a range of interests, from selling supermarket carts to photography, magazine publishing, film making, and African art collecting.

"Some people at WHOI were asking, 'who is this guy that hangs out with Michael Douglas and Mick Jagger?'" said Dan Stuermer, director of Development. "He's different from the traditional WHOI supporter. But different might be good for us."

Visit www.liquidjunglelab.com

—Amy E. Nevala

Jean Pigozzi

Nestled in tropical forests and surrounded by the Pacific Ocean (above), Liquid Jungle Lab was designed by architects Marco Zanini of Italy and Simon Velez of Colombia to blend with the environment. Bamboo and other regional colors and textures (below) are used to create the feel of a small village. The facility includes chemical and biological laboratories, dock, wet labs, library, conference rooms, workshops, and dormitories. About 15 scientists can work and live at the field station.

Jean Pigozzi

Launching into Coastal Research

Tom Kleindinst

"The feeling coming into Woods Hole was unbelievable," said Senior Scientist Rocky Geyer, who was aboard Tioga *as it cruised into the village for the first time on April 16. Bagpipers and spectators greeted the boat as it tied up behind Bigelow Laboratory.*

The Woods Hole Oceanographic Institution's new 60-foot coastal research vessel was christened and launched on March 29 in ceremonies at Gladding-Hearn Shipbuilding in Somerset, Massachusetts. After two weeks of outfitting and testing, *Tioga* arrived in Woods Hole on April 16.

"This marks a transition for WHOI," said Rocky Geyer, chair of the Applied Ocean Physics and Engineering Department and head of the science advisory committee that oversaw design of the vessel. "Building a new ship indicates a real commitment to coastal research."

Tom Kleindinst

WHOI employees, donors, and shipyard workers gathered on March 29 for the ceremonial blessing and launch of Tioga. *The name* Tioga *comes from the Iroquois for "swift current." It is also a Seneca word meaning "the meeting of two rivers."*

With twin 750-horsepower diesel engines, *Tioga* can easily cruise at 20 knots, affording efficient and quick access to the waters of Vineyard and Nantucket sounds and Massachusetts Bay. It can range as far as 350 miles, enabling it to reach New York Harbor and the Gulf of Maine, where several WHOI scientists are conducting research.

"*Tioga* can get to the edge of the continental shelf and back in daylight, and at a reasonable cost," Geyer said. "This is a boon to blue-water oceanographers who are trying to get to the next level in technological innovation and need to test their instruments in deep water."

A large A-frame on *Tioga*'s stern gives researchers the ability to deploy complex instrument arrays, moorings, and buoys. The versatile fantail and booms will allow testing and towing of new instrument systems.

But *Tioga*'s biggest impact will come in coastal studies. The boat is versatile enough to support research on everything from marine mammals and harmful algal blooms to coastal erosion and oil spills. It also will allow many students to gain invaluable research experience at sea.

The boat features special outfitting for divers—including a dive platform, dive locker, and shower—which will be a major asset for the extensive underwater activity required at WHOI's Martha's Vineyard Coastal Observatory (MVCO).

The boat is already achieving its designed goals. In the first few weeks of use, the vessel supported an education cruise and made several trips to MVCO to install new instruments and recover equipment for servicing. *Tioga* carried Brechner Owens, senior scientist in the Physical Oceanography Department, to the continental shelf break and back for deployment of a glider for a climate research program.

Tioga was built by Gladding-Hearn Shipbuilding, a family-operated business renowned for specialized craft such as fast ferries, police and fireboats, pilot boats, tugboats, and research vessels. The boat was designed by Roger Long Marine Architecture of Cape Elizabeth, Maine, which recently collaborated with Gladding-Hearn to build similar vessels for the University of New Hampshire (*Gulf Challenger*) and Old Dominion University (*Fay Slover*).

—Mike Carlowicz and Shelley Dawicki

Tom Kleindinst

Workers at Gladding-Hearn Shipbuilding assemble the aluminum hull of Tioga *in the summer of 2003.*

Ready for Launch

Bob Elder

The magazine of ocean research, engineering, and education is now online.

Join our expedition.

