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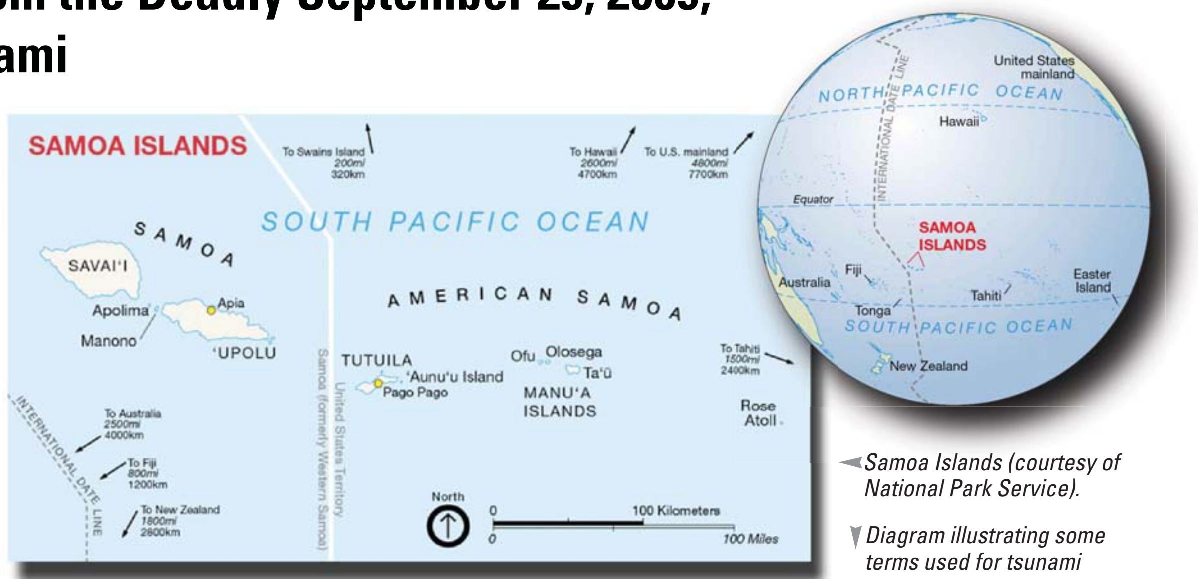
Fieldwork

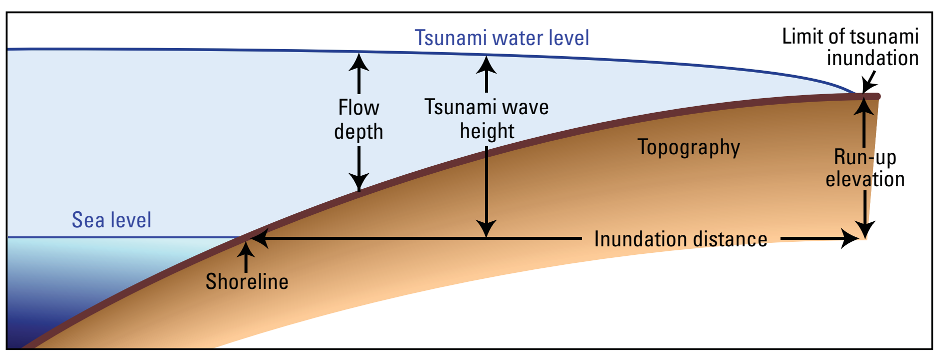
Surprises from the Deadly September 29, 2009, Samoa Tsunami

By Bruce Jaffe



Samoa Islands (courtesy of National Park Service).

Diagram illustrating some terms used for tsunami measurements.



The Samoa tsunami of September 29, 2009, was the fifth tsunami studied by U.S. Geological Survey (USGS) field teams in 15 years, and yet it presented many surprises. The tsunami was generated by a magnitude 8.1 earthquake that occurred about 190 km southwest of American Samoa at 6:48 a.m. Samoa Standard Time. The generating earthquake was different from those that most commonly trigger tsunamis (see "Samoa Disaster Highlights Danger of Tsunamis Generated from Outer-Rise Earthquakes," this issue), and the tsunami itself was striking in several ways, including the variability of its impacts, the effects of coral reefs on inundation, the evidence of a strong return flow, and the effectiveness of education in reducing deaths and injuries.

Tsunami scientists go to areas hit by tsunamis as soon as possible to collect ephemeral data before it is degraded or destroyed by cleanup activities or natural processes. USGS teams collected data in American Samoa from October 5 to 22 and November 5 to 12, 2009, and in Samoa from October 14 to 22, 2009. The tsunami was large; in some areas, the water reached elevations greater than 15 m above sea level. However, wave heights and damage varied from village to village. Even within villages, some structures were completely destroyed, some flooded but left standing, and others barely touched.

In order to improve tsunami-inundation models—which predict the behavior of tsunamis and are vital for helping communities design evacuation routes, build stronger structures, and determine the best areas for building—the USGS survey teams collected data that included:

- flow depths (the height above ground reached by water at various points on shore, commonly indicated by water stains on walls or debris in trees),
- flow directions,
- inundation distances (horizontal distances between the shoreline and the farthest points inland reached by the water), and
- runup heights (the difference between the ground elevation of the farthest point inland reached by a tsunami and sea level at the time of the tsunami).

The teams also measured topography and bathymetry near the shore, including reef-flat elevations. They collected sediment samples and documented the distribution and characteristics of both sand and boulder deposits. Eyewitness accounts of the tsunami were videotaped for use in educational materials.

One striking feature of the Samoa tsunami was that it was almost as large on the "lee" side of the island of Tutuila,

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Sound Waves

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Deadline: The deadline for news items and publication lists for the March issue of *Sound Waves* is Tuesday, January 12.
Publications: When new publications or products are released, please notify the editor with a full reference and a bulleted summary or description.
Images: Please submit all images at publication size (column, 2-column, or page width). Resolution of 200 to 300 dpi (dots per inch) is best. Adobe Illustrator© files or EPS files work well with vector files (such as graphs or diagrams). TIFF and JPEG files work well with raster files (photographs or rasterized vector files).

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American Samoa, as it was on the side facing the southwest where the tsunami was generated. Because tsunamis have long wavelengths (as much as hundreds of kilometers), they are affected by the depth of the water they traverse from the time they are generated until they inundate land. They slow down where the water is shallower, causing their crests to bend (refract) toward the shallowest areas. As a result, tsunami waves change direction as underwater topography refracts their travel path. The refraction caused by underwater topography can also focus the tsunami energy. Refraction and possibly other effects (including interference of reflected waves and generation of "edge" waves, which travel parallel to shore) resulted in the large wave heights on the north and east coasts of Tutuila.

Coral reefs may have affected the height of the tsunami onshore. Fringing reefs surround much of American Samoa and Samoa. Field measurements indicate that the tsunami was largest onshore of channels that cut through the reefs. Reefs and, in general, the shape of the nearshore seafloor are known to affect tsunami inundation. However, because of complicated interactions between the wave and seafloor features, it is difficult to predict exact effects. This complexity, along with the tremendous potential to help communities plan for tsunami hazards, makes tsunami-inundation modeling both challenging and intensely interesting to researchers. USGS scientists **Alex Apotsos** and **Guy Gelfenbaum** ran tsunami-inundation computer models in the field in American Samoa to understand the effects of reefs. Detailed tsunami-inundation modeling is an active area of research for USGS scientists, whose goals include determining under what conditions coral reefs mitigate or enhance tsunamis' destructive effects.

Another striking aspect of this tsunami was the abundant evidence of strong return flow. For example, at Poloa on the northwest coast of Tutuila, where the runup was greater than 11 m along a 300-m stretch of coast and flow depths exceeded 4 m, the coral-reef flat was strewn with debris, including chairs, desks, and books from a school located about 30 m from the shoreline. On other parts of the islands,

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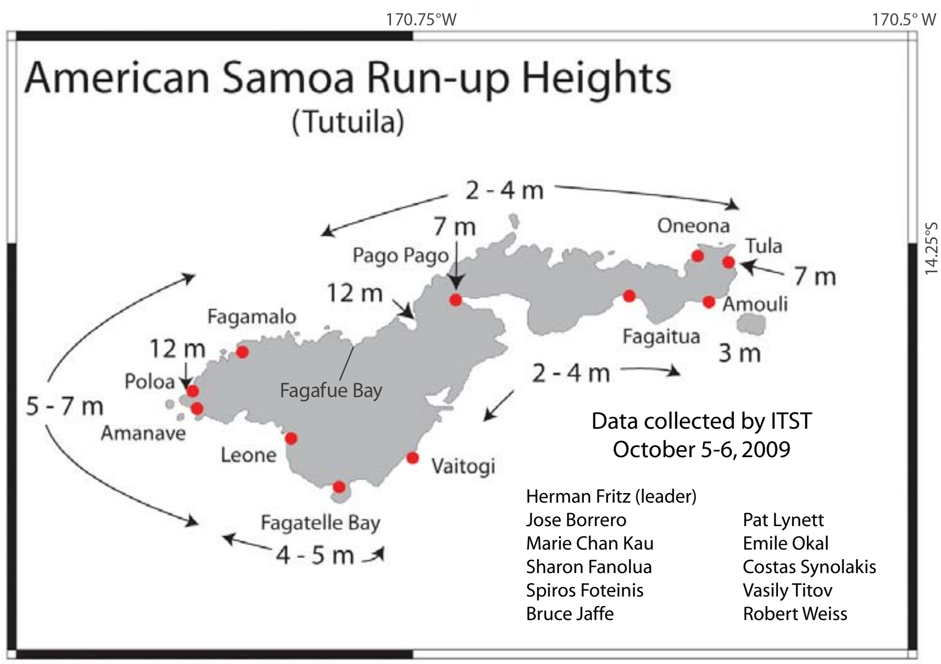

Varying tsunami runup heights (elevations of farthest points inland reached by tsunami) on the island of Tutuila, American Samoa. ***Bruce Jaffe****, USGS, was part of an international tsunami survey team (ITST) that measured runup heights on October 5-6, 2009. Values are not tide-corrected, and the scale of the figure precludes showing all details of observed spatial variations. Locations of some of the higher runups are shown.*

(Tsunami Surveys continued from page 2)

river channels were excavated and new channels formed as return flow scoured sediment and transported it offshore. A primary cause for the strong return flow is the steepness of the terrain. In many places, the tsunami hit cliffs instead of running farther inland. The combination of trapped water and gravity resulted in strong offshore flows. Another possible cause for the strong return flow is the shape of the waves in the tsunami wave train; this factor is being investigated using hydrodynamic models.

The people of American Samoa and Samoa did the right thing after they felt the early morning earthquake—they self-evacuated from the coast to higher ground in the 10 to 15 minutes before the tsunami arrived. Some fled as soon as the ground stopped shaking; others fled when they saw the sea withdraw from the shore. Had residents not evacuated, the fatalities would likely have been in the thousands instead of fewer than 200. This instance of self-evacuation underscores that education saves lives. Recent tsunami-education briefings and school drills—based on knowledge obtained after the devastating Indian Ocean tsunami of December 26, 2004 (**http://soundwaves.usgs.gov/2005/01/**)—were critical in preventing greater loss of life. Similar educational efforts could benefit coastal residents in other countries, including the United States.

Car being washed out to sea by the tsunami's return flow (moving toward lower right) at Pago Pago. Photograph courtesy of ***Richard Madsen****, of the yacht* Barbarella.

