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Sound Waves

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Fieldwork

Palos Verdes Shelf Experiment: What Will Happen to the Contaminated Mud?

By Christopher R. Sherwood

Let's say there's a pile of mud that's been accumulating on a continental shelf since the Marx Brothers made *A Day at the Races* in 1937. Then let's turn off the main source of sediment for that deposit. Will it erode?

This is the deceptively simple question that U.S. Geological Survey (USGS) scientists must answer at the Superfund site on the shelf off the Palos Verdes Peninsula in southern California. The pile of mud is an effluent-affected deposit containing material discharged from the Los Angeles County Sanitation District's outfalls off Whites Point.

In addition to sewage associated with fine sediment, the outfalls once discharged DDT, PCBs, and other pollutants. In 1971, the DDT-manufacturing plant was disconnected from the treatment system, and in the following years the effluent stream and discharged sediment became progressively less contaminated. By 2005, all of the effluent was receiving advanced secondary treatment, and the discharged fluid is now almost devoid of sediment; it has an average solids concentration of 17 mg/L, not all of which sinks.

The sedimentary deposit off the Palos Verdes Peninsula now has two layers: a bottom layer that contains material deposited before 1970 and is contaminated with some of the highest levels of DDT measured in open marine environments (more than 250 ppm), and an overlying, cleaner layer that insulates the bottom layer from the pelagic environment. The main part of the deposit lies along the 60-m isobath and is less than 1 m thick; the relatively clean upper layer is 20 to 30 cm thick. All of this sediment is stiff, gray, silty to sandy mud, and, except for a fluffy layer on top, it is difficult to erode. The question we hope to answer is: Will the cleaner upper layer continue to sequester the pollutants, or will it gradually erode and eventually allow the release of buried DDT and PCBs?

***Joanne Ferreira** is pleased to see the tripod she deployed on the Palos Verdes shelf 5 months earlier. Note the sediment trap (elongate cone on right side of tripod), upward-looking acoustic Doppler current meter (upright cylinder in steel cage), and three-pronged acoustic Doppler velocimeter (rear center of tripod). Photograph by **Bénédicte Ferré**.*

► *Scripps Institution of Oceanography's research vessel* Robert Gordon Sproul. *Photograph by **Chris Sherwood**.*

The USGS has been involved in Palos Verdes shelf studies since 1990, when the U.S. Department of Justice, plus the National Oceanic and Atmospheric Administration (NOAA) and the other Natural Resource Trustees, asked USGS scientists to determine the fate of the contaminated deposit and enlisted them as experts in a Federal suit against the manufacturers of the DDT. The legal battle led to some excellent science on both sides. The USGS mapped the Palos Verdes shelf in 1992; conducted measurements of waves, currents, and sediment transport; and modeled the evolution of the deposit. Scientists

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Sound Waves

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Fieldwork, continued

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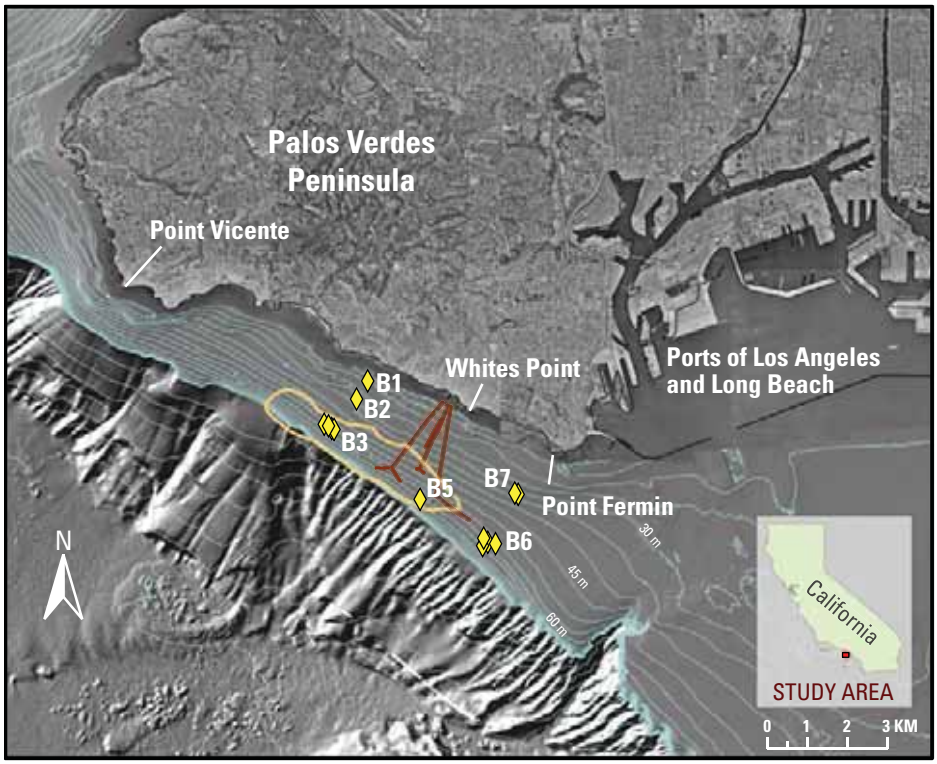
hired by the defendants made groundbreaking measurements of DDT degradation, proving that DDE (a degradation product of DDT and the most common DDT-related component) can lose chlorine during in-place transformation to DDMU in Palos Verdes shelf sediment. (DDMU is another breakdown product that may pose a lesser risk of accumulation in the food chain.) In the end, the plaintiffs won a consent decree in 2000, and a settlement of $136 million was divided among the Trustees and the U.S. Environmental Protection Agency (EPA) to be put toward a remedy. In the meantime, the Palos Verdes shelf off Whites Point was placed on the Superfund National Priorities List, and the EPA is now responsible for determining whether to try to somehow clean up or cap the deposit, or monitor it and spend remediation money elsewhere.

Although the legal issues were settled, the fundamental question concerning the fate of the DDT was left unanswered. Earlier studies found that bioturbation (mixing of sediment by mollusks, worms, and shrimp) and wave-induced sediment resuspension (lifting of sediment back into the water) were key to the fate of sediment and DDT on the Palos Verdes shelf (see *Sound Waves*, July 2002, URL **http://soundwaves.usgs.gov/2002/07/pubs.html**). DDT was being (1) mined from deeper sediments by burrowing fauna, (2) resuspended by strong wave events, (3) desorbed from sediment during resuspension events, (4) transported from the shelf with sediment, and (5) transformed in place. Measurements indicated that waves and currents were uniform over much of the shelf, and erosion

(Palos Verdes Experiment continued on page 3)