Rewriting the Story of Earth's Formation...Slowly

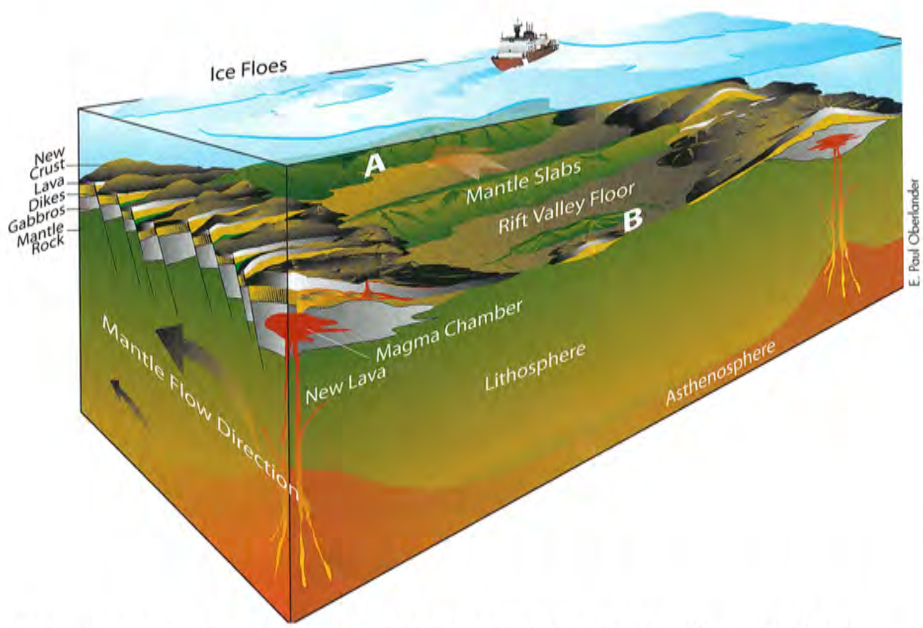
Henry Dick, on a cruise to the Southwest Indian Ridge, where he found evidence of a new type of seafloor ridge.

When Henry Dick started college in 1965, plate tectonics—the theory that Earth's surface is made up of great crustal plates in constant motion—was viewed as a wild hypothesis. By the time he was a young marine geologist in the early 1970s, it had become widely accepted theory. Dick and other young marine geologists thought all the major advances in their field had been made.

Happily, he was wrong.

Now a senior scientist in the WHOI Department of Geology and Geophysics (G&G), Dick and G&G colleagues Jian Lin and Hans Schouten recently identified a new type of ridge on the ocean floor. The "ultraslow spreading ridge," as the team called it in a November 2003 article in the journal *Nature*, could fundamentally change some aspects of plate tectonic theory.

"Marine geology textbooks will be rewritten," said David Epp, director of the marine geology and geophysics program at the National Science Foundation. As much as one-third of the seafloor may form differently than geologists had previously thought.



Volcanic activity at mid-ocean ridges creates new seafloor crust that spreads outward. Recent expeditions have led to the discovery of an entirely new type of mid-ocean-ridge—ultraslow spreading ridges—which may make up one-third of the global ridge system. Ultraslow ridges include places where solid slabs of mantle rock rise directly to the seafloor.

Crust in slow motion

In plate tectonic theory, Earth's surface is made up of about a dozen large sections of crust, or plates, all in constant motion. The boundaries form the mid-ocean ridge system, a 30,000-mile chain of underwater mountains and valleys that circle the globe like seams on a baseball.

Along sections of the ridge where plates are moving apart, new crust is formed. Scientists have believed since the 1970s that these ridges are either slow-spreading—the Mid-Atlantic Ridge creeps along at one to two inches a year—or fast-spreading—the East Pacific Rise races at five to seven inches per year.

By contrast, the Southwest Indian Ridge (SWIR) in the Indian Ocean and the Gakkel Ridge below the Arctic Ocean spread no more than fractions of an inch per year. Scientists have long said these regions are extreme examples of slow spreading ridges. That explanation did not satisfy Henry Dick.

"These ridges were rarely studied until the early 1990s," Dick said.

"These places are hard to reach, we didn't have some of the necessary tools, and the intellectual leap to a different type of ridge was just too big, so funding was tough to secure."

Lacking support for a full expedition to study the geology of SWIR, he cobbled together a few days here and there on other scientists' cruises. Between 1976 and 2003, Dick made fourteen visits to the ridge to collect evidence.

He made a breakthrough in 1987. After years of dredging for rock samples and mapping the seafloor in increasing detail, he found that the crust along the Southwest Indian Ridge was much thinner than at ridges found elsewhere in the ocean. "My eyes grew to the size of dinner plates when I looked at the first high-resolution maps," Dick recalled.

Dick and colleagues finally had convincing evidence that SWIR was in a class by itself. But they needed more evidence to make the case for a new type of ridge.

More evidence under ice

Dick believed a similar process was at work in the Gakkel Ridge, but studying the seafloor three miles beneath the ice cap of the Arctic Ocean was a challenge. The arrival of a new Coast Guard icebreaker, *Healy*, brought Dick and colleagues Peter Michael (University of Tulsa) and Charles Langmuir (Harvard University), a fresh opportunity in 2001. But no one expected them to accomplish much.