Each scientist who goes to an area devastated by a tsunami has a unique experience, but all are moved by the evidence of human loss. There is no better way to learn about a tsunami than to go quickly to a stricken area and collect ephemeral data before it is lost, but there is a price to pay for gathering this knowledge. While collecting data in American Samoa, I came across a small shrine on the foundation of the destroyed house of three girls who had died in the tsunami. The shrine contained pictures of the girls smiling, their sparkly shoes, and their teddy bears. Being the father of a young girl, I found it difficult to continue working, but I did. Like other scientists working in the aftermath of a tsunami, I suppressed my reaction and concentrated on collecting data needed to improve our understanding of tsunamis. The thought that the work we do helps to save lives focused our tsunami survey teams on the task at hand. At the opposite end of the emotional spectrum, we also experienced the joy of helping. Many

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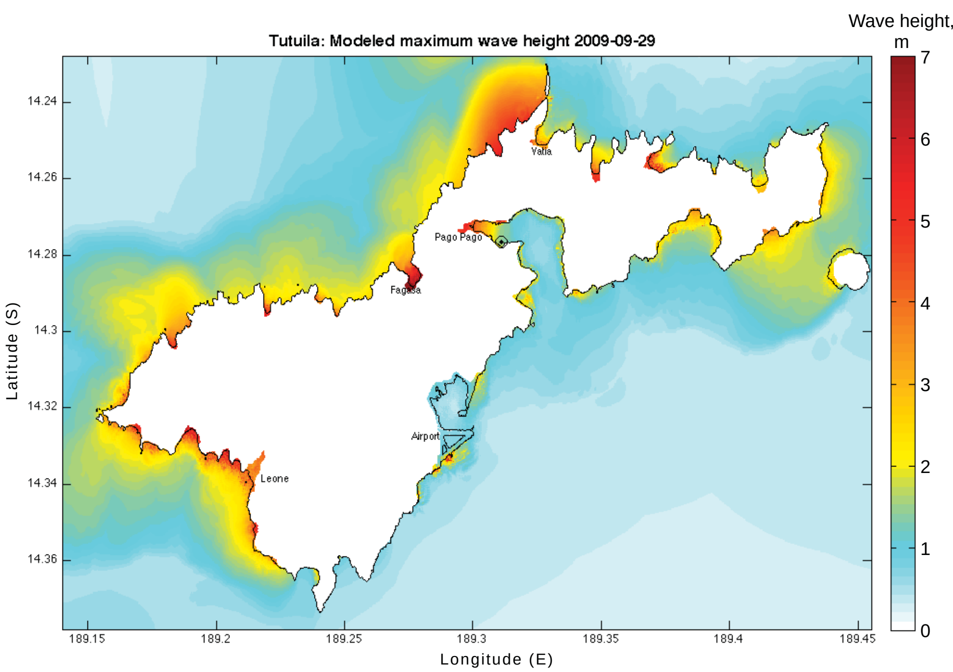

*Initial estimates of maximum tsunami-wave-height distribution for Tutuila, created with the MOST tsunami propagation and inundation model. This figure was created soon after the tsunami was triggered by an earthquake approximately 190 km to the southwest; it predicted that the tsunami height would be greatest on the southwest and northwest coasts, but also large on the east coast and at certain sites on the north coast. Many factors affect wave height, but a primary one is the refraction (bending) of the waves as they encounter shallower water. The wave-height pattern predicted on this map is similar to that measured by field teams. Image courtesy of National Oceanic and Atmospheric Administration (NOAA) Pacific Marine Environmental Laboratory (PMEL) Center for Tsunami Research (****http://nctr.pmel.noaa.gov/samoa20090929-local.html****).*

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people, including local officials and villagers alike, wanted to know more about this tsunami and to understand the risk from future tsunamis. We tried to answer their questions and felt glad to know that our research will help them, and other communities, plan for future tsunamis.

The USGS scientists who have participated so far in tsunami surveys on American Samoa and Samoa are (in alphabetical order by last name): **Alex Apotsos**, **Mark Buckley**, **Guy Gelfenbaum** (team leader in American Samoa), **Bruce Jaffe**, **Bruce Richmond** (team leader in Samoa), **Andrew Stevens**, and **Steve Watt**. To learn more about their activities and observations, please visit the Web site "Notes from the Field" at **http://walrus.wr.usgs.gov/news/samoareports.html**, which includes written observations, numerous photographs, and selected interviews with survivors (**http://walrus.wr.usgs.gov/news/samoainterviews.html**).

For more insights into how data collected after tsunamis are used to benefit coastal communities, read USGS news release "Waves of Survival in American Samoa" at **http://www.usgs.gov/newsroom/article.asp?ID=2348**, and listen to a podcast interview with **Bruce Jaffe**, USGS CoreCast 110, at **http://www.usgs.gov/corecast/details.asp?ep=110**.

To learn more about how the September 29 tsunami was generated, and to view computer animations of its propagation through the open ocean, visit "Preliminary Analysis of the September 29, 2009, Samoa Tsunami, Southwest Pacific Ocean" at **http://walrus.wr.usgs.gov/tsunami/samoa09/**. ☸

Vasily Titov *(left, NOAA/PMEL) and* ***Bruce Jaffe*** *on the south coast of Tutuila, beside a tsunami warning sign that was already in place before the September 29 tsunami. The death toll from the tsunami on American Samoa would likely have been in the thousands if people had not known to go to higher ground after the earthquake.*

Andrew Stevens *works in the rain, collecting differential global positioning system (GPS) data for documenting the elevation and location of tsunami sediment deposits and mapping the onshore topography at Fagafue Bay on the north coast of Tutuila, American Samoa.*

Scientists Cruise Deep into Coral Ecosystems

By Matthew Cimitile, Amanda Demopoulos, and Christina Kellogg

Research cruises exploring the seafloor of the Atlantic Ocean and Gulf of Mexico are opening up a new world of organisms and ecosystems to scientists as researchers descend into uncharted territory hundreds of meters below the sea surface. Several U.S. Geological Survey (USGS) scientists are co-leading a team of researchers from around the United States and Europe seeking to characterize deep-coral ecosystems and the abundance of organisms that live in and around them. Their research is shining a light on some of the darkest and least explored places on the planet.

In direct contrast to the shallow, colorful coral reefs full of tropical fish found in such places as the Great Barrier Reef and the Florida Keys are the equally colorful corals that thrive in dark, extremely cold undersea places being explored by scientists in the DISCOVRE program (Diversity, Systematics, and Connectivity of Vulnerable Reef Ecosystems, **http://fl.biology.usgs.gov/DISCOVRE/**). The purpose of the program is to uncover and document what exists at depth and begin the process of protecting deep-coral ecosystems. This interdisciplinary, global research initiative has already had positive impacts on deep-sea conservation. On the basis of current research, the South Atlantic Fishery Management Council has approved an amendment to protect more than 23,000 mi^2 of deep-coral habitats, ranging in depth from 370 to 800 m, off the coasts of the Carolinas, Georgia, and eastern Florida.

The 4-year multidisciplinary DISCOVRE research program includes expeditions that are a partnership among the USGS; the Minerals Management Service (MMS);

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the University of North Carolina, Wilmington; the University of North Carolina at Chapel Hill; the National Oceanic and Atmospheric Administration (NOAA); the Royal Netherlands Institute for Sea Research; and the Scottish Association for Marine Science. The expeditions focus on understanding the physical oceanography, biology, ecology, and genetic connectivity of deep-coral environments.

This year, the DISCOVRE team was involved in three cruises in the Atlantic Ocean and Gulf of Mexico. Their first cruise, in early August, explored deep-coral ecosystems off Cape Canaveral, Florida. Two USGS scientists, **Amanda Demopoulos** and **Cheryl Morrison**, went straight from that cruise to participate in a NOAA Ocean Explorations cruise funded jointly by NOAA and MMS, and then directly from that to another DISCOVRE cruise. Both the second and third cruises explored the Gulf of Mexico from offshore of Texas to the west Florida slope.

Some of the team members from the third 2009 DISCOVRE cruise. The science crew contains an interdisciplinary group of researchers from the United States, the United Kingdom, and the Netherlands. Kneeling (left to right): ***Michele Grinar, Andrea Quattrini, Christina Kellogg, Amanda Demopoulos, Furu Mienis, Martha Nizinski,*** *and* ***Kaitlin Kovacs****. Standing (left to right):* ***Adela Roa-Varon, Sandra Brooke, Cheryl Morrison, Lorendz Boom, Steve Ross, Jennie McClain, Cheryl Lewis Ames, Tara Casazza,*** *and* ***Mike Rhode****. Photograph courtesy of USGS DISCOVRE.*

"We have for decades known that deep-sea corals exist in U.S. waters, based on a few biological and geological studies done in the Gulf of Mexico and off the southeastern United States. However, intensive deep-coral research in the area only began within the last decade," said **Amanda Demopoulos**, a benthic ecologist with the USGS in Florida and co-principal investigator for the DISCOVRE program. **Demopoulos** is characterizing the diversity and abundance of small animals living within the coral matrix and nearby sediments.

"Our goal is to understand the diversity and ecology of deep-sea coral environments across these biogeographic regions, compare our data from the Gulf and southeastern U.S. with ongoing research in Europe, and communicate the combined results to scientific and governmental organizations," she said.

DISCOVRE expeditions use a combination of techniques—including photography, sample collection, multibeam sonar, and submersible dives—to examine deep corals and identify organisms ranging from microbes to fish. Submersibles descend hundreds to a thousand meters

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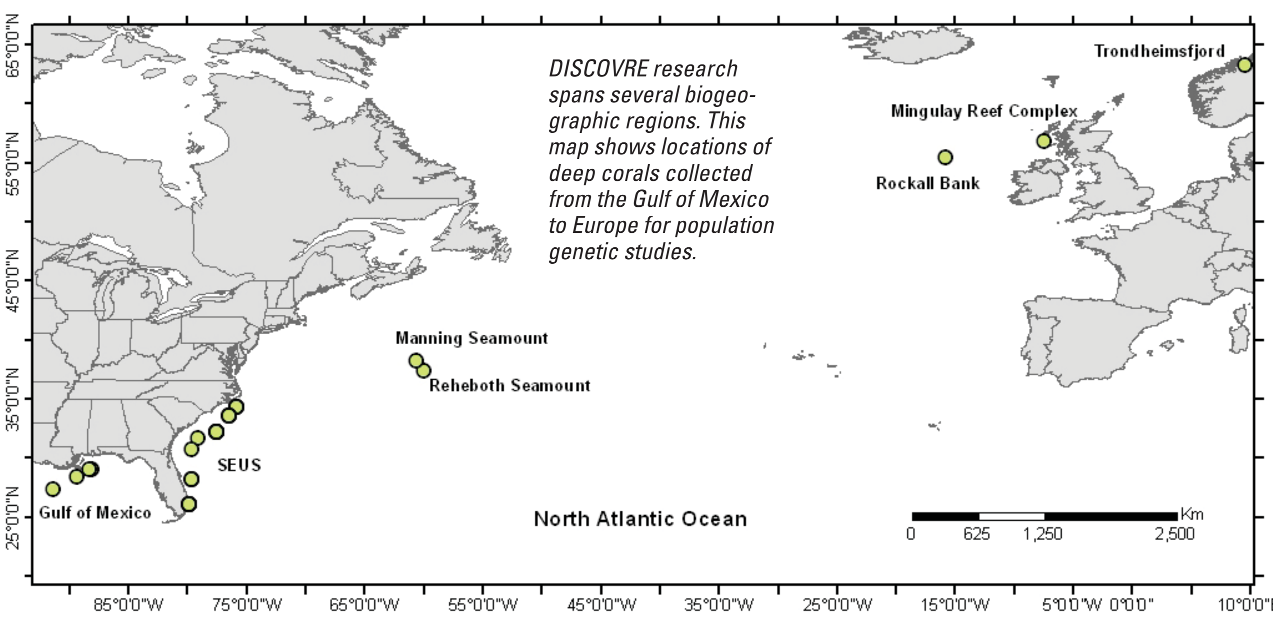

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below the sea surface and enable their occupants to videotape the environment and collect specimens, as well as take measurements of temperature, salinity, dissolved oxygen, and currents.

Two benthic landers—stable sea-bottom platforms that suspend sensors, cameras, and data-acquiring gear—were deployed during annual cruises to document the deep-coral environments and associated biological activity, providing a long-term window into these ecosystems. In addition, a newly developed lander, a microlander, was designed to record the deep-sea environment without the lights and noise of a submersible. Altogether, these sampling and digital-recording techniques leave little or no permanent footprint on the environment while yielding tremendously valuable information.