*Study area on the Palos Verdes shelf encompassing 6 sites (B1-B7), with 13 platforms (yellow diamonds) housing oceanographic instrumentation. Three of the sites had been occupied in 2004, one of which was a Geoprobe site in 1992. Sea-floor image from USGS multibeam bathymetry; aerial photographs from the California Spatial Information Library (URL **http://gis.ca.gov/**). Light-orange line, outline of sea-floor area with higher DDT concentrations; red-brown lines, Los Angeles County Sanitation District outfall pipes. Ocean-floor contours in 5-m increments from 5- to 100-m depth and in100-m increments below 100-m depth. National Data Buoy Center station 46222 is just below bottom of map, about 8 km south of station B5.*

(Palos Verdes Experiment continued from page 2)

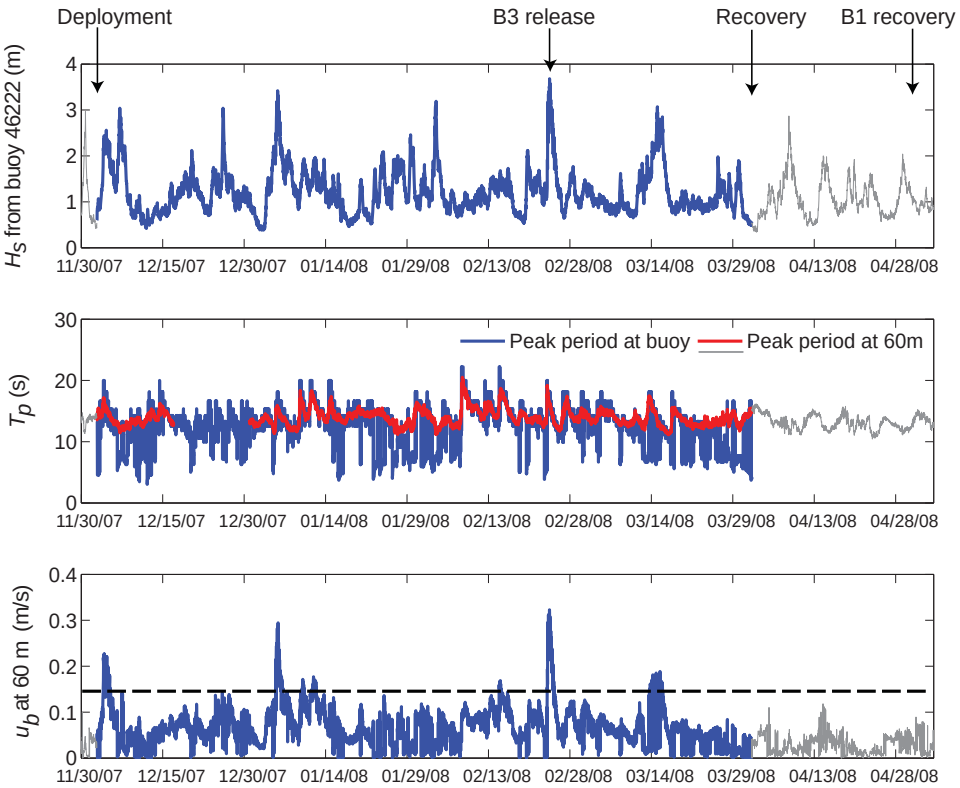
and deposition patterns were believed to depend on subtle changes in bed sediment. In particular, we worried that the southeast edge of the deposit was eroding.

The EPA provided funding for fieldwork by Science Applications International Corporation (SAIC), the USGS, and others in 2004 to map the geotechnical properties of the deposit, evaluate erodibility and bioturbation, and conduct measurements in the bottom boundary layer (the layer of water just above the sea floor that is particularly important for moving sediment). In addition, USGS scientists **Marlene Noble**, **Jingping Xu**, and **Kurt Rosenberger** analyzed a valuable series of current-meter measurements (now extending to nearly 6 years at 13 sites on the Palos Verdes and San Pedro shelves) made by the Los Angeles County Sanitation Districts. These analyses indicate that internal bores (solitary waves traveling on density interfaces) associated with internal tides cause persistent near-bottom flows that are sometimes strong enough to erode and transport sediment, but our understanding of what controls the timing and distribution of these events is sketchy. The bottom-boundary-layer measurements from the 2004 field program were disappointing: it was a very calm year, and only one tepid sediment-resuspension event occurred while the instruments were in the water.

This past winter (2007-08), the EPA supported a more ambitious program to measure bottom-boundary-layer processes that affect transport of sediment and contaminants on the Palos Verdes shelf. The objectives of this field program were to measure (1) bottom stresses and suspended-sediment concentrations in order to determine thresholds for erosion and the transport rates for sediment along the 60-m isobath (with instrumented tripods that sit on the seabed), (2) internal-wave motions at several alongshore and cross-shelf sites (with moored temperature arrays and current profilers), and (3) temporal changes in sediment erodibility (with erosion-chamber measurements).

The instruments were deployed in early December 2007 from the Scripps Institution of Oceanography's research vessel

(Palos Verdes Experiment continued on page 4)



*Waves during the Palos Verdes experiment. Top panel, significant wave height (H_s) at the San Pedro Channel Waverider Buoy (National Data Buoy Center station 46222; URL **http://www.ndbc.noaa.gov/station_page.php?station=46222**); middle panel, peak wave periods (T_p) measured at the buoy (blue) and calculated for 60-m depth (red); bottom panel, near-bottom wave-orbital velocity (u_b) at 60-m depth, calculated from buoy data. Dashed line, approximate threshold for resuspension of Palos Verdes sediment (0.14 m/s). The following times are indicated by arrows in the top panel: Deployment of all instruments in December, early release of the subsurface float at site B3, recovery of most instruments in late April, and recovery of last instrument at site B1 in early May.*

*Waves break south of Whites Point and resuspend sediment as the giant swells of late February subside. Photograph by **Chris Sherwood**.*

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*Plastic sheets that slowly absorbed PCBs from surrounding water were deployed during the Palos Verdes experiment for collaborators from the EPA and University of Rhode Island. Photograph by **Chris Sherwood**.*

◄ *Rigging a tripod for deployment on the Palos Verdes shelf on a calm day in early December 2007. Photograph by **Joanne Ferreira**.*

***Marlene Noble** and **Chris Sherwood** ponder their notes during the Palos Verdes mooring recovery in May. Photograph by **Brandy Armstrong**.*

Robert Gordon Sproul. A total of 13 moorings were deployed at six sites, supporting 65 instruments with data loggers recording an uncounted number of individual sensors. The somewhat lengthy saga of recovering all of these instruments began in February 2008 and was completed in early May (see "Palos Verdes Shelf Program: Whatever *Can* Go Wrong…," this issue).

During the deployment cruise, Professor **Pat Wiberg** (University of Virginia) made erodibility measurements on the (nearly) pristine tops of cores obtained with **Mike Bothner's** hydraulically damped gravity corer (URL **http://www.whoi.edu/page.do?cid=11258&pid=8415&tid=282**). Those measurements, which were repeated in February and May, may reveal temporal changes in erodibility.