During a nine-week summer cruise the research team exceeded all expectations. They proved that Gakkel Ridge is volcanically active, but also found that the ridge spreads so slowly that large chunks of Earth's mantle, instead of volcanic magma, are deposited directly onto the seafloor.

In fast-spreading and even slow-spreading ridges, magma rises to the seafloor through submarine volcanoes and fractures in the crust, filling in the gaps as the plates move apart. The process creates layers of volcanic rock up to six miles thick.

But at ultraslow ridges, the Earth cracks apart so slowly that magma from the mantle cools before it reaches the seafloor. There is no layer of volcanic rock. Instead, great slabs from Earth's interior are slowly pushed up directly onto the seafloor, providing geologists with their first direct look into the Earth's mantle.

They might provide more than that. Hot springs are far more abundant at these ridges than anyone had suspected. The ultraslow springs are likely the longest lived on the seafloor and may produce the largest potential ore deposits for nickel, zinc, and copper.

"All my career I have wanted to make a small contribution to the field of plate tectonics, but I didn't expect this," Dick said. "I can't wait to go back. We've truly just started to explore."

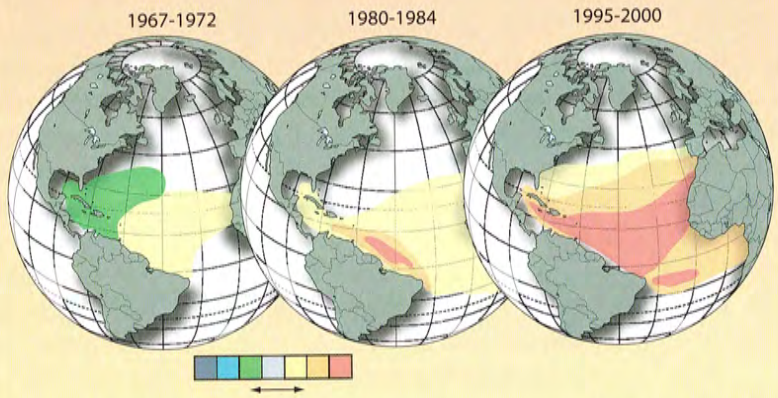
For more information, visit http://oceanusmag.whoi.edu/v42n2/dick.html

—Shelley Dawicki

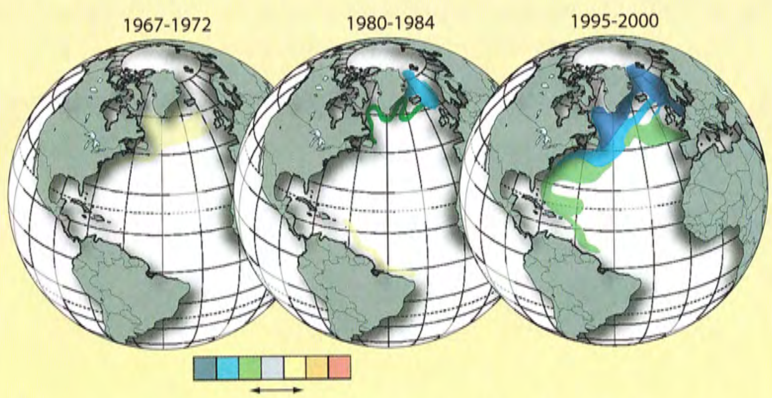
Left: WHOI researchers empty a dredge of volcanic rock during an expedition on R/V Knorr *to the Southwest Indian Ridge. Right: Students Yaz O'Hara and Neil Banerjee examine fresh lava from a submarine volcano.*

Study Suggests the Atlantic is Responding to Global Warming

Tropical seas have become saltier over the past 40 years, while waters closer to Earth's poles have grown fresher, according to a recent study led by Ruth Curry, a research specialist in the WHOI Physical Oceanography Department. These trends suggest that recent climate changes—including global warming—may be altering the fundamental systems that regulate the movement of fresh water around the globe.



Tropical and subtropical Atlantic waters have become dramatically saltier over the past 40 years, especially in the past decade.



Over the same 40-year period, deep waters have become less salty in critical North Atlantic locations, where salty, dense waters sink to drive the global ocean circulation system called the Ocean Conveyor.

Ruth Curry and Jack Cook

"The properties of Atlantic water masses have been changing—in some cases radically—over the five decades for which reliable and systematic records of ocean measurements are available," Curry and colleagues wrote in the December 17 issue of *Nature*. Curry collaborated on the study with Bob Dickson of the Centre for Environment, Fisheries, and Aquaculture Science (United Kingdom) and Igor Yashayaev of the Bedford Institute of Oceanography (Canada).

The research team analyzed measurements of salt content (salinity) collected along a transect from the tip of Greenland to the tip of South America. They found that surface waters in the tropical and subtropical Atlantic have become markedly more saline. Simultaneously, much of the water column in the high latitudes became fresher.