To collect samples near deep corals, **Demopoulos** uses push cores, clear plastic tubes with a T-handle, held in the exterior arm of the submersible and pushed into the sediment vertically. A rubber gasket at the base of the T-handle creates a vacuum that keeps the sediment sample within the core as the sub pulls up on the T-handle to retrieve the core. The core is then placed in a cylindrical container called a "quiver" and brought back to the ship for researchers to analyze the organisms in the sediments.

"I have collected more than 600 samples from this summer's cruises, and we are beginning to find organisms in the sediments that we haven't yet seen in the lab," said **Demopoulos**, who was in charge of sediment collections of coral-associated meiofauna (animals between 0.045 and 0.29 mm in size) and macrofauna (animals more than 0.30 mm) from all three cruises. Analysis of the core samples may lead to the discovery of new species. Because cores were taken both near corals and farther away, they will shed light on

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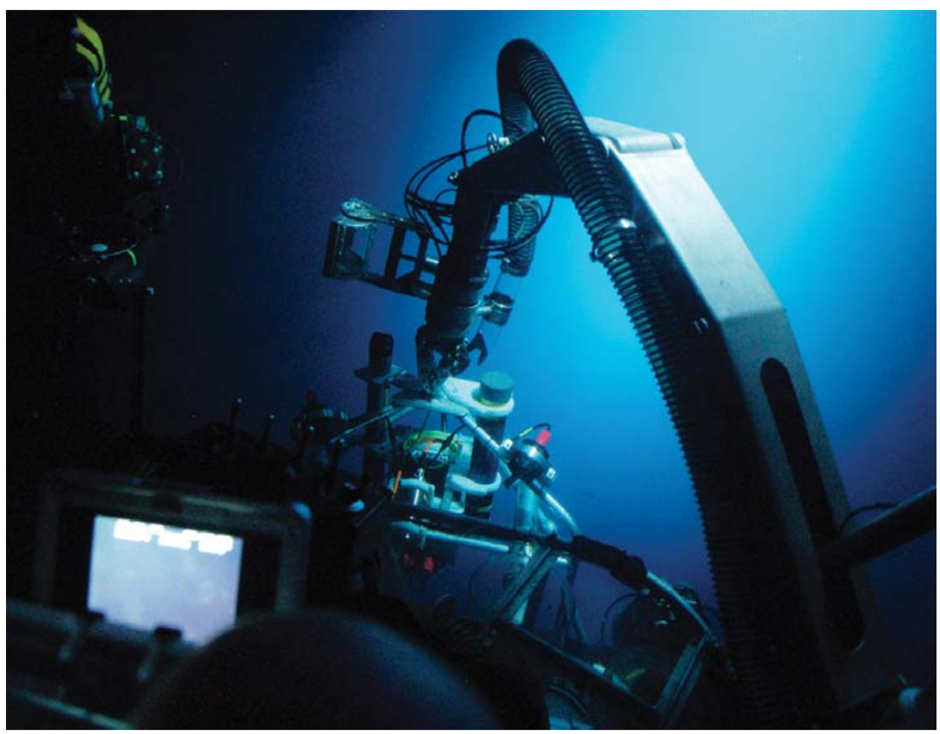
Before a submersible dive, ***Amanda Demopoulos*** *labels push-core T-handles and inserts each core tube into its quiver. Photograph by* ***Elizabeth Baird****, North Carolina State Museum of Natural Sciences.*

The Johnson-Sea-Link*, a manned submersible that can accommodate four people, is a critical component of these deep-coral ecosystem studies. Equipped with a manipulator arm, vacuum-suction sampler, specimen boxes, and push cores, it is lowered into the ocean for its daily dive. Photograph courtesy of USGS DISCOVRE.*

The Sùil na Mara *(Scots Gaelic for "Eye of the Sea") microlander is made of a lightweight aluminum frame designed to be deployed by submersibles. It contains an infrared digital video recorder, acoustic Doppler recording current meter, a hydrophone, and sensors to record temperature and conductivity. Photograph by* ***J.M. Roberts****, Heriot-Watt University, Edinburgh, Scotland.*



The microlander is recovered by the submersible after collecting data and recording video of deep-sea corals. Image taken through the submersible sphere at a depth of 754 m (2,474 ft) by ***J.M. Roberts****, Heriot-Watt University, Edinburgh, Scotland.*

(Deep Coral continued from page 6)

whether the presence of corals enhances the diversity of the marine benthos.

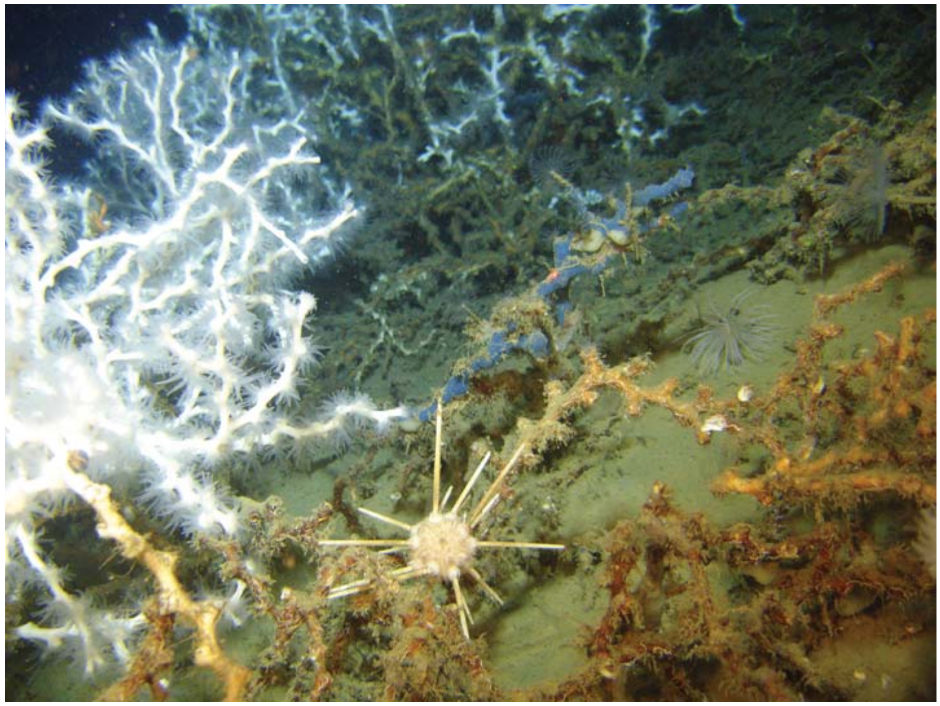
In addition to gathering and studying organisms living around deep-coral ecosystems, researchers are extracting microbial DNA directly from the corals for analysis. "Multiple studies have shown that shallow and deep corals host complex and diverse bacterial communities that are distinct from those in the water column," said **Christina Kellogg**, a research microbiologist with the USGS in Florida.

Kellogg collects mucus, tissue, and skeletal matter from corals in deep water using a sealing bin that she and her husband designed. The bin contains 10 individual chambers that keep samples from touching each other or being exposed to the water column. DNA is extracted from the samples and then sequenced to provide estimates of bacterial diversity. Understanding microbial diversity can provide greater insight into the overall coral ecosystem.

"The presence of coral-species-specific bacteria makes it clear that these interactions are not random or passive. Coral-associated bacterial populations are closely attuned to host metabolism and may change in number or composition in response to a change in coral health, making the bacterial populations a possible diagnostic of coral health. Bacteria may also ward off other potentially harmful microbes by producing antibiotics or just by occupying the available space," said **Kellogg**.

In December, DISCOVRE will explore deep corals off the coast of North Carolina, and benthic landers will be deployed to make observations for a year. The project will continue through 2011 to characterize and discover more deep corals on the seafloor.

For additional information, visit the DISCOVRE Web site at **http://fl.biology.usgs.gov/DISCOVRE/**, or read a USGS Fact Sheet describing the project: *Gulf of Mexico Deep-Sea Coral Ecosystem Studies, 2008-2011*, **http://pubs.usgs.gov/fs/2009/3094/**. Also see "Flat Isabel Goes on a Research Cruise," in the Outreach section of this issue (**http://soundwaves.usgs.gov/2009/12/outreach.html**).



Deep-sea cold-water coral Lophelia pertusa *and associated animals. Jointed white structures at left and top are live* Lophelia*, with polyps visible; jointed orange-brown structures at bottom and right are dead* Lophelia*. A pencil urchin (looks like ball with spines) is visible near bottom of image. Blue encrusting sponge grows on dead coral in center of image. Barely visible above the blue sponge are the delicate tentacles of feather-duster polychaete worms. To the right and below the sponge is an anemone on the sediment surface. A galatheid crab perches on the live* Lophelia*, its orange claws and arms visible near upper left part of image. Photograph courtesy of USGS DISCOVRE.*

An ophiuroid, or brittle star, perched on the surface of a sediment push core. Core is about 9 cm (3.5 inches) in diameter. Photograph courtesy of USGS DISCOVRE.

Ground-Truthing Data for Mapping of Seafloor Habitat and Geology along the California Coast

By Pete Dartnell and Guy Cochrane

U.S. Geological Survey (USGS) scientists recently conducted two research cruises along the California coast as part of the California Seafloor Mapping Program (**http://walrus.wr.usgs.gov/mapping/csmp/**). They collected seafloor video, still photographs, real-time observations, sediment samples, and seismic-reflection profiles. The California Seafloor Mapping Program is a State and Federally funded program to create a series of geologic and seafloor-habitat basemaps for all of California's State waters (from the shore out 3 nautical miles). This work is being performed in support of the Marine Life Protection Act and is a cooperative effort between Federal and State agencies, universities, and industry.

The California Seafloor Mapping Program has five main components:

- **Bathymetry and acoustic-backscatter data**: ship-based collection of high-resolution sonar data for all parts of the coast that are currently unmapped. (Bathymetry is water depth, calculated from the time it takes a pulse of sound to travel to the seafloor and back; acoustic backscatter is the strength of the sound energy reflected back to the sonar system, which yields information about seafloor materials.)
- **Data ground-truthing**: video, still photography, and (or) physical sampling of the seafloor.
- **Subbottom profiling**: high-resolution seismic-reflection profiling to determine the thickness and distribution of sediments and other geologic units, locations of active faults and folds, and other features.
- **Geographic-information-system (GIS) data and map production**: creation of GIS databases and multisheet map sets (1:24,000 scale) that will include bathymetric, geologic, and habitat maps spanning the entire California land-sea margin.
- **Data management and dissemination**: creation of an online data repository for public access to all digital data and map products covering the California State waters.