In addition to all the fancy electronics, we also deployed passive PCB samplers for researchers **Robert Burgess** (EPA's Atlantic Ecology Division Laboratory in Narragansett, Rhode Island) and **Rainer Lohmann** (University of Rhode Island). To the untrained eye, the PCB samplers look like little sheets of plastic. They are. But their ability to absorb hydrophobic contaminants like PCBs has been carefully characterized, and attached to various parts of our moorings, they acted as long-term samplers.

Luckily for the experiment, 2007-08 was an eventful winter, as most Californians can attest. Three of the largest wave events we have measured at the seabed off the Palos Verdes Peninsula occurred during the deployment, and preliminary examination of the data shows significant resuspension and transport of sediment. We hope this experiment helps us understand the role of internal waves and provides data that will constrain our sediment-transport models and ultimately help us answer the question: Will the mud move or stay there?

Carmen White is site manager for EPA Region 9 (Pacific Southwest). Principal investigators on the USGS Palos Verdes shelf experiment are **Marlene Noble**, **Jingping Xu**, and **Kurt Rosenberger** of the USGS Western Coastal and Marine Geology Team (WCMG) in Santa Cruz and Menlo Park, California, and **Chris Sherwood** of the USGS Woods Hole Science Center (WHSC) in Woods Hole, Massachusetts. Credit for instrument and cruise preparation and data processing goes to **Marinna Martini**, **Jon Borden**, **Ellyn Montgomery**, **Rick Rendigs**, and **Chris Sabens** of WHSC and **Joanne Ferreira**, **Dave Gonzales**, **Hal Williams**, **Kevin O'Toole**, and **Jamie Grover** of WCMG. **Bénédicte Ferré** and **Brandy Armstrong** (WHSC) helped out on the recovery cruise, and **Maarten Buijsman**, **Eileen Idica**, and **Sam Wilson** (volunteers from University of California, Los Angeles) helped with erodibility measurements in the lab.❁

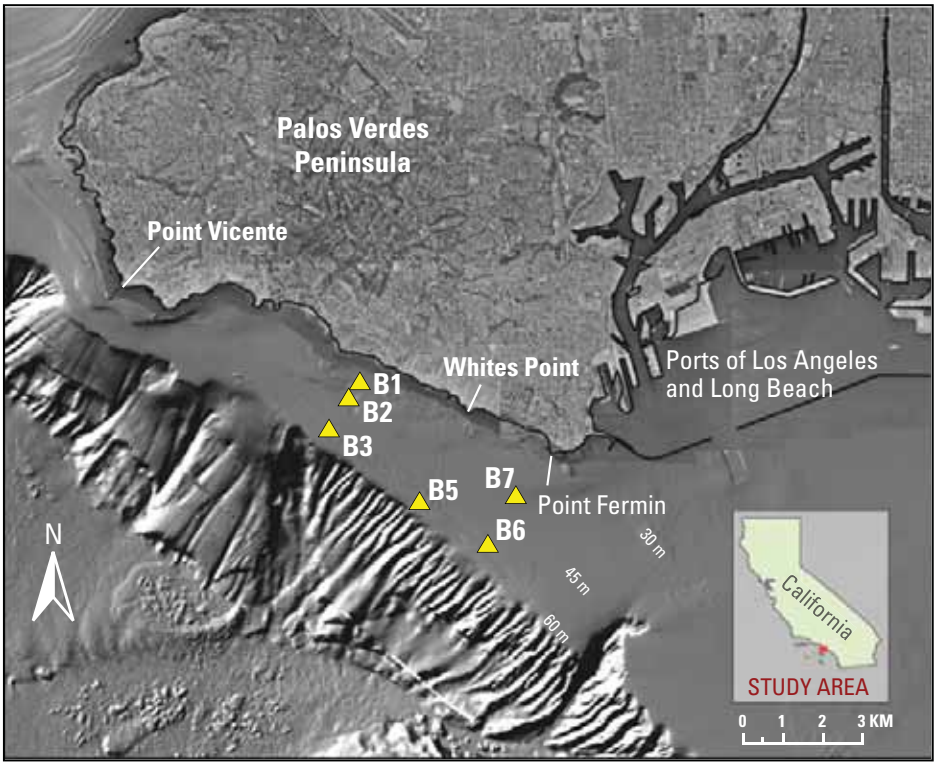
Palos Verdes Shelf Experiment: Whatever *Can* Go Wrong…

By Kurt Rosenberger

"Murphy was an optimist…" read the poster of Murphy's law that hung in my older brother's room when we were growing up. I believe it should have said, "Murphy was an oceanographer…" because in oceanographic field programs, it seems that anything that can go wrong, will.

Of course, in any scientific field program, we do the best we can to have a backup plan, wait to see what Murphy will throw at us, and hope the backup plan works. However, when it comes to putting instrumentation on the ocean bottom in water deep enough that you can't send a diver to rescue your equipment, but shallow enough that the instruments are affected by waves, strong tides, marine growth, and more, you need to have a *couple* of backup plans. Invariably, things go wrong that are beyond your control, and as a result, there are lots of lost instruments in the ocean.

And so we responded with cautious optimism when **Carmen White** of the U.S. Environmental Protection Agency (EPA) Region 9 office in San Francisco, California, recently approached the U.S. Geological Survey (USGS) Coastal and Marine Geology Program to design and carry out an extensive oceanographic experiment on the continental shelf off the Palos Verdes Peninsula in southern California. The experiment would include measuring such parameters as current velocity, water temperature, salinity, and suspended-sediment concentration in the bottom boundary layer (the water near the sea floor) and the water column (from the bottom boundary layer to the surface) over a whole winter season. The USGS had carried out successful field programs on the Palos Verdes shelf in 1992 and 2004, but certainly not without difficulty. We always love a challenge though, and in early December 2007 a team of USGS scientists and marine technicians from the USGS Western Coastal and Marine Geology Team in Santa Cruz and Menlo Park, California, and the USGS Woods Hole Science Center in Woods Hole, Massachusetts, embarked on another ambitious field effort (see "Palos Verdes Shelf Experiment: What Will Happen to the Contaminated Mud?", this issue).



*Study area on the Palos Verdes shelf encompassing 6 sites (yellow triangles), with 13 platforms housing oceanographic instrumentation. Three of the sites had been occupied in 2004; however, we had access to more complex instrumentation in 2007-08. Sea-floor image from USGS multibeam bathymetry; aerial photographs from the California Spatial Information Library (URL **http://gis.ca.gov/**). See more detailed map in "Palos Verdes Shelf Experiment: What Will Happen to the Contaminated Mud?"(this issue).*

Oceanographic equipment tends to be large and complex, to strike a balance between gathering as much data as possible and withstanding the rigors of the ocean environment. Three of the tripods we deployed, for example, are over 3 m tall; each weighs more than 1,500 lb and houses 11 waterproof pressure cases just to hold batteries. Two of these tripods are the infamous "Geoprobe" tripods, originally designed in the late 1970s and modified over the years to accept the most state-of-the-art equipment. Geoprobes have been used to monitor sediment-resuspension processes in the bottom boundary layer of coastal waters all around the United States and even in Europe.