The oceans and atmosphere continually exchange fresh water. Evaporation over warm tropical and subtropical oceans transfers water vapor to the atmosphere, which then transports it toward both poles. At higher latitudes, that water vapor precipitates as rain or snow and ultimately returns to the oceans, which complete the cycle by circulating fresh water back toward the equator. The process maintains a balanced distribution of water around our planet.

But Earth's warming in recent decades may be intensifying evaporation over oceans in the low latitudes, raising salinity concentrations there and transporting more water vapor toward Earth's poles. The scientists estimated that net evaporation rates over the tropical Atlantic have increased by 5 to 10 percent over the last four decades. This trend appears to have accelerated since 1990; ten of the warmest years on record (since 1861) have occurred in that period.

An acceleration of Earth's global water cycle could affect global precipitation patterns, altering the distribution, severity, and frequency of droughts, floods, and storms. It also could exacerbate global warming by rapidly adding more water vapor—itself a potent, heat-trapping greenhouse gas—to the atmosphere.

This warming of the planet and the movement of more water vapor to high latitudes has contributed to the melting of glaciers and Arctic sea ice, pouring additional fresh water into the North Atlantic. Increasing precipitation in higher latitudes already seems to be contributing to the freshening of North Atlantic waters.

Among other possible climate impacts, an accelerated evaporation-precipitation cycle could continue to freshen waters in the North Atlantic to a point that could disrupt ocean circulation. The North Atlantic is one

Photo Op

WHOI Research Specialist Ruth Curry explains her ocean salinity findings to Paul Epstein, associate director of the Harvard Center for Health and the Global Environment, following a briefing on Capitol Hill.

of the few places on Earth where surface waters become dense enough to sink to the abyss. The plunge of this great mass of cold, salty waters helps drive a global ocean circulation system, often called the Ocean Conveyor. This conveyor helps draw warm Gulf Stream waters northward in the Atlantic, pumping heat into the northern regions, where it significantly moderates wintertime air temperatures, especially in Europe.

If the North Atlantic becomes too fresh, its waters will stop sinking, and the conveyor could slow down. Analyses of ice cores, deep-sea sediment cores, and other geologic evidence clearly demonstrate that the Conveyor has abruptly slowed or halted many times in Earth's history. That has caused the North Atlantic region to cool significantly and brought long-term drought conditions to other areas of the Northern Hemisphere over time spans as short as years to decades.

"Our results indicate that fresh water has been lost from the low latitudes and added at high latitudes, at a pace exceeding the ocean circulation's ability to compensate," Curry, Dickson and Yashayaev wrote. Taken together with other recent studies revealing parallel salinity changes in the Mediterranean, Pacific, and Indian Oceans, a growing body of evidence suggests that the global hydrologic cycle has changed in recent decades.

To learn more, visit www.whoi.edu/institutes/occi/currenttopics/ct_abruptclimate.htm

—Laurence Lippsett

WHOI Researchers Among the "Most Cited"

Two international surveys have ranked WHOI among the top ten institutions for the number of times their research papers are cited in other refereed scientific publications. Another statistical survey ranked one of the Institution's scientists among the most-cited for earthquake research.

The Institute for Scientific Information (ISI) Essential Science Indicators ranked WHOI ninth among 338 institutions in attracting citations to its work in geosciences from 1993 to 2003. Scientific authors made 32,847 citations to 1,935 WHOI-authored research papers in geosciences, or 16.98 citations per WHOI paper.

NASA topped the geosciences citation list with a total of 83,362 citations for its 5,151 papers. WHOI ranked higher on the citation list than MIT, the Russian Academy of Sciences, Harvard, Princeton, UCLA, and the French National Center for Scientific Research, among others. WHOI achieved its rank despite conducting research in only half of the 18 geoscience subject areas covered by the study. WHOI also had the smallest number of employees and the smallest operating budget of those institutions in the top 20.

Jian Lin, an associate scientist in the Department of Geology and Geophysics, was recognized by ISI as a co-author of the most cited paper on earthquake research in the past decade. "Static stress changes and the triggering of earthquakes," co-authored with Ross Stein and Geoffrey King in the *Bulletin of the Seismological Society of America*, ranks first among all earthquake papers with 243 citations. Overall, Lin has published 46 papers in the geosciences, and his work had been cited 1,040 times through November 2003.

In another ISI survey, WHOI was second among institutions in the rate at which their papers in pharmacology and toxicology were cited. Forty-one papers by WHOI authors were cited 1,950 times, or 47.56 citations per paper.

—Mike Carlowicz

Going Deep for an Education

Diane Poehls studies the dispersal of hydrothermal vent creatures.