The first cruise took place in northern California from July 13 to August 2, 2009, aboard the Humboldt State University research vessel *Coral Sea* (USGS cruise ID C-1-09-SC, **http://walrus.wr.usgs.gov/infobank/c/c109nc/html/c-1-09-nc.meta.html**). Work focused on ground-truthing data from the California-Oregon

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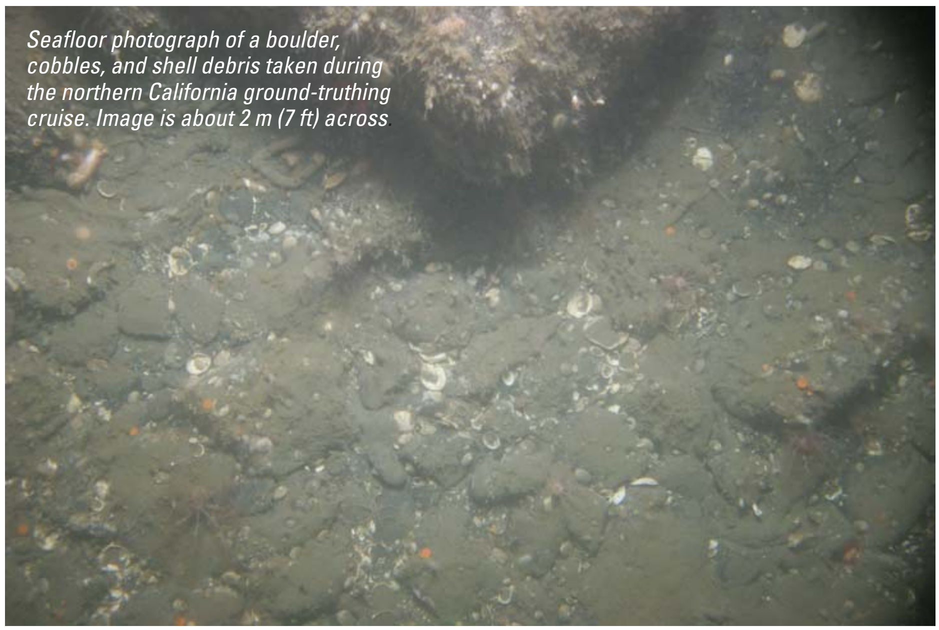
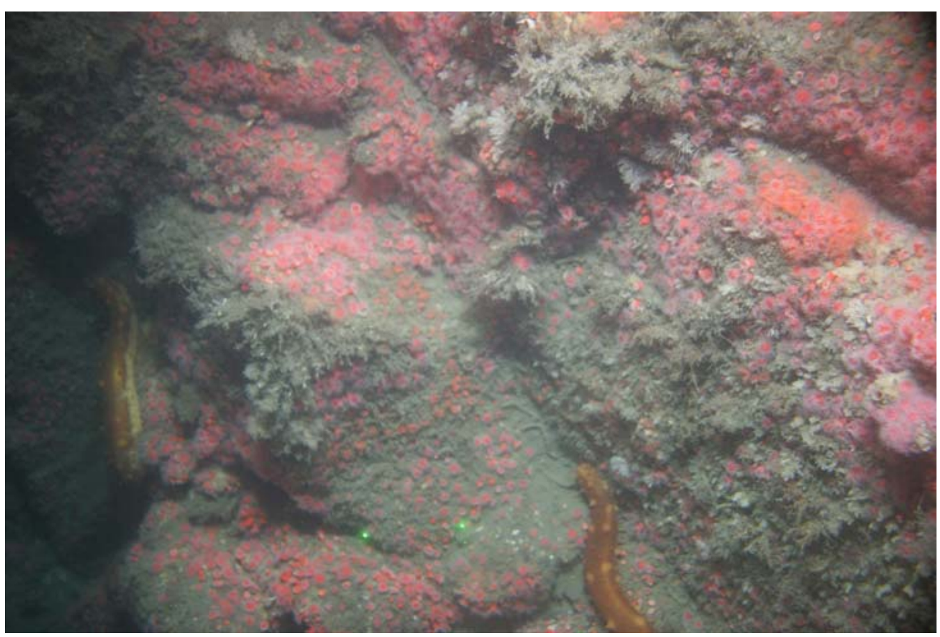


Seafloor photograph of a boulder, cobbles, and shell debris taken during the northern California ground-truthing cruise. Image is about 2 m (7 ft) across.



Seafloor photograph of a rock outcrop covered with strawberry anemones, taken near Reading Rock in northern California. (See map of northern California, next page, for location.) Green laser dots (near bottom of photograph, just left of center) are 9 in. apart.

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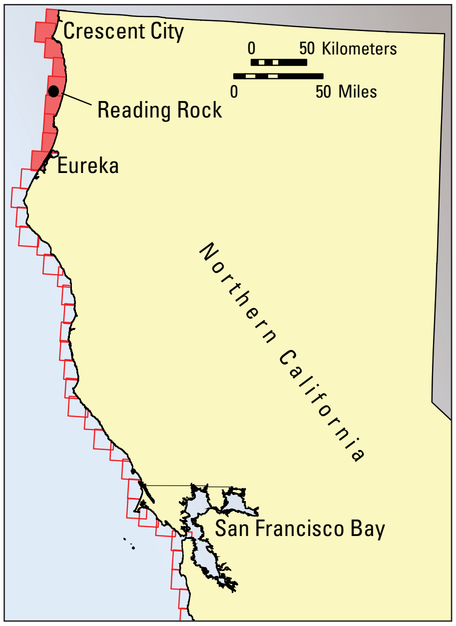

Northern California, showing extent (solid red) of ground-truthing effort during July 13-August 2 cruise. Open squares are additional areas that have been or will be mapped as part of the California Seafloor Mapping Program.

border to Eureka, a distance of about 145 km. Participants on the cruise included **Guy Cochrane**, **Eleyne Phillips**, **Lisa Krigsman** (National Marine Fisheries Service [NMFS]), **Pete Dartnell**, **Andy Ritchie**, **Hank Chezar**, **Tim Elfers**, **Dave Gonzales**, **Pete Dal Ferro**, **Jackson Currie**, **Peter Harkins**, and **Nadine Golden**. Although seafloor visibility was poor in water depths shallower than about 30 m, it was better in the deeper regions and allowed for good imaging of seafloor environments. In areas of poor visibility, ground-truthing focused on sediment sampling and seismic-reflection profiling.

The second cruise took place one week later in southern California, from August 10 to 21, aboard the Channel Islands National Marine Sanctuary (CINMS) research vessel *Shearwater* (USGS Cruise ID S-1C-09-SC, **http://walrus.wr.usgs.gov/infobank/s/sw109sc/html/s-w1-09-sc.meta.html**). On this cruise, work focused on three main areas: Point Conception, Point Mugu, and Santa Catalina Island. Participants on this cruise included **Pete Dartnell**, **Brian Edwards**, **Eleyne Phillips**, **Lisa Krigsman** (NMFS), **Jackson Currie**, **Peter Harkins**, **Tim Elfers**, **Hank Chezar**, **Nadine Golden**, and **Lisa Gilbane** (Minerals Management Service). Good weather and seafloor visibility allowed for 70 camera-sled transects that imaged many seafloor environments, including tar mounds, fields of brachiopods, and rock outcrops.

On both cruises, the video footage and photographs were taken from a USGS camera sled towed about 1 to 2 m above the seafloor at speeds of less than 1 knot. The sled housed three regular video cameras, one high-definition video camera, an 8-megapixel still camera, lights, and

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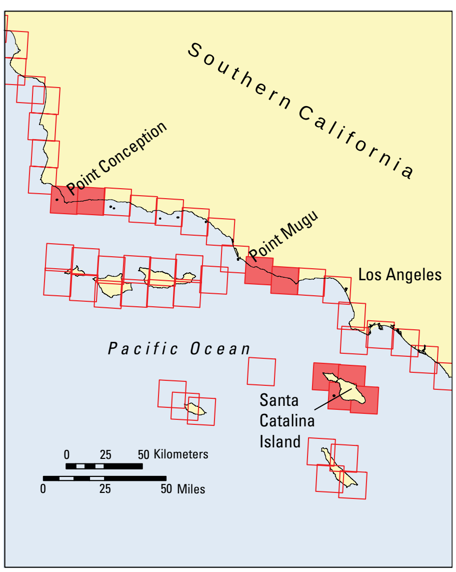
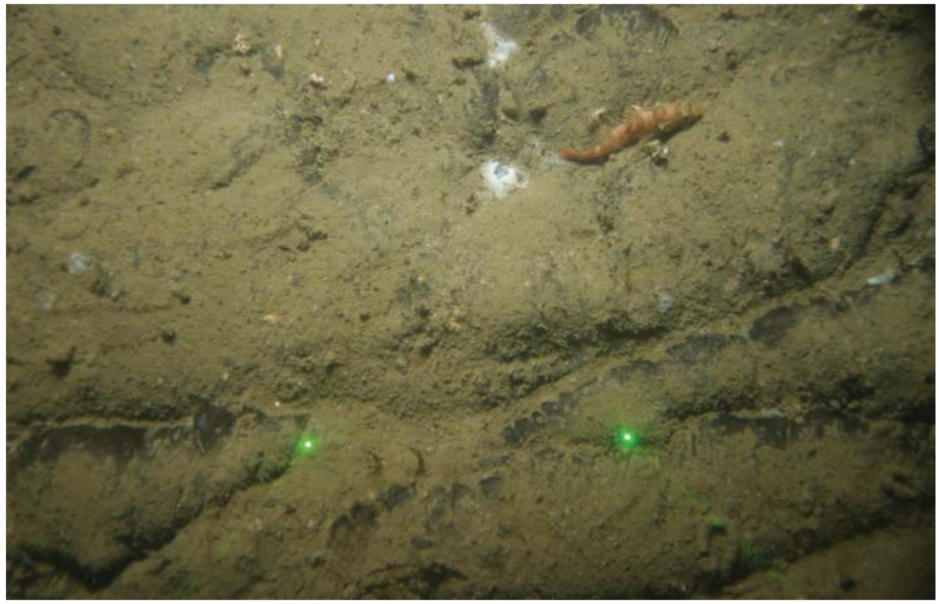


Southern California, showing the three near-shore regions (solid red) ground-truthed during the August 10-21 cruise. Open squares are additional areas that have been or will be mapped as part of the California Seafloor Mapping Program.

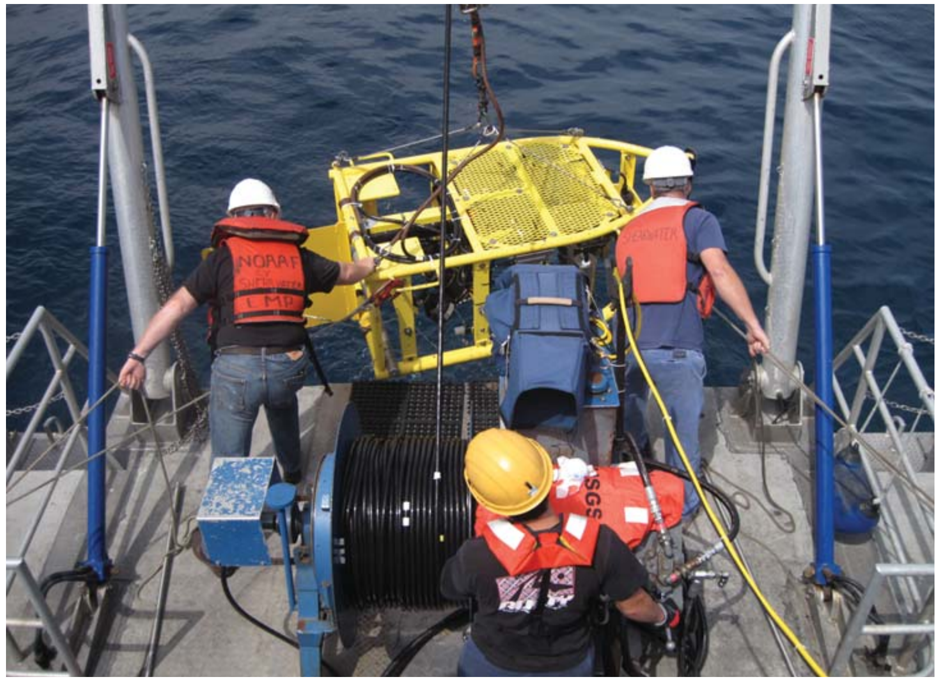


Seafloor photograph of a tar mound covered with a thin veneer of sediment, taken near Point Conception, California. Green laser dots are 9 in. apart.