So, what's the backup plan to recover heavy tripods packed with instruments and deployed in 60-m water depth? First, you try to put two acoustic-release recovery systems on each tripod, so that if one fails, the other will still be able to release your lifeline, the recovery float. (The acoustic release responds to acoustic signals transmitted from a ship at the surface; see URL **http://www.dosits.org/gallery/tech/bt/ar1.htm**.) You also put an acoustic-ranging device on each tripod that can be interrogated from the surface, in case both of your acoustic releases fail and you need to go searching for the tripod. You *also* include a tilt sensor so that you know your tripod is sitting upright before you drive away for 4 months (otherwise you must recover and redeploy). If none of these systems works, then the last backup plan comes into play—our secret weapon, the remotely operated vehicle (ROV).

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For the Palos Verdes shelf experiment, we deployed tripods to collect data in the bottom boundary layer and moorings (instruments on a cable attached to an anchor at one end and a surface or subsurface buoy at the other) to collect data in the water column. Deployment went smoothly in December, and then… Murphy strikes the first time: after surviving 3 months of a particularly intense winter storm season, one Geoprobe had simply had enough; it decided to give up and send up the white flag (the recovery float), begging to be brought home. We saw the recovery float on the surface in late February, more than a month too early, during a mid-deployment coring cruise. Apparently, the wave action at 60-m depth was enough to work the release mechanism loose and let the ball go. It was extraordinarily lucky that we happened to be there and were able to recover the tripod by using the research vessel (R/V) *Sea Watch* out of the Southern California Marine Institute (SCMI; see URL **http://scmi.us**/).

After 5 months on the sea floor, and having been dragged and had a leg broken by a passing vessel, one of our low-profile tripods is back on deck.

Two other tripods deployed at the 60-m-depth sites were small, low-profile tripods designed to measure the current profile in the bottom boundary layer as close to the sea floor as possible. Because these tripods were low profile, they could support only one acoustic release, and so we decided to augment the release system by including a ground line leading from each tripod to a weight and a separate pickup float at the surface. If our acoustic release failed, we could recover the tripod using the pickup line. Murphy strikes the second time: though intended to assist us, the recovery floats merely attracted other vessels. Upon returning to the site in early April, we discovered that one float was missing and the other was hanging on by a thread. It turned out that both had been hit and dragged by passing vessels. One tripod had a broken leg; the other was flipped over.

A Geoprobe "hangs in the balance" off the stern of the R/V Sea Watch. *Because the recovery float released early, the recovery line got wrapped around the tripod on the bottom—this is one of the reasons why the tripods are built so strong!*

Murphy strikes a third time: one of the subsurface moorings decided not to come to the surface when we asked it to—the acoustic release transmitted a signal indicating that the recovery float had been released, and so by all accounts it should have come up, but it stayed on the bottom. We waited as long as we could, until dark, at which point we had to head off to another site. When we returned the next night, the mooring was still where we had left it. A few hours later, however, at dawn, when we planned to try again for recovery, the mooring was more than 2 km away. So we fired up the ship and went chasing after it. Because the ship had been drifting down the coast during the late night hours, we headed in that direction, stopping every half-kilometer or so to query the acoustic-ranging device to see whether we were getting closer to or farther from the runaway mooring.

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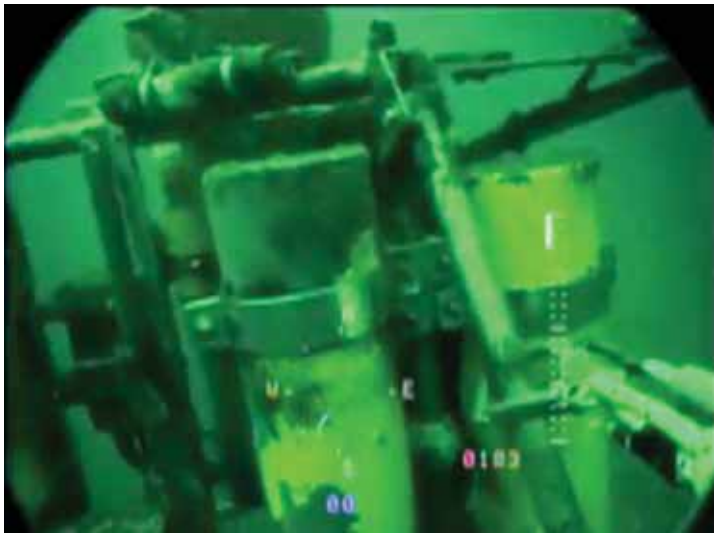
(Palos Verdes Recovery continued from page 6)



Tales from the deep: still image from video footage taken by an ROV as it hooked a recovery line onto a Geoprobe whose acoustic release had failed. (See short video clip at URL ***http://soundwaves.usgs.gov/2008/07/fieldwork2.html****.)*

We finally found it a few hundred meters from the main shipping channel to the Port of Los Angeles, one of the largest ports in the world. A container ship more than 500 ft long was bearing down on our little mooring, but we were able to save it in the nick of time.

Murphy's not done with us yet: logistics prevented us from putting a second acoustic release on one of the Geoprobes. Well, as Murphy would have it, that tripod, with just one acoustic release, decided not to talk to us at all. I guess it was feeling left behind, since we had picked up its companion tripod early. It was time for our final backup, the ROV. We returned to the site a few days later on a smaller, more maneuverable vessel, the SCMI R/V *Yellowfin*, and sent a helping hand down to our lost tripod. Luckily, the acoustic-ranging device, our second backup, worked as planned and enabled us to locate the tripod quickly. We used the ROV to hook a recovery line onto it and brought it back safely with all gear intact.

When you put expensive gear in the ocean for months at a time, problems are to be expected. Fishermen trawl through the site; things grow on and foul the release mechanisms; some instruments just fail. Given its complexity, the 2007-08 Palos Verdes shelf experiment was incredibly successful, thanks partly to the many backup-recovery plans but mainly to an extremely hardworking team, boasting more than 100 people-years of oceanographic experience: **Marinna Martini**, **Jonathan Borden**, **Rick Rendigs**, **Chris Sherwood**, **Christine Sabens**, **Ellyn Montgomery**, **Bénédicte Ferré**, and **Brandy Armstrong** of the USGS Woods Hole Science Center and **Joanne Ferreria**, **Marlene Noble**, **David Gonzales**, **Hal Williams**, **Kevin O'Toole**, **Jamie Grover**, and **Kurt Rosenberger** of the USGS Western Coastal and Marine Geology Team. Thanks are also due to the expert crews and support personnel for the recovery vessels provided by SCMI (R/V *Sea Watch* and R/V *Yellowfin*) and Scripps Institution of Oceanography (R/V *Robert Gordon Sproul*). With their invaluable help, we not only recovered all of our instruments but also recorded more than 15 gigabytes of oceanographic data. Now the fun really begins—trying to decode and analyze such an extensive data set!

With a deck loaded up with instruments, it's time to head home.