Tom Kleindinst

On her 22nd birthday, Diane Poehls received an unusual present: a chance to spend the next day under 2,500 meters of seawater.

On January 18, 2002, the MIT/WHOI Joint Program student made her first dive in Deep Submergence Vehicle *Alvin*, joining WHOI Assistant Scientist Tim Shank and Pilot Pat Hickey on a voyage to the famed hydrothermal vents at 9° North on the East Pacific Rise. She saw black smokers, shrimp, mussels, and clusters of *Riftia* tubeworms. With that dive, Poehls realized a childhood dream.

She was researching a 7th grade science project when she found a *National Geographic* article about a seafloor eruption at 9° N. "I saw the photos of this strange world miles below the surface of the ocean," Poehls said. "I was intrigued by how it looked like a barren desert in places, and yet there were pockets of absolutely fascinating animals."

She took a marine biology class in high school, studied aquatic biology in college, and enrolled in the MIT/WHOI graduate program. At age 24, Poehls has already made two *Alvin* dives and spent 135 days at sea on five oceanographic expeditions.

She plans several more visits to 9°N, as her thesis research focuses on the creatures who make their homes there. Poehls wants to understand how species migrate from one vent site to the next, a process that has implications for the survival of species.

"Vent environments are ephemeral," she noted. The black smoker that is spewing today might be dormant in a month or a year. "These animals must somehow get from one patch to the next, sometimes traveling many miles between vents."

"As soon as vents were discovered, biologists recognized that the dispersal of larvae was an essential yet unknown component of the communities," said Lauren Mullineaux, a senior scientist in the Biology Department and advisor to Poehls. "Population geneticists assume that larvae arrive at new vents from a large, well-mixed gene pool. Diane knows that dispersal doesn't work this way in shallow or coastal systems, and it probably doesn't work this way in vents."

One of the most controversial questions in modern biology is how populations are connected. "These grandiose communities persist despite constant environmental change and extinction," Poehls said. "If you accept that fragmentation is a risk to the survival of a species, then vent organisms should be extinct or should never have existed. How do they do it?"

Answering that question is going to require a lot of long hours in the laboratory and a few more trips to the ocean floor. Poehls won't mind.

"Going to the sea floor is like taking a trip to another world without leaving Earth," she said. "It sure beats the pictures that we've recently seen from Mars, and it doesn't cost billions of dollars to go there."

Learn more about the MIT/WHOI Joint Program at http://web.mit.edu/mit-whoi/www/

—Mike Carlowicz

Did you know?

- Diane's father, Kenneth Poehls, graduated from the MIT/WHOI Joint Program in 1976. Her mother, Aileen (Woo) Poehls, worked as a research assistant in WHOI's Bigelow Laboratory in the 1970s. And Ching Chang Woo, Diane's grandfather, earned a Ph.D. from MIT and later worked for the U.S. Geological Survey in Woods Hole.
- In 2002, Diane was one of five Americans to spend a month in the North Atlantic on R/V *Akademik Keldysh*, a Russian research vessel and tender to the *Mir 1* and *Mir 2* submersibles.

Federal Funding for Ocean Science Remains Tight

Oceanographers are struggling to find light at the end of the funding tunnel, as federal spending on ocean science remained relatively flat in 2004 and is expected to just keep pace with inflation in 2005. WHOI is heavily reliant on federal funding to conduct ocean research.

The 2004 budget for the National Science Foundation (NSF) rose 5 percent, to $5.6 billion, but funding for the ocean science and earth science directorates grew by 3 percent, just ahead of the national inflation rate. WHOI receives about 40 percent of its science and facility funding through grants and contracts written by Institution investigators to NSF.

The Bush Administration's proposed budget for fiscal year 2005 (which begins in October 2004) includes a number of increases and decreases that would affect WHOI. The overall funding request for NSF was raised to $5.75 billion, an increase of 3 percent over the 2004 level. However, increases in the agency's ocean sciences and earth sciences programs stand at roughly 2 percent, just below the national inflation rate.

Funding for several major ocean science initiatives—including the International Ocean Drilling Program (IODP), the Ocean Observatories Initiative (OOI), and the Oceanographic Fleet Renewal—has been repeatedly postponed over the past few years. So it was a pleasant surprise when the President requested $40 million in 2005 for IODP, which seeks to understand the fundamental mechanics and history of the seafloor. (The current drill ship, *Resolution*, will be replaced or refitted with more modern equipment.) The President's 2005 budget request also suggested that OOI could be funded next year.

This good news is tempered by proposed cuts at the National Oceanic and Atmospheric Administration, which funds 8 to 10 percent of WHOI science. Budgets for peer-reviewed research outside federal labs would be reduced by 30 percent, and programs in harmful algal blooms, ecosystem science, and climate change would be substantially reduced.