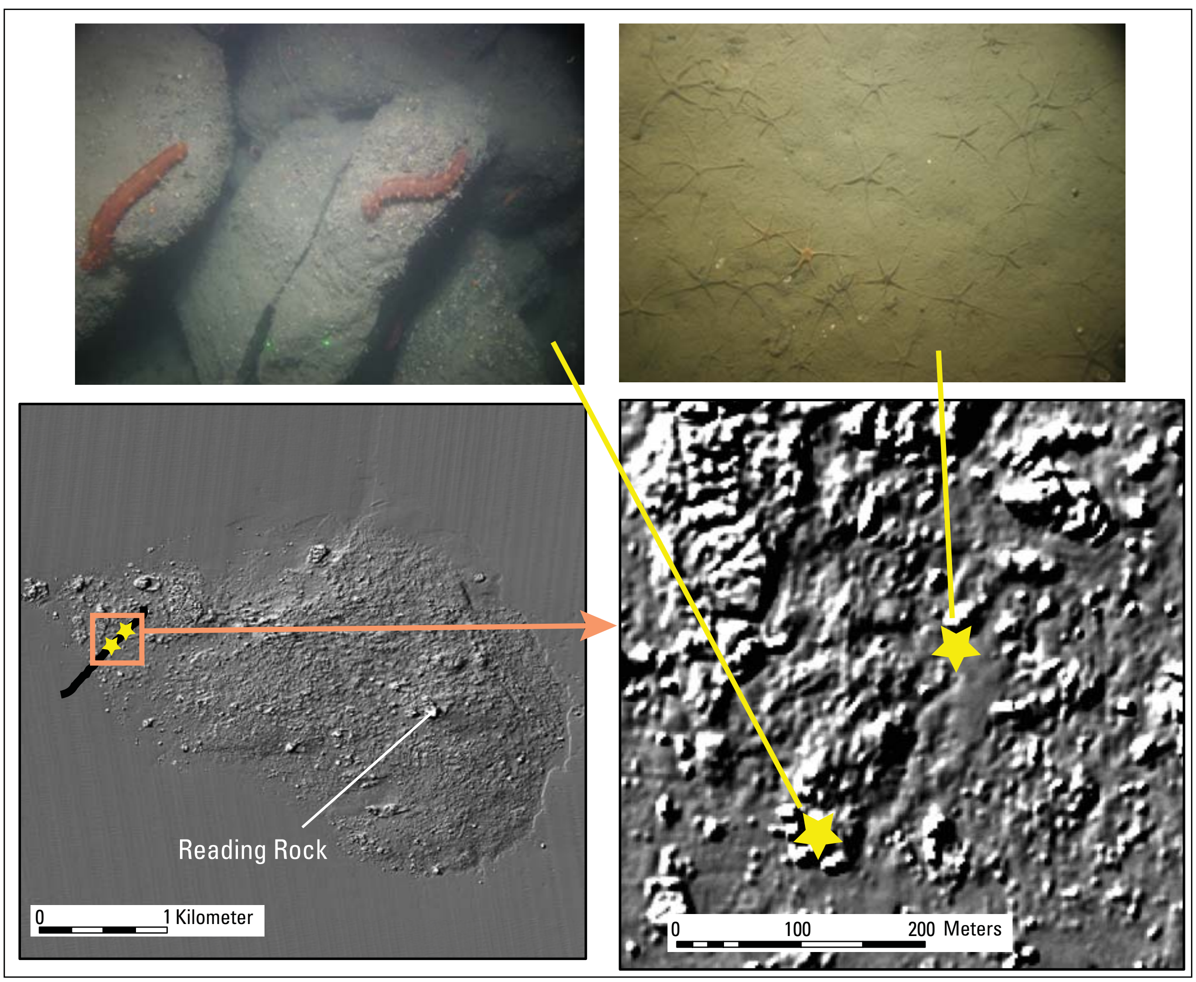
Seafloor photograph of a field of brachiopods covering seafloor sediment on the northern side of Santa Catalina Island, California. Green laser dots are 9 in. apart.

(Ground-Truthing continued from page 9)

paired lasers (to provide scale in images). As the video and photographs were recorded to tape and disk, real-time observations of both geologic characteristics (such as rock or sediment type, local slope, complexity) and biologic characteristics (such as species and percent cover) were recorded to a GIS using a programmable keypad. These data will be incorporated with the bathymetric and acoustic-backscatter maps to create 1:24,000-scale seafloor character and habitat maps. ☸



USGS camera sled being deployed off the stern of the Channel Islands National Marine Sanctuary research vessel Shearwater. *Crew members included (left to right)* ***Brian Edwards***, ***Peter Harkins***, *and* ***Pete Dartnell***.



Comparison of seafloor photographs with shaded-relief bathymetry near Reading Rock in northern California (see map of northern California, previous page, for location). Top left photograph confirms that the rougher seafloor (see enlargement in lower right) is composed of rock outcrop, while the top right photograph confirms that the intervening smooth seafloor is composed of sediment.

Belize Fieldwork Shows How Oceanic Mangrove Islands Kept Up With Sea-Level Rise for 8,000 Years

By Karen L. McKee

Fieldwork off the coast of Belize in Central America is revealing how coastal tropical forests composed of mangroves have kept up with sea-level rise over the Holocene Epoch.

A U.S. Geological Survey (USGS) project is being conducted in the Mesoamerican Barrier Reef system, which extends 220 km (140 mi) from the southern part of the Yucatan Peninsula to the Bay Islands of Honduras and contains the longest unbroken coral reef in the Western Hemisphere. Scattered throughout the barrier reef complex are hundreds of low-lying mangrove islands, which are the target of this research.

From September 2 to 17, 2009, USGS scientist **Karen McKee** conducted research on mangrove islands off Belize with her assistant, **William Vervaeke**, in partnership with the Smithsonian Institution and university colleagues. The information gathered during this recent trip will aid in understanding how U.S. coastal regions may be affected by future sea-level rise and climate change.

McKee has studied various aspects of these mangrove ecosystems for the past 25 years and knows that the logistics involved in carrying out fieldwork in such remote areas can be daunting. Mangrove forests are one of the most difficult environments in which a scientist can conduct field research.

First, there are the tangled masses of aerial roots that make every step tedious and time consuming. Walking through mangroves is also difficult because the ground is soft and mucky. Mangroves occur in the intertidal zone, which means they are flooded part of the time, and research must be timed to coincide with the tides. To top it all off, the tropical setting is hot, humid, and full of biting insects. Fortunately, the Smithsonian Institution's field station on Carrie Bow Cay provides a base of operations from which several mangrove islands can be reached by a short boat ride. The station is equipped with laboratories, dormitories, and other facilities necessary to support studies of reef, seagrass, and mangrove ecosystems.

(Mangrove Islands continued on page 12)

Conducting research in a mangrove forest is logistically challenging because of changing water levels, soft sediments, and tangled roots.

*Fieldwork conducted on mangrove islands off the coast of Belize is revealing how sea level has changed over the past 8,000 years and how it has affected low-lying coastal areas. Photograph of Yucatan Peninsula (left) courtesy of the National Aeronautic and Space Administration (NASA); Twin Cays, Belize (right) courtesy of **I.C. Feller**, Smithsonian Institution. Location map modified from U.S. Central Intelligence Agency map of Middle America posted at **http://www.lib.utexas.edu/maps/americas.html**.*

(Mangrove Islands continued from page 11)

Why Study Mangroves and Sea-Level Change in Belize?

The mangrove islands in Belize are isolated from the influence of terrigenous (land derived) sediment and fresh water and thus are sensitive monitors of changes in sea level. Tectonically, the study area is considered to be relatively stable, without significant tectonic subsidence or uplift. Also, until very recently, the mangrove islands have been relatively unaffected by humans, unlike mangroves in other parts of the Caribbean or coastal wetlands in the United States.

These islands are underlain by deep deposits of peat (organic matter formed from plants) as much as 11 m (36 ft) thick, or as deep as a three-story building is high. These peat deposits have accumulated over the past 8,000 years as climate has warmed and sea level has risen. The peat is composed of the decaying parts of mangroves, mostly fine roots and other organic matter that are preserved in the flooded and anoxic (without oxygen) soil.

A Surface Elevation Table (SET) is used to track changes in soil elevations on mangrove islands. As peat forms, the soil surface expands upward, allowing mangroves to keep up with rising sea level.

Because the roots and organic matter accumulated at or near sea level, the thick section of peat provides a record of rising sea level. The Belize site contains the longest continuous peat record of sea-level change currently known. The mangrove islands in Belize and other peat-forming mangroves in the Caribbean region are thus vital indicators of sea-level change and natural laboratories for examining the processes that allow coastal wetlands to keep up with rising seas.

How Are Elevation Change and Soil Accretion Measured in Mangrove Ecosystems?

High-resolution measurements of elevation change and soil accretion are made with Surface Elevation Tables (SETs) and sand marker horizons. We established 27 SETs at Twin Cays, Belize, by driving stainless steel rods 10 to 12 m (30 to 40 ft) into the ground to create a stable benchmark in the ancient limestone underlying the peat. A portable measuring arm is attached to the benchmark rod, and fiberglass pins are lowered to the soil surface.

The length of the pins relative to the arm is measured on each sampling date and plotted over time. As the soil surface changes, the height of the pins changes. Sand is used to mark the soil surface nearby, and over time, the depth of sediment deposited above the sand provides a measure of soil-accretion rate.

Are Belizean Mangrove Islands Sinking or Keeping Up with Sea-Level Rise?

Measurements of elevation change at Twin Cays are showing that the surface in more productive, fringing mangroves (growing along the periphery of islands and along tidal creeks) is gaining elevation, whereas the interior of the islands is sinking. Adding nutrients to some experimental sites has altered the direction and rate of elevation change. Addition of phosphorus to interior mangroves, for example, caused peat expansion resulting from increased mangrove growth and created hummocks that are now higher than surrounding areas.

These findings are showing that vertical building of mangrove islands varies with the health and productivity of mangroves. Even though nutrient addition had a positive effect in some areas, there were negative effects in other areas. Thus, alteration of the nutrient regime could have unexpected and unwanted consequences for these mangrove ecosystems by disrupting the balance among processes controlling peat formation and soil elevations.

How Have Caribbean Mangroves Responded to Past Changes in Sea Level?

To answer this question, peat cores must be collected from the mangrove islands. A hand-driven corer is inserted into the peat, and segments are extracted one piece at a time. These peat sections are radiocarbon-dated to determine their age. The peat record at Twin Cays spans almost the entire Holocene Epoch (10,000 years) and the rise of human civilization. Botanical and chemical analyses show what plants were present and what the environmental conditions were like at various times. A video showing the field site in Belize and extraction of a peat core can be seen on a

(Mangrove Islands continued on page 13)

(Mangrove Islands continued from page 12)

USGS National Wetlands Research Center Web page: **http://www.nwrc.usgs.gov/featured/mckee/mckee.htm**.

The peat record indicates that these islands have been continuously dominated by mangrove vegetation throughout their Holocene history but have undergone natural cycles of building, dieback, and recolonization by mangroves. Additional cores from other areas show that mangroves became established on the Caribbean coasts of Honduras and Panama about 1,500 to 2,500 years ago.

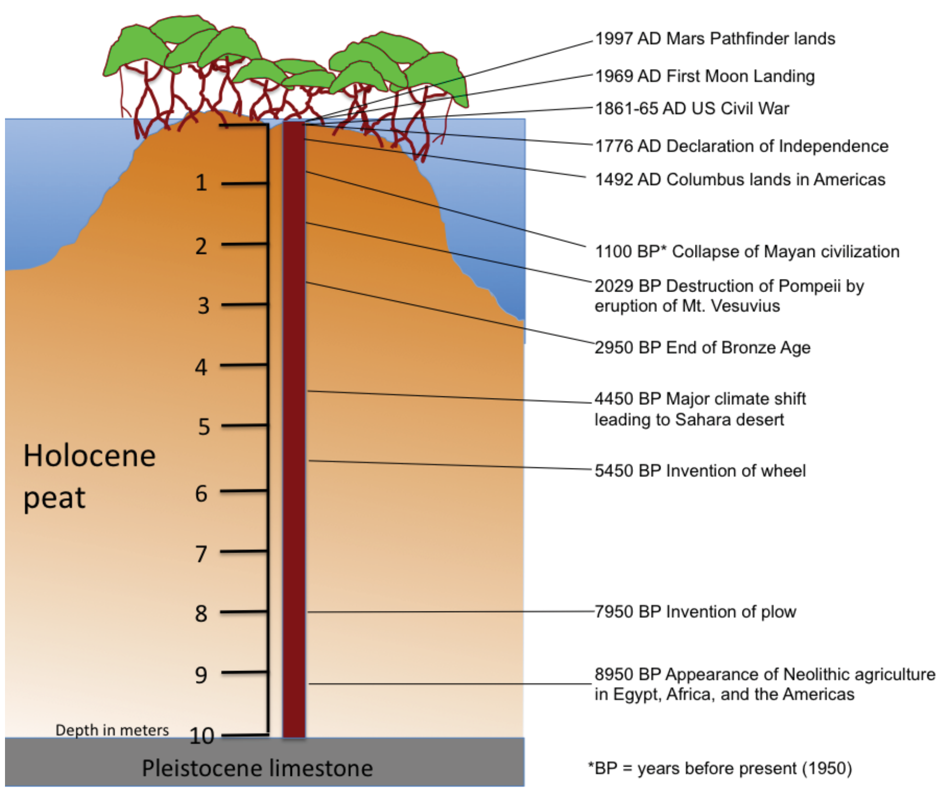
These findings have been published in the journal *Global Ecology and Biogeography* (2007, v. 16, no. 5, p. 545-556, **http://dx.doi.org/10.1111/j.1466-8238.2007.00317.x**).