Gravity Coring Offshore Puerto Rico and the U.S. Virgin Islands to Investigate the Timing of Submarine Landslides and Large Earthquakes

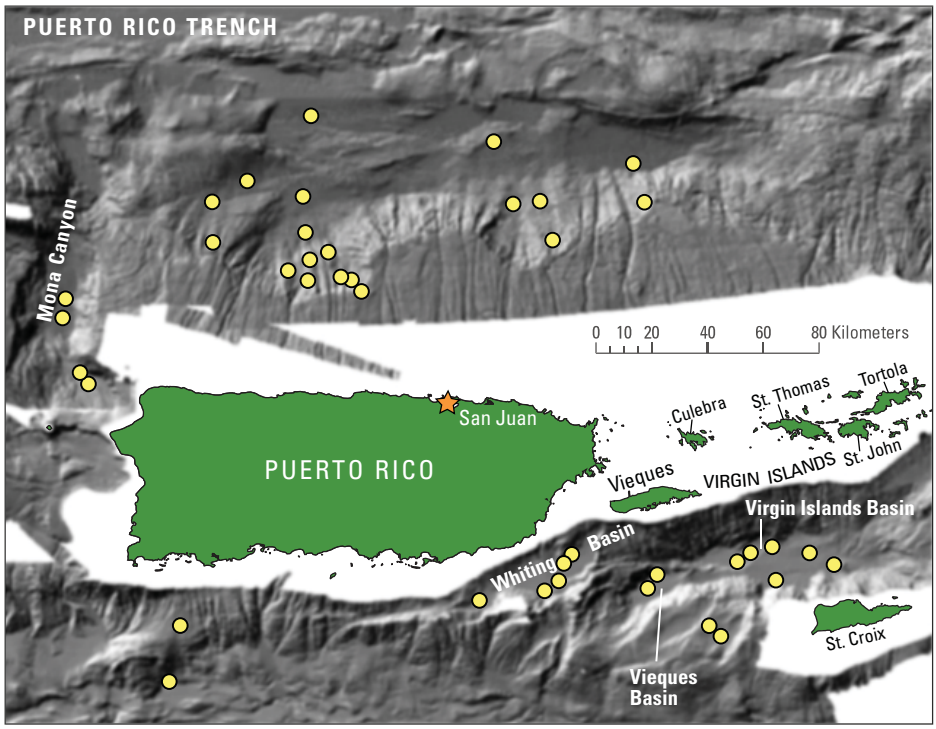
By Jason Chaytor and Uri ten Brink

Recent analysis of the destructive 1918 tsunami that devastated western Puerto Rico has shown that the tsunami was likely caused by a large (10-km^3 volume) earthquake-induced submarine landslide in the Mona Passage west of Puerto Rico. Many landslides have also been mapped along the edge of the submerged carbonate platform about 40 km seaward of the north shore of Puerto Rico. Volume analysis and hydrodynamic modeling indicate that at least eight of these submarine landslides could have caused damaging tsunamis; however, because the age of these landslides is unknown, their recurrence interval could not be estimated.

The goal of a recent USGS research cruise was to core and date submarine-landslide-related sediment north of Puerto Rico in order to determine the age of these landslides. Dating of these landslides is needed in order to calculate tsunami probability for the north coast of Puerto Rico. Another coring target of the cruise was the Virgin Islands Basin, the epicenter of the devastating 1867 earthquake and tsunami. There we focused on dating disturbances in the sedimentary layers caused by ground shaking, in hopes of extending the area's earthquake record backward in time. A long earthquake record is needed to adequately estimate the probability of additional earthquakes in the area in the near future.

Coring was carried out aboard the Harbor Branch Oceanographic Institution's research vessel (R/V) *Seward Johnson* (URL **http://www.hboi.edu/marineops/sj.html**) during a 9-day cruise from March 16 to 24, 2008, leaving from and returning to San Juan, Puerto Rico. Cores were collected with the Woods Hole Oceanographic Institution (WHOI)'s Giant Gravity Corer, a 4-in.-diameter pipe, suspended from a cable, that penetrates the sea floor under its own weight and can collect cores as long as 6.5 m (URL **http://www.whoi.edu/corelab/hardware/systems_giantgravity.html**). In this cruise, many of the coring sites were expected to have a relatively hard sandy bottom, which is difficult to penetrate, and so we rigged the corer for a maximum core length of only 3 m.

Caribbean region, showing approximate location of study area (shaded box).



Study area, showing locations of coring stations (yellow dots) occupied during the cruise. Stations north of Puerto Rico are within and at the base of landslide scarps and deposits; stations southeast of Puerto Rico are within basins that may hold evidence of earthquake shaking.

A total of 40 coring sites were occupied during the cruise—within Mona Canyon, on the south wall and floor of the Puerto Rico Trench, and in the Virgin Island, Vieques, and Whiting Basins south of the U.S. Virgin Islands—with site depths ranging from 1,350 m down to 8,000 m.

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(Puerto Rico Coring continued from page 8)

***Matt Arsenault** (USGS, left) and **Jim Broda** (WHOI) recover the Giant Gravity Corer aboard the R/V* Seward Johnson *after deployment of the corer into the Mona Canyon. Photograph by **Uri ten Brink** (USGS).*

***Emily Himmelstoss** (USGS, right), **Kate McMullen** (USGS, bottom), **Brian Buczkowski** (USGS, middle), and **Jason Chaytor** (WHOI, top) prepare a recovered core for transport and storage by cutting the core liner at the top of the sediment. Inset, dark gray mud at the bottom of one core. Photographs by **Sandy Baldwin** (USGS).*

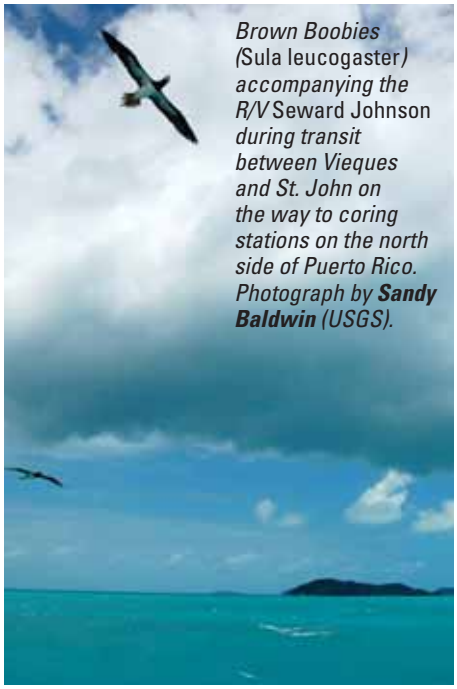
Coring sites were chosen on the basis of multibeam bathymetry and seismic-reflection data collected by the USGS on several recent cruises in the northeastern Caribbean (for example, see "New Bathymetric Map of Mona Passage, Northeastern Caribbean, Aids in Earthquake and Tsunami-Hazard Mitigation," *Sound Waves*, May 2007, URL **http://soundwaves.usgs.gov/2007/05/**), as well as GLORIA side-scan-sonar data (URL **http://pubs.usgs.gov/dds/dds15/**).