Similarly, funding from the U.S. Navy—which typically supplies about 20 percent of WHOI's science and facility income—continues to drop. While the overall Department of Defense budget is expected to grow by $20 billion in 2005, funding for science and technology will drop by 15 percent—more than 20 percent in naval research related to oceanography.

"We have not done enough to show the American people the connection between the work underway in your laboratories and the problems that affect their lives. This must change..."

—Senator Tom Daschle

In a review of the President's 2005 budget request, the Science Committee of the U.S. House of Representatives called proposed funding for basic research "insufficient," noting that while spending on defense and medical research is booming, most federal science programs are barely keeping pace with inflation.

"We must not overlook the fact that scientific research and development underpins our economic and national security," said Representative Vernon Ehlers (R-Michigan), a member of the Science Committee. "Scientific research and development...is an investment that promises, and has historically delivered, significant returns."

For several years, Congress has been working to double the budget for NSF, hailing it as an investment in economic competitiveness. In fact, Congress passed legislation in 2002 to increase funding for NSF from $4.8 billion in 2002 to $9.8 billion by 2007. But a lack of support from the Executive Branch has kept NSF appropriations from increasing substantially.

"We should be honest with ourselves: outside the scientific community, there is no hue and cry for more government funding of R&D," said Senate Minority Leader Tom Daschle (D-South Dakota). "It's unlikely that the science gap growing between the United States and other developed nations will become a major issue in the upcoming presidential campaign."

"We have not done enough to show the American people the connection between the work underway in your laboratories and the problems that affect their lives," Daschle added. "This must change. When rumors of a Nazi bomb program reached President Roosevelt, he said simply, 'Whatever the enemy may be planning, American science will be equal to the challenge.' Will future presidents be able to speak with such confidence?"

To learn more about the funding of research, visit www.aaas.org/spp/rd/

—Terry Schaff and Mike Carlowicz

Awash in Medals and Awards


Tom Kleindinst

Bob Gagosian (left) presents the Ketchum Award to John Farrington.

John Farrington, vice president for Academic Programs and dean of Woods Hole Oceanographic Institution, was presented with the 13th Bostwick H. Ketchum Award. He was recognized for his pioneering work on the inputs and fates of organic contaminants (such as oil) in coastal and open-ocean sediments, and for his leadership in the scientific community, including numerous activities for the National Research Council. Farrington is the first WHOI scientist to receive the award.

The Ketchum Award was established by WHOI in 1983 to honor a scientist who demonstrates an innovative approach to coastal research, leadership in the scientific community, and attention to the effects of marine pollution on the coastal environment and society. The award is named for oceanographer "Buck" Ketchum, who served WHOI for more than 40 years as a graduate student, scientist, chair of the Biology Department, member of the corporation, and associate director.

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The American Geophysical Union (AGU) has named ***Bruce Warren,*** scientist emeritus in the WHOI Physical Oceanography Department, as the 2004 recipient of the Maurice Ewing Medal. Warren was cited for "contributions to the understanding of the general circulation of the ocean, including water mass formation by sea-air interaction, deep and surface boundary currents and interior flow, planetary waves, and the impact of global integral momentum constraints on the ocean circulation."

The Ewing Medal is presented to geoscientists who make significant contributions "to the understanding of physical, geophysical, and geological processes in the ocean; to those who advance oceanographic engineering, technology, and instrumentation; and to those who perform outstanding service to the marine sciences."

Warren is among five WHOI scientists to have been awarded the Ewing Medal, including Henry Stommel (1977), John Ewing (1982), Kenneth Emery (1985), and current Scientist Emeritus Richard Von Herzen (1998).

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Three WHOI staff are among 41 scientists selected in 2004 as Fellows of the American Geophysical Union. Fellows are selected for the "acknowledged eminence in a branch of the geophysical sciences" and their "outstanding contributions to the advancement of the geophysical sciences, to the service of the community, and to the public's understanding." The new fellows from WHOI are:

William Curry, senior scientist in the Geology and Geophysics (G&G) Department and director of the WHOI Ocean and Climate Change Institute, "for his broad pioneering contributions allowing reconstruction of ocean circulation from paleoceanographic tracers."

Peter Kelemen, senior scientist in G&G, "for seminal contributions to the physics and chemistry of melt migration and the formation of oceanic and continental crust."

John Toole, senior scientist in the Physical Oceanography Department, "for his significant discoveries and descriptions of ocean processes from turbulent mixing to the general circulation and for his innovative development of instruments to observe these processes."

Nineteen current members of the WHOI scientific staff are fellows


Tom Kleindinst

WHOI scientists recognized by the American Geophysical Union (from left): John Toole, Bruce Warren, Peter Kelemen, and Bill Curry.