Future Work Will Focus on Sea-Level History and Sudden Climate Change

An accurate reconstruction of sea-level history since the last ice age is important to the development of models and the identification of rapid climatic events that may have occurred. Cores collected from Belize and other Caribbean locations are key to this reconstruction because these sites were outside the influence of glaciers and have a small tidal range, factors that reduce error and lead to more accurate models.

McKee will work with geologists from the Smithsonian Institution and universities to construct a sea-level curve for the Caribbean region by using new techniques that allow high-resolution measurements of peat components. The sea-level data produced from this project will be used by Earth-ice modelers to refine predictions of sea-level change and by researchers conducting national and regional hazard assessments along the U.S. Atlantic and Gulf coasts. This work will be carried out over the next 2 years through a grant from the National Science Foundation.❆

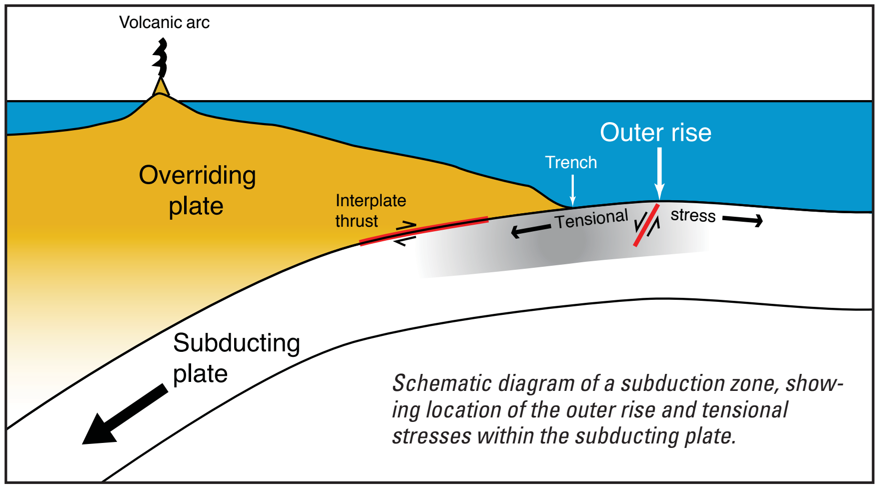
***Karen McKee** (wearing cap) and assistant **William Vervaeke** collect a peat core in a mangrove forest in Belize (top panels). A section of mangrove peat that was formed 2,000 to 2,500 years ago (lower panel; scale in centimeters). View a short video of **McKee** and **Vervaeke** collecting peat cores at **http://www.nwrc.usgs.gov/featured/mckee/mckee.htm**.*



➤ Chronology of selected events that occurred over the time period recorded in mangrove peat cores collected on Belizean islands. The peat record spans almost the entire Holocene Epoch (10,000 years) and shows how these mangrove islands have built vertically as sea level rose during this time period.

Samoa Disaster Highlights Danger of Tsunamis Generated from Outer-Rise Earthquakes

By Eric Geist, Stephen Kirby, Stephanie Ross, and Peter Dartnell



Schematic diagram of a subduction zone, showing location of the outer rise and tensional stresses within the subducting plate.

The tsunami that hit Samoa, American Samoa, and Tonga on September 29, 2009, was generated by an unusual type of earthquake that occurs near oceanic trenches, called an “outer-rise” earthquake. Unlike typical tsunamigenic earthquakes that occur on the thrust fault that separates tectonic plates in a subduction zone (termed the interplate thrust), outer-rise earthquakes occur *within* the subducting or downgoing plate before it enters the subduction zone.

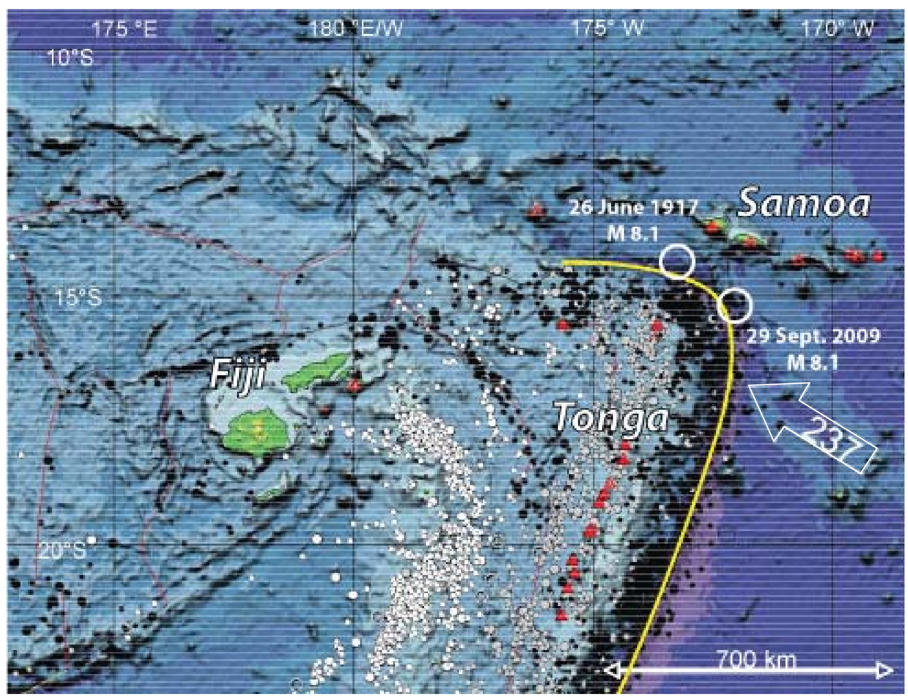
There have been only a few verified instances of tsunamis generated by outer-rise earthquakes, but those that have occurred have been devastating. The 1933 Sanriku tsunami generated from a magnitude 8.6 outer-rise earthquake resulted in more than 3,000 deaths in Japan and significant damage on the Island of Hawai‘i. The 1977 Sumba magnitude 8.2-8.3 outer-rise earthquake resulted in 189 deaths in Indonesia. The September 29, 2009, Samoa outer-rise earthquake, of magnitude 8.1 according to the National Earthquake Information Center (NEIC; see **http://neic.usgs.gov/neis/eq_depot/2009/eq_090929_mdbi/neic_mdbi_w.html**), resulted in comparable fatalities. It was the fourth largest outer-rise earthquake to have been instrumentally recorded since 1900.

For several years, the U.S. Geological Survey (USGS) Menlo Park Tsunami Sources Working Group has been reexamining the 1933 Sanriku earthquake and tsunami and its tectonic setting, as well as identifying trends among other large outer-rise earthquakes worldwide. This investigation is a part of an overall effort to evaluate the tsunamigenic potential of the world’s subduction zones.

Outer-rise earthquakes are caused by stresses in the subducting oceanic plate induced by bending as the plate enters the trench (see subduction-zone diagram, above). Flexure of the plate elevates the sea floor, creating an oceanic feature that parallels the oceanic trench and is known as the “outer rise.” As the plate flexes, tensional stresses in the oceanic crust can create large normal faults, in which rock on one side of the fault moves down and away from rock on the other side (see animation of normal-fault movement at **http://earthquake.usgs.gov/learning/glossary.php?termID=59**). Crustal stresses caused by earthquakes on the interplate thrust fault in subduction zones can also be transferred to the outer rise, triggering earthquakes on normal faults that are already close to failure.

At the Tonga trench, the Pacific plate entering the subduction zone is particularly old and dense, resulting in a steep angle

(Outer-Rise Earthquakes continued on page 15)



*Location of the 2009 epicenter and that of a similar earthquake in 1917 (white circles) in relation to the bend in the Tonga trench (yellow line). Large open arrow shows direction and speed (237 mm/yr) of relative convergence between the Pacific plate and the overriding plate. Islands labeled “Samoa” include Samoa and American Samoa. Dots are epicenters of previous earthquakes; larger dots indicate earthquakes of greater magnitude. Red triangles, volcanoes. For detailed legend, visit “This Dynamic Planet” at **http://mineralsciences.si.edu/tdpmap/**, select “Click for interactive map,” and click “Legend/Layers” near top of new window.*

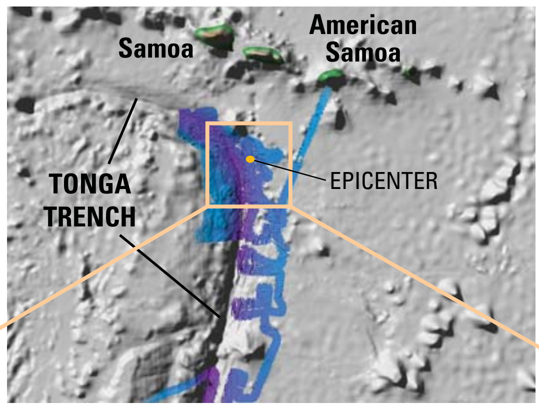
(Outer-Rise Earthquakes continued from page 14)

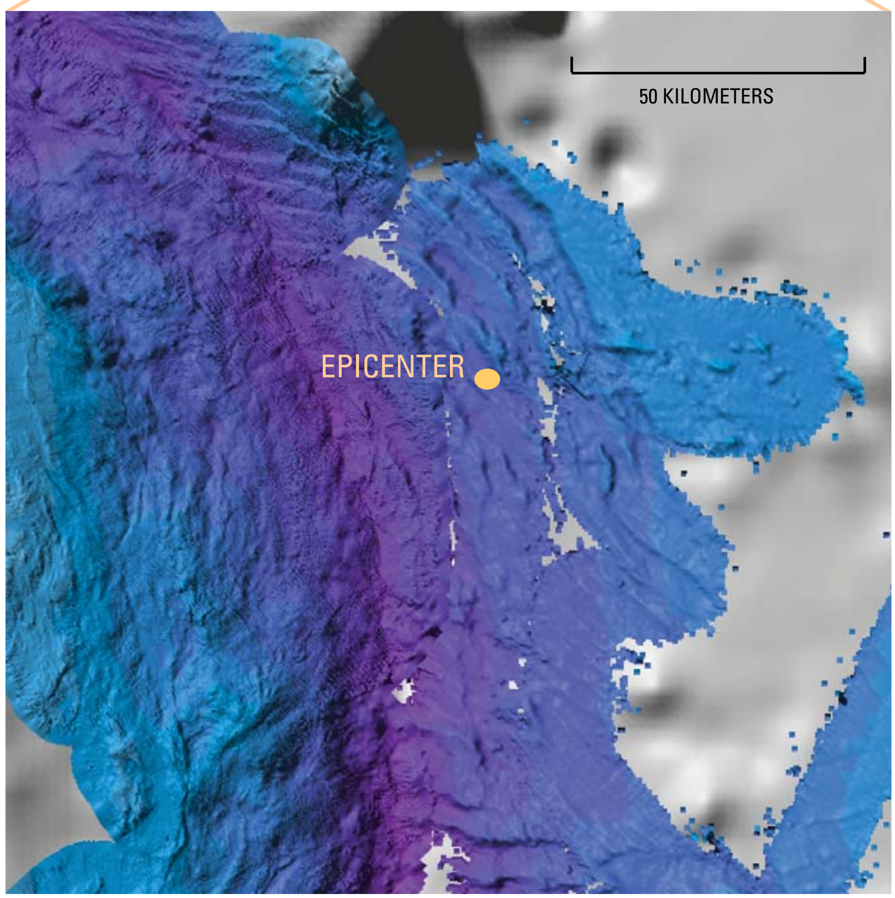
of descent and many normal faults near the trench. The 2009 Samoa earthquake occurred east of the Tonga trench, near the northern terminus of the Tonga volcanic arc, where the trench takes a sharp bend to the west (see map, previous page). Correspondingly, normal faults in the outer-rise and trench slope change orientation from northeast-southwest trends near the main part of the Tonga trench to east-west trends near the east-west-trending part of the Tonga trench. The fact that the normal faults are nearly parallel to the trench suggests that the faults occur primarily in response to bending stresses in the oceanic plate. These and other tectonic characteristics in outer-rise regions where great earthquakes occur are also found in many other subduction zones in the western Pacific and northeastern Indian Oceans.