Just 2 days after we left port, the worst storm of Puerto Rico's winter arrived, generating 16-ft swells along the north side of the island, closing San Juan harbor for 3 days, and forcing the ship to seek shelter along the south side of the island. In spite of these conditions, the dedication and efforts of the science team and Captain **George Gunther** and the crew of the R/V *Seward Johnson* resulted in the recovery of more than 24 m of sediment from 21 of the 40 coring sites. The cores are now undergoing nondestructive testing, including multisensor core logging (MSCL), X-ray fluorescence (XRF), and lithologic logging, after which the sediment above and below submarine-landslide-debris deposits will be sampled for ^{14}C radiometric dating.

Participants in the cruise included **Matt Arsenault**, **Sandy Baldwin**, **Brian Buczkowski**, **Michael Casso**, **Claudia Flores**, **Emily Himmelstoss**, **Kate McMullen**, and **Uri ten Brink** from the USGS Woods Hole Science Center, **Jason Chaytor** (chief scientist, WHOI-USGS Postdoctoral Scholar), and **Jim Broda** (coring specialist, WHOI).

For additional information about submarine landslides and tsunamis in the Caribbean region, see:

- López-Venegas, A.M., ten Brink, U.S., and Geist, E.L., in press, Submarine landslide as the source for the October 11, 1918 Mona Passage tsunami; observations and modeling: Marine Geology, doi:10.1016/j.margeo.2008.05.001 [URL **http://www.sciencedirect.com/science/journal/00253227**].
- ten Brink, U.S., Geist, E.L., Lynett, P., and Andrews, B.D., 2006, Submarine slides north of Puerto Rico and their tsunami potential, *in* Mercado-Irizarry, A., and Liu, P., eds., Caribbean tsunami hazard: Singapore, World Scientific Publishers, p. 67-90 [URL **http://www.worldscibooks.com/engineering/5969.html**].
- ten Brink, U.S., Geist, E.L., and Andrews, B.D., 2006, Size distribution of submarine landslides and its implication to tsunami hazard in Puerto Rico: Geophysical Research Letters, v. 33, L11307, doi:10.1029/2006GL026125 [URL **http://www.agu.org/pubs/crossref/2006/2006GL026125.shtml**].



*Brown Boobies (*Sula leucogaster*) accompanying the R/V* Seward Johnson *during transit between Vieques and St. John on the way to coring stations on the north side of Puerto Rico. Photograph by **Sandy Baldwin** (USGS).*

Research on Whitings (Floating Patches of Calcium Carbonate Mud) Leads to Possible Explanation of Immense Middle East Oil Deposits

By Barbara Lidz and Helen Gibbons

"Whitings"—mysterious patches of milky water that drift around on the Great Bahama Bank and on other shallow carbonate banks—have long been a topic of scientific curiosity and controversy. What makes the seawater look milky are suspended, mud-size particles of aragonite, a form of calcium carbonate. The question is, does the aragonite in whitings precipitate spontaneously from seawater, or is the cloudiness simply aragonitic mud resuspended from the bottom by schools of fish?

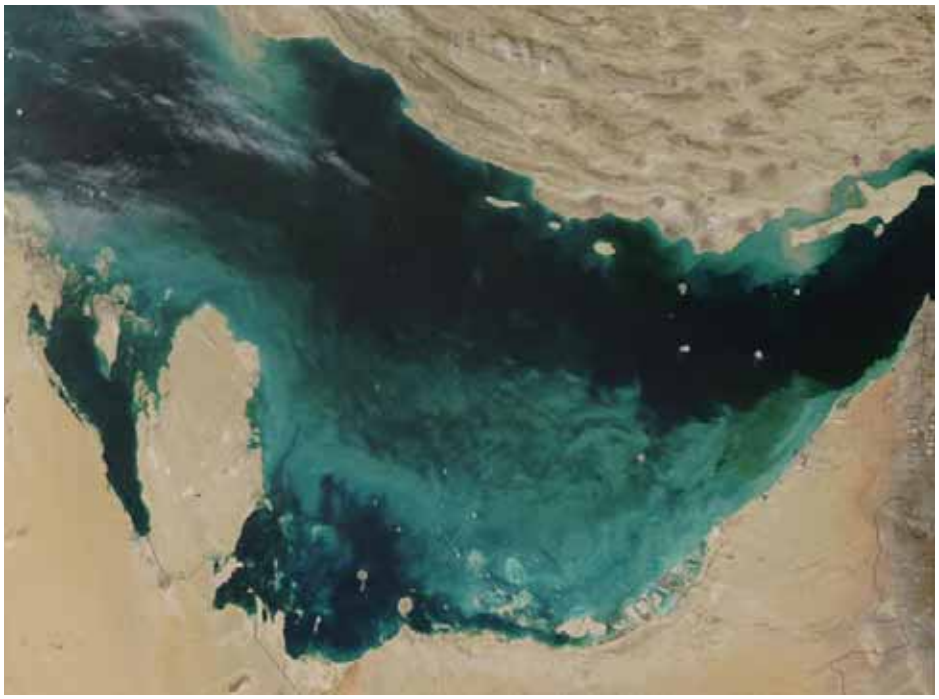
A recent outgrowth of research into this question demonstrates how curiosity-driven science can lead to important information that, in this case, is particularly relevant to the "oil crisis" controversy of today. In a poster presented at the April 2007 American Association of Petroleum Geologists (AAPG) Annual Convention in Long Beach, California, scientists **Christopher Kendall** (retired and Emeritus Professor at the University of South Carolina), **Gene Shinn** (retired, U.S. Geological Survey [USGS], and currently a Courtesy Professor at the University of South Florida), and **Xavier Janson** (Research Associate at the University of Texas, Austin) proposed "that whitings of the modern Arabian Gulf are the key to the origin of the vast petroleum reserves of this region."

The poster, entitled "Holocene Cyanobacterial Mats and Lime Muds: Links to Middle East Carbonate Source Rock Potential," won the 2007 Excellence of Poster Presentation award, which was presented to the authors in April 2008 at the Society for Sedimentary Geology (SEPM) Annual Meeting in San Antonio, Texas. This is the story of the research leading to that award.

For years, the origin of aragonite in whitings—whether as seawater precipitate or derived from aragonitic mud stirred into the water by fish—was considered an academic question. Investigations produced anything but consensus. In the 1950s, **Preston Cloud**, the first USGS geologist to study whitings, concluded that they form by instantaneous precipitation. **Wally Broecker** and **Taro Takahashi** (Lamont Geological Observatory of Columbia University) observed in the mid-1960s that the pH and other major chemical characteristics of seawater were the same inside and outside Bahamian whitings and thus concluded that the whitings could not be precipitating from

(Whitings and Oil continued on page 11)

United Arab Emirates (lighter shading) and other countries on the Persian Gulf.