Tom Kleindinst

Rob Olson

of the AGU, and 13 graduates of the MIT/WHOI Joint Program have achieved the honor.

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The WHOI Henry Bryant Bigelow Chair for Excellence in Oceanography has been awarded to ***Rob Olson*** of the Biology Department. The award, named for the Institution's first director, is given to a senior scientist in recognition of extraordinary accomplishments in marine scientific research and education.

Colleagues praised Olson for his fundamental contributions to the modern understanding of plankton. "In the last 20 years, Rob has developed a world renowned reputation in the application of single-cell approaches to studying marine microbes…Rob served as a technological leader, pioneering the use of flow cytometry at sea."

The Bigelow Chair provides five years of support for researchers to further their scientific research and higher education activities.

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This winter, ***Greg Hirth*** of the Geology and Geophysics Department was elected secretary of the tectonophysics section of the AGU. During his two-year term as secretary, Hirth will be a primary communicator and organizer for scientists in his field and will help organize scientific meetings of the AGU.

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Scott Doney, associate scientist in the Marine Chemistry and Geochemistry Department, was one of 20 scientists chosen for a fellowship in the Aldo Leopold Leadership Program for 2004. Doney will spend two weeks in intensive training designed to help environmental scientists from the United States, Mexico, and Canada become better communicators of scientific information and of the societal relevance of research.

Dave Gray

Scott Doney

The Leopold Leadership Program was launched in 1998 to improve the flow of accurate, clear scientific information to policymakers, media, and the public. The program is named for Aldo Leopold, a renowned environmental scientist and author of *A Sand County Almanac.*

Doney applied for the fellowship because he has found it difficult to communicate to nonscientific audiences about his research on the ocean carbon cycle. "I realized that policymakers, reporters, and the general public come at these issues from a different angle," Doney said. "I want to learn to be more effective in explaining what I am doing, what my colleagues are doing, and where it all fits into the bigger picture."

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WHOI Scientist Emeritus ***Robert Ballard*** was one of 10 recipients of the National Humanities Medal in 2003. Along with his achievements as a scientist and explorer, Ballard was cited for his role in using advanced technology to bring ocean science and undersea archaeology to students and the public through "telepresence" programs such as the JASON Project.

The National Humanities Medal, first awarded in 1989, honors "individuals whose work has deepened the nation's understanding of the humanities, broadened citizens' engagement with the humanities, or helped preserve and expand America's access to important resources in the humanities." Ballard was joined by *Sesame Street* creator Joan Ganz Cooney, actor Hal Holbrook, and novelist John Updike, among other medalists.