When a fault ruptures beneath the seafloor, the rocks surrounding the fault are permanently uplifted in some areas and downdropped in others, with the ocean going along for the ride to generate the tsunami (see “Life of a Tsunami,” panel 1, at **http://walrus.wr.usgs.gov/tsunami/basics.html**). Rupture of an interplate thrust at a subduction zone typically occurs below a substantial thickness of sediment, and the rupture does not reach the seafloor (see subduction-zone diagram, previous page). In contrast, outer-rise normal faults typically rupture brittle oceanic basalt in a region that has very little sediment cover, and so the rupture commonly reaches the seafloor. For this reason, it is likely that the fault that ruptured during the 2009 Samoa earthquake can be mapped using bathymetric techniques.

Particularly detailed images of the seafloor can be obtained using multibeam mapping systems, which send out a fan of sound energy and then record sound reflected from the seafloor through a set of narrow receivers aimed at different angles. **Dawn Wright** (professor of geography and oceanography at Oregon State University) and colleagues conducted a multibeam survey of the Tonga trench in 1996 that includes images of the seafloor near the epicenter of the September 29, 2009, earthquake (**http://dusk.geo.orst.edu/tonga**). In a map created from their data and data collected by Scripps Institution of Oceanography, several prominent, curved normal faults are visible entering the trench at an oblique angle where the trench curves around the northern Tonga arc (see map of multibeam bathymetry, below). The orientation of these faults is similar to the faulting geometry of the September 29 earthquake as determined from analysis of seismic waveforms (see “Scientific and Technical” tab on the NEIC event page **http://earthquake.usgs.gov/eqcenter/recenteqsww/Quakes/us2009mdbi.php**), and it may well be one of these faults that ruptured during the

(Outer-Rise Earthquakes continued on page 16)



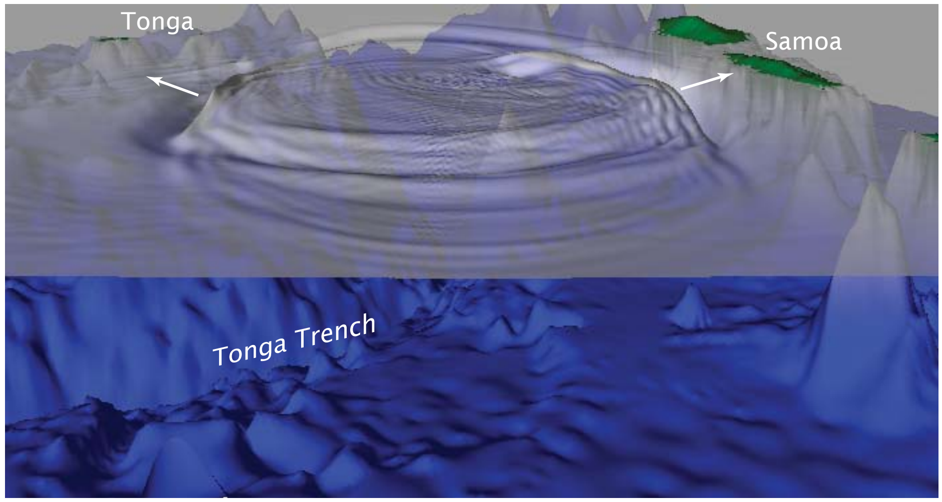


Multibeam bathymetric map of the Tonga trench near the September 29, 2009, earthquake epicenter. Detailed shaded-relief bathymetry (in shades of blue and purple) generated from multibeam data available from the National Geophysical Data Center (NGDC, survey KIWI11RR, chief scientist ***Nancy Kanjorski****) and Oregon State University (****Dawn Wright****); lower resolution bathymetry (in shades of gray) generated from ETOPO-1 bathymetric data available from NGDC. Curved ridges above the word “EPICENTER” are interpreted as normal-fault scarps. Depths in this view range from approximately 5 km below sea level (light blue) to 8 km below sea level (reddish purple).*

(Outer-Rise Earthquakes continued from page 15)

recent earthquake. Preliminary analysis by **Gavin Hayes** (NEIC) of how much the fault slipped during the September 29 earthquake indicates that there was a large amount of slip (as much as 14 m) near the seafloor on a steeply dipping rupture, further suggesting that the earthquake may have produced a mappable step, or scarp, where the ruptured fault intersects the seafloor. New mapping data from this area could be compared with existing multibeam bathymetry to look for a seafloor scarp produced by the September 29 fault rupture.

Many of the aforementioned characteristics of outer-rise earthquakes can explain why the tsunami was so large. The maximum fault slip for this earthquake (approximately 14 m) is much higher than for an interplate thrust earthquake of comparable magnitude (typically 3-8 m). Greater slip translates into greater vertical movement of the seafloor, affecting the entire ocean above the rupture zone. Moreover, tsunami generation by this outer-rise earthquake occurred in much deeper water than the more typical tsunami generation above an interplate-thrust earthquake (see subduction-zone diagram, page 14). When a tsunami travels from deep water to shallow water, the speed of the wave crest or trough slows, the wavelength decreases, and the amplitude (and wave height) increases. This process is sometimes referred to as "shoaling amplification" (see "Life of a Tsunami," panel 3, at **http://walrus.wr.usgs.gov/tsunami/basics.html**). A tsunami that starts off in deeper water will be more amplified by the time it reaches shore than a comparable tsunami that starts off in shallower water. Preliminary field-survey data indicate that the tsunami runups (height above mean sea level) in American Samoa reached more than 15 m, which is higher than for most tsunamis generated by magnitude 8.1 earthquakes on the interplate thrust (typically 2-10 m).



Snapshot of simulated tsunami waves approximately 7 minutes after they were triggered by the September 29 earthquake. View northwestward. To make subtle features easily visible, vertical scales of seafloor and waves are exaggerated with respect to horizontal scale; thus waves and seafloor features look much steeper than they really are. Scale of waves is also exaggerated with respect to topography; for reference, the height of the waves in this view is about 3.5 m. Depth of Tonga trench is about 7,000 m. Excerpted from a computer animation posted at ***http://walrus.wr.usgs.gov/tsunami/samoa09/****.*

For additional information, including animations of the generation and propagation of the September 29 tsunami, visit **http://walrus.wr.usgs.gov/tsunami/samoa09/**.

It is hoped that continued research on the nature and occurrence of outer-rise earthquakes around the world will help identify potential sites for future outer-rise earthquakes of this size and help mitigate the tsunami hazard associated with such rare but devastating events.

Saving Sand: South Carolina Beaches Become a Model for Preservation

By Diane Noserale

While most people head to Myrtle Beach for vacation, a group of scientists have been hitting the famous South Carolina beach for years to figure out how to keep the sand from washing away.

Although they studied only a limited segment of beach, their work is a model for beach preservation that can apply elsewhere. And with talk of "balancing the sand budget" and money saved on restoration, their findings sound financial.

"Effective beach preservation requires knowing the beach's sand budget and understanding the geology that constrains it," said U.S. Geological Survey (USGS) lead scientist **Walter Barnhardt**. "It takes a systematic approach and strong partnerships at all levels of government with neighborhood associations and universities to keep a beach from simply washing away."

The main objective of this 7-year study, done in cooperation with the South Carolina Sea Grant Consortium, was to improve projections of coastal change by determining the geologic features and ocean processes that control sediment movement along the coast.

"As a result of this work, we were able to identify offshore sand sources that could be used for future beach replenishment without causing a bigger erosion problem elsewhere," said **Barnhardt**.

Controlling beach erosion will likely become more difficult as a result of climate change, with its attendant sea-level rise and increase in the number and intensity of storms. This is particularly true

(Saving Sand continued on page 17)

(Saving Sand continued from page 16)

in places like South Carolina that have a broad, low-elevation coast and a sand shortage.

"The comprehensive nature of this study—considering the geologic framework, behavior, and driving processes regionally—has resulted in a remarkable baseline for better managing our beach and nearshore resources," said **Paul Gayes**, Director of Coastal Carolina University's Center for Marine and Wetland Studies.

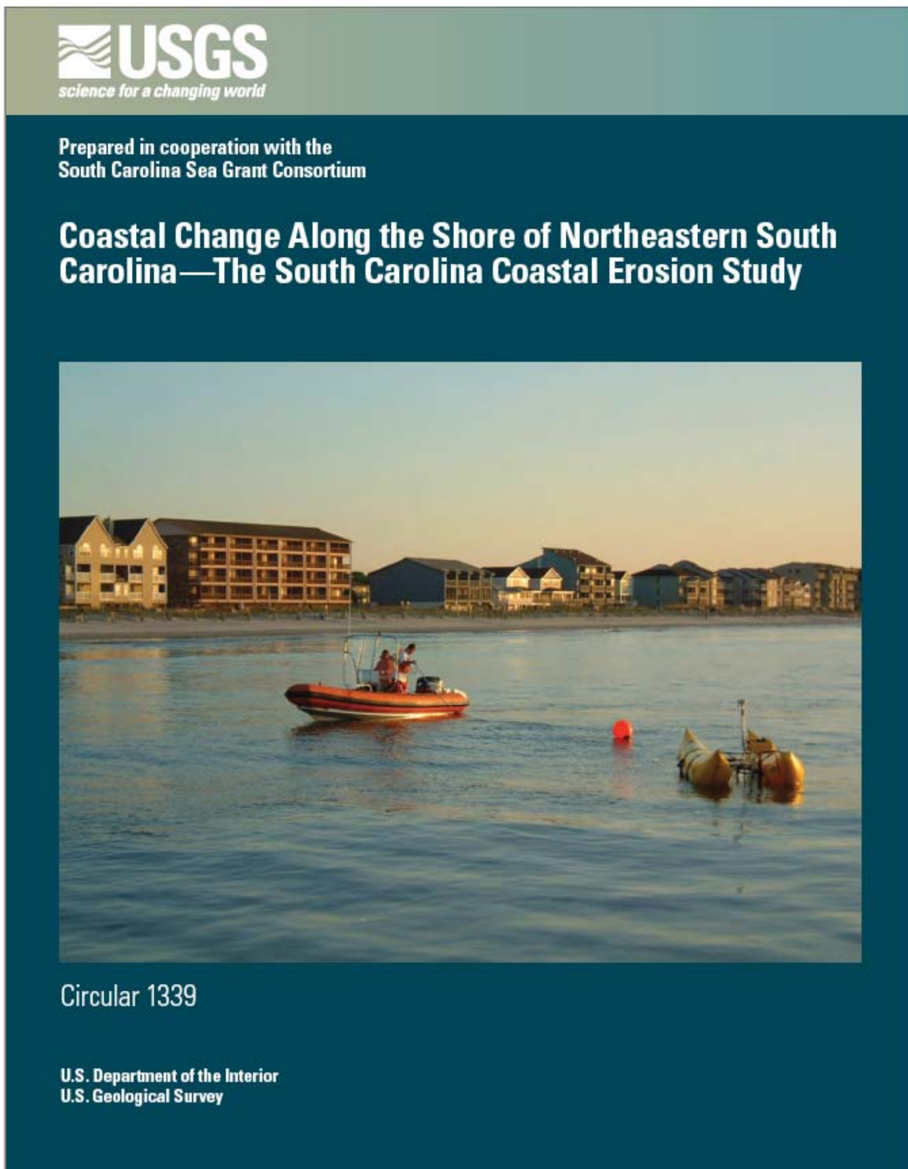
"From inventory of potential future beach-nourishment sand resources, to distribution of important hardbottom fish habitat, to models of beach behavior, this study forms the starting point for many present and future efforts. This work is regularly cited as a model approach and result for similar studies and efforts around the country," said **Gaye**s.