Satellite image of the Persian Gulf shows a gulf-wide whiting extending from the coast of the United Arab Emirates. Qatar is in the peninsula at the bottom, with Saudi Arabia to the west. The mountainous country to the north is Iran. The northern extent of the whiting (milky water) is in about 100 ft of water. Localized whitings appear after passage of dust storms that apparently supply nutrients for cyanobacterial growth. Strong winds from the north blow the sediment-rich water onto the famous outward-building sabkhas of the Emirates' coasts. Cyanobacteria form thick (30 cm) mats along the margin of the accreting sabkha.

(Whitings and Oil continued from page 10)

seawater. **John Morse** (Texas A&M University) supported these findings in a paper published in 1984. In the 1950s, **Heinz Lowenstam** (California Institute of Technology) pointed out the similarities between aragonite needles made by algae and those found in whitings.

In the early 1960s, geologist **Gene Shinn**, who would go on to a highly productive 31-year career at the USGS (see article in *Sound Waves*, February 2006, URL **http://soundwaves.usgs.gov/2006/02/staff2.html**), was working for **Bob Ginsburg** at the Shell Development Field Station in Coral Gables, Florida. At that time, **Shinn** concurred with the "fish mud" theory for the origin of whitings. He participated in a study with **Ginsburg** and **Ken Stockman**, also a Shell Development Co. geologist, in which they monitored the growth rate of *Penicillus* (an alga that produces aragonite crystals) in the Florida Keys and concluded that *Penicillus* species were capable of making about a third of the mud that had accumulated in Florida Bay. Two Royal Dutch Shell geologists, **Leslie Illing** and **Allen Wells**, examined whitings in the Persian Gulf and decided that they were seawater precipitates. Others in Shell said, "Impossible!" and insisted that seawater chemistry would not allow precipitation.

While **Shinn** was working for Shell in the Persian Gulf city of Doha, Qatar, in the 1960s, not far away in Abu Dhabi **Chris Kendall** was working under the guidance of **Douglas Shearman** (Imperial College, London) on a dissertation on algal mats that form on Abu Dhabi's huge coastal sabkha, or salt flat. **Kendall** and **Shinn** each knew the other was there, but the ruler of Abu Dhabi would not allow anyone from Shell to visit his sheikhdom. It would be another 10 years before the two would meet—in Houston, Texas, where **Shinn** was working for Shell and **Kendall** for Exxon Production Research. Similar interests and a strong affection for their respective experiences in the Middle East caused them to quickly become friends as well as scientific colleagues.

Shinn joined the USGS in the 1970s and, in 1974, established the USGS Fisher Island Field Station in Miami Beach, Florida. In 1982, **Randy Steinen** (University of Connecticut, Storrs) and **Shinn**, **Bob Halley**, and **Barbara Lidz** from the Fisher Island Field Station returned to the Bahama Bank for a better look at whitings. **Eric Sundquist**, a USGS geologist studying atmospheric CO_2 and the global carbon cycle, contributed some of his project funds to the cause. No fish were found in the whitings.

In the late 1980s, **Lisa Robbins**, a USGS postdoctoral researcher who would later become Center Chief of what is now the USGS Florida Integrated Science Center in St. Petersburg, demonstrated with amino-acid analysis that the aragonite in whitings is not the same as that made by algae. She also found spherical cyanobacteria associated with whiting formation. In the meantime, the USGS Fisher Island scientists published their first paper on whitings in the *Journal of Sedimentary Petrology* (Shinn, E.A., Steinen, R.P., Lidz, B.H., and Swart, P.K., 1988, Whitings, a sedimentological dilemma: v. 59, no. 1, p. 147-161). The data showed that fish were not the cause of the Bahamian whitings. The Electric Power Research Institute (EPRI) became interested. If whitings were precipitates, then they might scrub CO_2 from the atmosphere, which had been the thought of **Eric Sundquist** when he helped fund whitings research in 1982.

The USGS could not accept research funds from EPRI, but **Robbins**, who had taken a job as an Associate Professor at the University of South Florida (USF) in Tampa, could. Over the next several years, she obtained about $1 million in funding from EPRI. In a 1992 paper published in *Geology* (Biochemical and ultra-structural evidence for the origin of whitings: A biologically induced calcium carbonate precipitation mechanism: v. 20, no. 5, p. 464-468), **Robbins** and **Patricia Blackwelder** (Rosenstiel School of Marine and Atmospheric Science of the University of Miami) became the first researchers to document the association between organic matter and calcium carbonate in Bahamian whitings; the paper included scanning and transmission electron micrographs of aragonite crystals attached to the cell walls of cyanobacteria. In her dissertation, **Kim Yates**, **Robbins'** first graduate student, reported on her studies of whitings and the organic chemistry associated with their formation. That research showed that the metabolism of cyanobacteria creates local conditions that cause calcium carbonate to precipitate on the cell walls.

From the late 1990s through mid-2000 during vacations in the Bahamas, **Shinn** lived aboard a boat and spent time chasing and studying whitings when he wasn't fishing. About that time, **Chuck Holmes**, then a USGS geochemist (now retired), suggested using short-lived isotopes that occur in water to shed light on the origin of whitings. Beryllium-7, which is produced in the atmosphere and is present in water, has a half-life of only 53 days. **Holmes** reasoned that if fish, or anything else, stirred up bottom mud, the mud would likely be more than 53 days old and would therefore produce very little gamma radiation. On the other hand, if whitings were precipitating from seawater, and if the samples were run within a few days of collection, the water samples should be "hot." They were. Although some geochemists remain skeptical, **Shinn**, once a proponent of the fish-mud theory, now embraced the theory that aragonite in Bahamian whitings precipitates from seawater. In a 1996 paper in the *Bahamas Journal of Science* (Whitings on the Great Bahama Bank: A microscopic solution to a macroscopic mystery: v. 4, no.1, p. 2-6), **Robbins**, **Yates**, **Shinn**, and **Blackwelder** proposed that blooms of cyanobacteria initiate aragonite precipitation to create whitings.

Cyanobacteria are also a topic of interest to **Kendall**. While investigating the geochemistry of oil during a sabbatical in 2007 at the Jackson School of Geosciences (University of Texas, Austin), **Kendall** became convinced that the un-oxidized stable remains of cyanobacteria, matching those generated within algal mats and whitings in shallow-marine settings, might be converted to oil more effectively than other potential sources of petroleum that include marine algae and zooplankton. Putting together the oil-producing potential of cyanobacteria and the close association between cyanobacteria and whitings

(Whitings and Oil continued on page 12)

(Whitings and Oil continued from page 11)

led to the award-winning poster, which consisted of three parts: Bahama whitings (**Shinn**), Persian Gulf whitings (**Janson**), and tidal-flat algal mats and the subsurface geology of the Persian Gulf region (**Kendall**). This winding road of research that investigated how whitings form now shed startling new light on the potential source of the immense oil deposits of the Middle East. The poster hypothesized that the dispersed un-oxidized biological membranes of cyanobacteria associated with Permian and Mesozoic algal mats and whitings likely collected in the arid rain shadow of Gondwanaland on the southern margin of the Tethys as they do today in the shadow of Arabia and Africa. Though low in total organic carbon, this material was preserved in sufficient quantities to ensure that the large volumes of oil we find today could be generated over a short time. It's a wonderful story on how curiosity-driven science can have large applications.