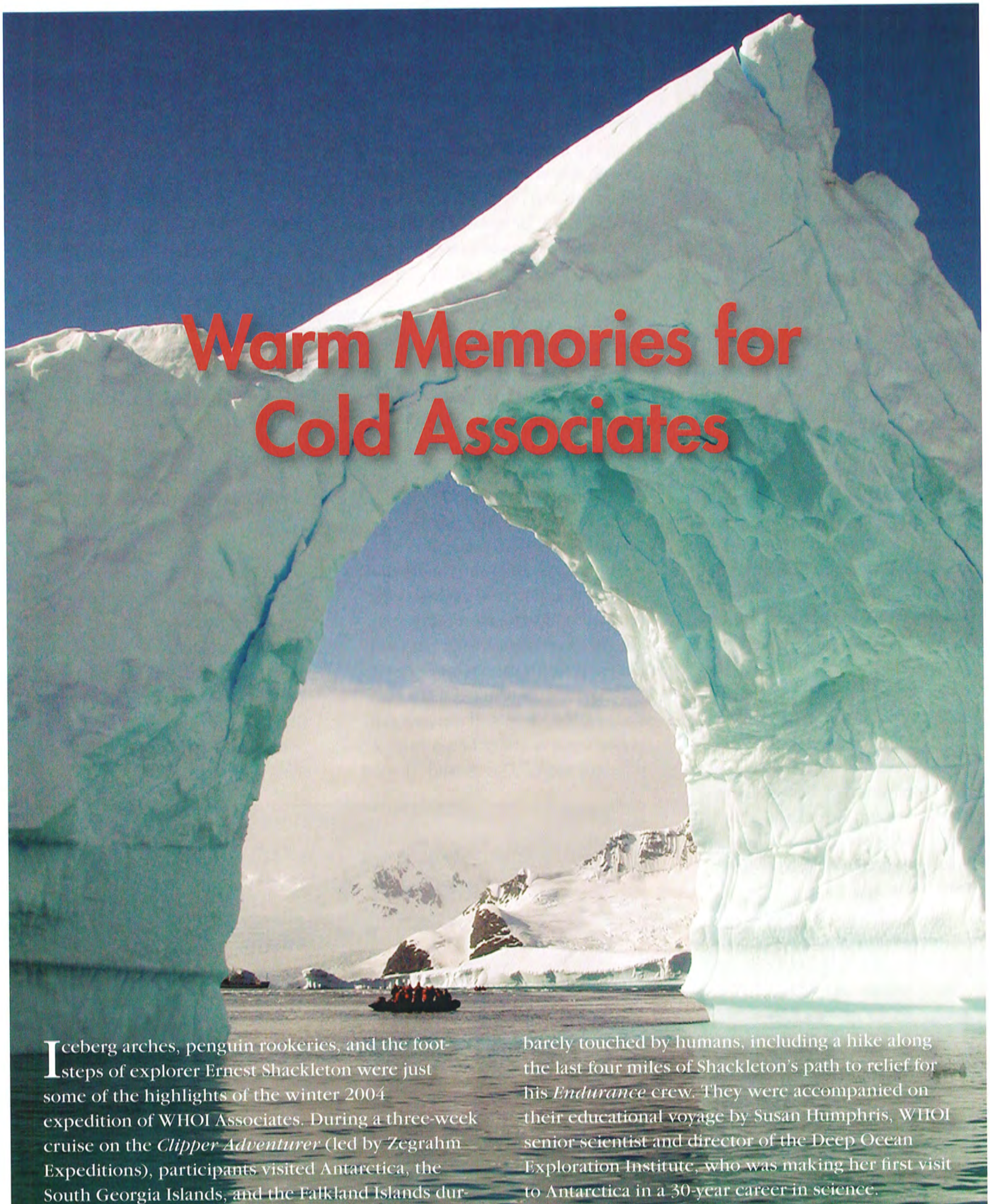
WHOI Ranks in Top 10 for Postdocs

WHOI is one of the ten best U.S. institutions for postdoctoral researchers, according to a recent survey by *The Scientist* magazine. WHOI ranked eighth in a list that was otherwise dominated by medical and cancer research centers.

Fox Chase Cancer Center in Philadelphia ranked first in the web-based survey, which garnered more than 3,500 responses from scientists in 21 countries. The National Institutes of Health placed 10th and the California Institute of Technology was 12th.

The survey asked scientists to assess their working environment according to 45 criteria, including access to books and journals, support from principal investigators and laboratory colleagues, quality of research facilities, training, and pride in their research.

To learn more, visit www.the-scientist.com/postdoc/postdoc.htm



Susan Humphris

Warm Memories for Cold Associates

Iceberg arches, penguin rookeries, and the footsteps of explorer Ernest Shackleton were just some of the highlights of the winter 2004 expedition of WHOI Associates. During a three-week cruise on the *Clipper Adventurer* (led by Zegrahm Expeditions), participants visited Antarctica, the South Georgia Islands, and the Falkland Islands during southern summer.

Using zodiak landing craft, they explored regions barely touched by humans, including a hike along the last four miles of Shackleton's path to relief for his *Endurance* crew. They were accompanied on their educational voyage by Susan Humphris, WHOI senior scientist and director of the Deep Ocean Exploration Institute, who was making her first visit to Antarctica in a 30-year career in science.

"The whole experience was both a pleasure and a privilege...the best trip of my well-traveled lifetime," said Cecily Cannan Selby, honorary trustee of WHOI and a participant in the cruise. "It was like Switzerland filled with water up to the tree line, with icebergs designed by Frank Gehry and Henry Moore."

Each year, WHOI Associates have a unique opportunity to travel to exotic destinations and explore natural wonders with a WHOI scientist as their guide.

The next trip is a cruise from Tahiti to Fiji in November 2004, with WHOI's Audrey Rogerson, a physical oceanographer and director of Foundation and Corporate Relations, as the scientist-guide. Another expedition in November 2005 will carry Associates to Tasmania, the Sub-Antarctic Isles, and New Zealand.

To learn more about the WHOI Associates Program, contact Lesley Reilly at 508-289-4895 or associates@whoi.edu

Opposite: A zodiak boat carries a group of WHOI Associates and other ecotoursts through an iceberg arch off Antarctica. Above: Associate Scientist Pat Lohmann and Senior Scientist Susan Humphris made their first-ever trip to Antarctica a leisurely one, meeting thousands of penguins during one of their stops. The scientists from the Geology and Geophysics Department led a group of Associates on a trip that blended adventure travel with education about the marine environment.

Members of the WHOI family visit the grave of Sir Ernest Shackleton on South Georgia Island. From left, front row: Holly and Heather Aron; second row: Peter Aron, Susan Humphris, Erika Aron; back row: Julia Thoron, Sally Lee, Cecily Selby, Charlie Lee, Sam Thoron, Ann Hale, and Pat Lohmann.

Photo by Tom Kleindinst

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