For this study, scientists examined land and marine environments in a 62-mi-long segment of South Carolina's coast. The swath extends more than 3 mi inland and 6 mi seaward. They tracked waves and sand movement, drilled cores, mapped the topography and geology onshore and offshore, and monitored coastal change.

Key Findings:

- Sand is a scarce resource near Myrtle Beach
  - The beaches are thin ribbons of sand that sit on top of sedimentary rocks. They receive little or no sand from nearby rivers.
  - Offshore, there is little sand to wash ashore and replenish the beach. Large expanses offshore are exposed as hardgrounds that are locally overlain by sand less than 3 ft thick.
- Sand is transported primarily from northeast to southwest in the area. Large sand deposits have accumulated seaward of Murrell's Inlet and Winyah Bay, South Carolina. These and other sand deposits could serve as offshore sources of beach nourishment in the future.
- Effective beach management requires a regional, systematic effort to
  - understand the geology and how it constrains sand supplies and sand movement,
  - determine patterns of shoreline change by surveying beaches at regular intervals over several years, and
  - identify ocean processes that drive coastal erosion.
- A detailed record of coastal change provides guidance for land use and a rationale for development decisions, such as determining setbacks necessary to protect property.
- Climate change will affect many beaches; the impacts will extend farther inland in low-lying coastal areas, such as those that are common on the U.S. Atlantic and Gulf coasts.

The study has been reported in a new publication, *Coastal Change Along the Coast of Northeastern South Carolina—The South Carolina Coastal Erosion Study* (USGS Circular 1339), available online at **http://pubs.usgs.gov/circ/circ1339/**. Printed copies are available from the online USGS Store at **http://store.usgs.gov/** (Product #222905).



Cover of new USGS Circular on South Carolina Coastal Erosion Study.

Flat Isabel Goes on a Research Cruise

By Christina Kellogg

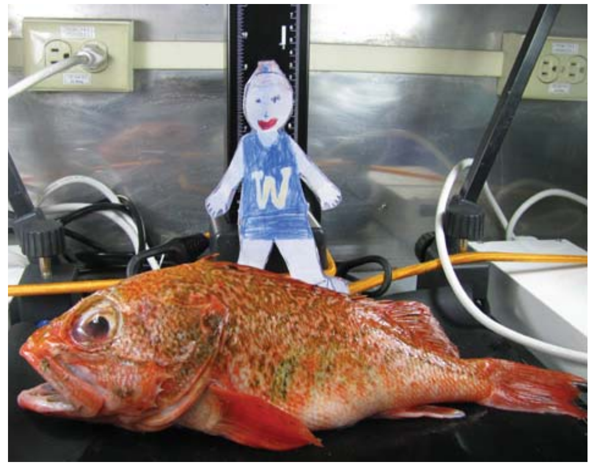
My scientific colleagues were understandably curious about why I seemed to be playing with paper dolls (in addition to isolating bacteria from deep-sea corals and invertebrates). Admittedly, it was a bit out of character for me. But, then, this wasn't just any paper doll. It was Flat Isabel, and she was my special guest on a deep-sea research cruise in the Gulf of Mexico.

Flat Isabel is a friend of Flat Stanley. Flat Stanley is the title character of a children's book and has become the basis of a popular school project that promotes literacy, writing skills, and "connectivity" between students and new people, places, and activities. **Dale Hubert**, a grade-school teacher in Canada, started the Flat Stanley Project in 1995 (**http://www.flatstanley.com/**). There are variations on the project, but usually the class reads the book and then they make paper Flat Stanleys (or flat versions of themselves). These figures are then mailed to other people, who are asked to treat the figures like visiting guests. The hosts typically take photographs of the paper doll with local landmarks or participating in interesting activities and then return the doll with the photos and sometimes maps, postcards, or other souvenirs. The students then get to learn about all the places their various "flat friends" have visited. It is particularly appropriate for Flat Isabel to go to sea with us this year, since the Flat Stanley Project has declared 2009 "The Year of Science" and, in collaboration with the Coalition on the Public Understanding of Science (**http://www.copusproject.org/**), is inviting students and teachers to send Flat Stanley on scientific adventures of all kinds.

Nine-year-old **Isabel Castro** of Alpharetta, Georgia, sent Flat Isabel on this research cruise, which was part of the DISCOVRE program (Diversity, Systematics, and Connectivity of Vulnerable Reef Ecosystems, **http://fl.biology.usgs.gov/DISCOVRE/**). Like her maker, Flat Isabel is a cheerleader and kept the scientists' morale up during their 12-hour shifts. She toured the research vessel *Seward Johnson*, supervised loading of sampling gear onto the *Johnson-Sea-Link* submersible, and participated in the sorting and photographing of deep-sea animals we've collected, including fish, a variety of crabs, and corals. Of course, it wasn't all work and no play! When Flat Isabel wasn't on a duty watch, she had the same options to relax that the science team had—go on deck and get a little sun, read a book from the ship's library, work out on the treadmill or stationary bike, watch a movie in the lounge, or catch up on sleep before the next 12-hour shift!

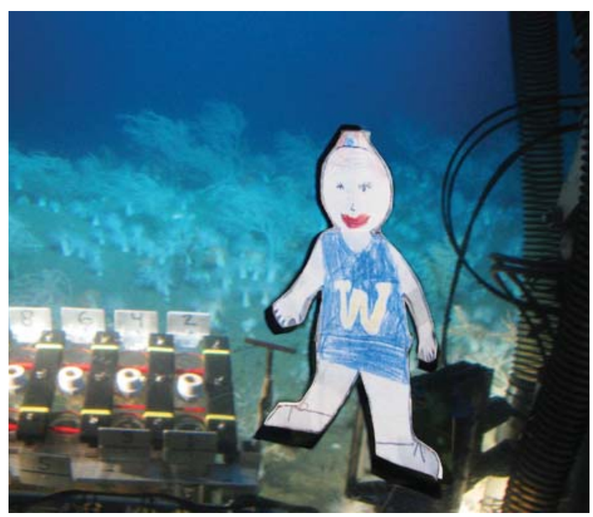
September 20 was a big day for Flat Isabel (and me)! It was finally our turn to dive with the submersible. We visited a site called Viosca Knoll (VK862) and collected some *Lophelia* coral for my microbial ecology study. I sampled the very same coral mounds in 2004, so this was a rare opportunity to look at anything that might have changed in the past 5 years. Flat Isabel had a 180-degree view of the ocean floor from the front acrylic sphere of the submersible. I'm betting she's the only one in her class to visit the bottom of the Gulf of Mexico (1,000 feet deep)!

To learn more about the project Flat Isabel assisted us with, read the USGS Fact Sheet *Gulf of Mexico Deep-Sea Coral Ecosystem Studies, 2008–2011* at **http://pubs.usgs.gov/fs/2009/3094/**. Also see "Scientists Cruise Deep into Coral Ecosystems" in the Fieldwork section of this issue (**http://soundwaves.usgs.gov/2009/12/fieldwork2.html**). ☸



Flat Isabel with a black-bellied rosefish.

Christina Kellogg *(right) and Flat Isabel with senior submersible pilot* ***Craig Caddigan****, immediately pre-dive.*



Flat Isabel visits the bottom of the Gulf of Mexico in the Johnson-Sea-Link *submersible.*

Awards

USGS Employees in Louisiana Garner Awards

By Gabrielle Bodin

Several employees at the U.S. Geological Survey (USGS)'s National Wetlands Research Center and the USGS Lafayette Publishing Service Center have recently received national, regional, and local awards recognizing their contributions.

Research Center Director **Janine Powell** received the 2009 Eugene M. Shoemaker Communication Award for her work on the "USGS Managers Meeting Suite of Communication Products." **Powell** and her team developed several products designed to make a managers' meeting accessible to all USGS employees nationwide by online posting of videos and presentations of key sessions, session summaries, and daily podcasts and blogs during the meeting.

USGS National Wetlands Research Center and Lafayette Publishing Service Center employees who recently received awards (left to right): ***Karen L. McKee, Janine Powell, Wayne Wiltz, Beth Vairin,*** *and* ***Christina Boudreaux****.*

Research Center scientist **Karen L. McKee** received the USGS Central Region Diversity Award in the individual category for her support of women in science. Besides her years of guiding young scientists at the center, she co-founded and serves as trustee for a private foundation that supports and mentors young scientists. She also founded a new section in the Society of Wetland Scientists, "Women in Wetlands," designed to aid the advancement of women in wetland ecology.

Beth Vairin, Chief of the Publishing Service Center based at the National Wetlands Research Center, was awarded the Department of the Interior's Superior Service Award for her commitment to producing high-quality publications, cultivating creative partnerships, and displaying leadership in creating publishing standards that have improved efficiency and quality on a regional and national level. **Vairin** also continues to design and present training for USGS authors throughout the nation.

Research Center computer engineer **Wayne Wiltz** received the Center's Exemplary Service Award, which honors employees who perform above and beyond the normal call of duty. **Wiltz** is responsible for voice and access control systems for the Center and the adjacent Estuarine Habitats and Coastal Fisheries Center. He was recognized for having spent many nights and weekends repairing phone, surveillance, or access systems damaged by lightning or other natural or manmade disasters. He has also helped several other USGS facilities with phone issues.

Christina Boudreaux, visual information specialist with the Publishing Service Center, received the Research Center's Leading From Any Chair Award for exhibiting leadership and management skills. For some publishing projects, she played the role of moderator, technical expert, creative consultant, printing specialist, and trouble-shooter for computer hardware and software. ☸

Staff and Center News

New Director of USGS Woods Hole Science Center

By Dave Grason, USGS Deputy Regional Executive for the Northeast Area

I am pleased to announce that **Walter Barnhardt** has become the new director of the U.S. Geological Survey (USGS) Woods Hole Coastal and Marine Science Center in Woods Hole, Massachusetts.

Walter received his bachelor's degree in geology from the College of William and Mary in 1984. After 2 years in the Peace Corps in Costa Rica, he attended the University of Maine, where he received an M.S. (1992) and a Ph.D. (1994) in geology. **Walter** conducted postdoctoral research at the University of Maine (1994-96) and with the USGS in Menlo Park, California (1996-2001). He spent 3 years as an assistant professor of geology at the University of North Carolina at Chapel Hill before coming to the USGS Woods Hole Science Center in 2004.

Walter is a marine geologist and sedimentologist, investigating the causes of coastal erosion, the effects of dam removal on sediment transport, and the processes controlling sediment deposition in the coastal ocean. He has an extensive bibliography that includes publications on seafloor geologic mapping, coastal hazards, and the impacts of relative sea-level change on the evolution of continental margins. He has served as chief scientist or co-chief scientist on more than 30 research cruises off the Atlantic, Pacific, and Great Lakes coasts. He lives in East Falmouth on Cape Cod and began his new duties on November 2, 2009.

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At this time, USGS Northeast Regional Executive **Dave Russ** and I want to express our gratitude to outgoing director **Bill Schwab** for his outstanding technical and managerial leadership of the USGS Woods Hole Science Center since 2003 (see related *Sound Waves* article at **http://soundwaves.usgs.gov/2002/06/staff2.html**). **Bill** is turning over the direction of an exceptional program of world-class USGS coastal and marine scientific studies at Woods Hole as he returns to devote himself once again full-time to hands-on science. We would like to thank **Bill** for his able management of the center and wish him continued success in his scientific career.

*Back in port after a couple of weeks mapping the seafloor off Massachusetts, **Walter Barnhardt** gives his daughter a tour of the research vessel* Megan Miller *(June 2009). (Read a* Sound Waves *story about the cruise at **http://soundwaves.usgs.gov/2009/09/fieldwork3.html**.)*

*Scientists at play (right to left): **Walter Barnhardt** and colleagues **Neal Driscoll** (Scripps Institution of Oceanography), **Bill Schwab**, and **Wayne Baldwin** (USGS, Woods Hole) celebrate another come-from-behind victory by the New England Patriots at the San Diego Chargers' stadium (January 2007).*

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