To read the poster abstract, visit URL **http://aapg.confex.com/aapg/2007am/preliminaryprogram/abstract_110223.htm**.

Upholding the Importance of Sediment: USGS Participation at MarineQuest 2008

By Nancy T. DeWitt

Once again, the MarineQuest open house hosted annually by the Fish and Wildlife Research Institute (FWRI) in downtown St. Petersburg, Florida, was a hustle-and-bustle with curious and eager visitors of all ages. The day (Saturday, April 19) began with a cool morning and progressed into a beautiful, sunny, clear blue-sky day in which more than 4,000 visitors roamed the 74 different indoor and outdoor exhibits.

Surrounded by displays on biology and wildlife, the U.S. Geological Survey (USGS) exhibit brought sediments and rocks into the mix. Future scientists wandered up to the microscopes to identify sand samples and inquire how the USGS is capable of getting such materials, where USGS scientists travel to get the samples, and "why are there so-o-o-o-o-o many colors, shapes, and sizes?"

When the kids had their fill of studying sand and seemed satisfied with answers to their questions, they shuffled on to the booth displaying a portable vibracore. There they could play Science Chief and perform the powerful task of turning the vibracore engine on (to drill for their sediment core sample) and then turning it off. People at nearby fish displays had to come find the source of engine noise and for a brief moment got lost in the world of geology.

If and only if the sediments were not enough for the future scientists did they challenge themselves to experience the "Underwater Black Mask," monitored by

(Marine Quest continued on page 13)

*Scientists **Molly McLaughlin** (USGS) and **Emily Klipp** (Jacobs Technology Inc., contracted to the USGS) get a quick break and stand by for the next wave of visitors.*

*Scientists **Molly McLaughlin**, **Emily Klipp**, and **Ava Blouin** (USGS outreach volunteer) take questions from the public.*

(Marine Quest continued from page 12)

*Scientist **Marc Blouin** briefs **Joseph Hamilton** of St. Petersburg (visitor to MarineQuest 2008) before **Joseph** dons the diving mask.*

Marc Blouin (USGS) and special surface-support outreach volunteer **Ava Blouin**. Here the future scientists could learn the importance of sample collection and science while diving in zero-visibility conditions. Each diver in training received a briefing from divemaster **Marc Blouin** on the particular underwater assignment he or she needed to accomplish. Tasks included (1) obtaining biological or geological samples and placing them properly and safely in a mesh sample bag and (2) constructing or repairing underwater equipment. The divemaster then debriefed each diver to gain comments on his or her experience.

All in all, it was a great day for the interaction of scientists and the public! The USGS booth was made possible through the generous help of volunteers, including **Marc Blouin** (USGS) and his wife **Ava**; **Molly McLaughlin, Emily Klipp**, and **McCarron Best** (Jacobs Technology Inc., contracted to the USGS); and **Laurinda Travers, Chris Kellogg,** and **Nancy T. DeWitt** (USGS).

***Joseph Hamilton** executes construction and repair of underwater scientific equipment.*

***Michelle Doe** of St. Petersburg (visitor to MarineQuest 2008) conducts underwater sampling with **Marc Blouin** watching.*

USGS Visit to Alaska to Discuss Law of the Sea Studies

By Debbie Hutchinson

U.S. Geological Survey (USGS) scientist **Debbie Hutchinson** traveled to Barrow, Alaska, on April 20-23 to visit the Barrow Arctic Science Consortium, talk with Native Inupiat whaling captains, and give a public talk on an upcoming field program that will use two icebreakers to survey parts of the Arctic Ocean in support of defining the extended continental shelves of the United States and Canada. The extended continental shelf is that part of the sea floor and sub-sea floor that extends beyond 200 nautical miles from shore and for which nations hold certain sovereign rights if they can demonstrate that they meet the conditions set forth in Article 76 of the United Nations Convention on the Law of the Sea.

***Debbie Hutchinson** presents a public lecture in Barrow, Alaska, explaining connections between the Law of the Sea, the Arctic Ocean, and marine research.*

The USGS and the Geological Survey of Canada are planning to conduct a joint expedition in September to map the sedimentary deposits of the Canada Basin and the Chukchi Cap (a large undersea plateau), primarily in international waters north of Alaska. Not only will the mapping help meet the conditions of Article 76, but it will also be the first time that some of these parts of the Arctic Ocean have ever been surveyed with modern navigation and technology. Because of a lack of information about sedimentary deposits in the Canada Basin, theories about sea-floor-spreading processes there and the timing of opening of the basin are plentiful and controversial. The data of primary interest—multichannel seismic-reflection data—will be collected by the Canadian Coast Guard icebreaker *Louis S. St. Laurent*, while the U.S. Coast Guard icebreaker *Healy* collects multibeam bathymetric and gravity data. Another purpose of the *Healy* will be to lead the two ships through thick sea ice expected in areas along the Canadian margin; providing a clear path for the *Louis* will help maximize the continuity and quality of the seismic-reflection data. (See maps of Arctic sea-ice thickness at URL **http://soundwaves.usgs.gov/2008/06/research2.html**.)

While in Barrow, **Hutchinson** spoke with four whaling captains and the acting mayor of Barrow about the purposes of the experiment and ways to ensure that embarking and disembarking the *Healy* in Barrow will not interfere with the fall whale hunt. She also presented a lecture on "Law of the Sea, the Arctic Ocean, and Marine Research: Why All the Interest?" In addition to the whaling captains, **Hutchinson** spoke with biologists from the North Slope Borough about the seismic experiment. ❁

USGS/DOI Santa Barbara Channel Workshop Held March 26-27, 2008, in Santa Cruz, California

By Sam Johnson, Tom Suchanek, Kim Taylor, and Len Gaydos

The U.S. Geological Survey (USGS), a bureau within the U.S. Department of the Interior (DOI), hosted a USGS/DOI workshop focused on coastal and ocean science in the Santa Barbara Channel. Held at the USGS Pacific Science Center in Santa Cruz, California, on March 26-27, 2008, the workshop attracted 45 participants, including representatives from several DOI bureaus—the USGS, the Minerals Management Service (MMS), the National Park Service (NPS), and the U.S. Fish and Wildlife Service (FWS)—as well as State agencies and academia. The Santa Barbara Channel is a DOI focus because of ongoing offshore oil production in Federal waters (MMS), the presence of endangered species (FWS), Channel Islands National Park (NPS), the California State Waters Mapping Program (USGS), im-

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(Santa Barbara Channel continued from page 14)

portant coastal-zone-management issues, and numerous Federal, State, and local stakeholders. The goals of the workshop included the following:

- Communicate and provide updates on active research efforts
- Share data and improve coordination of responses to information requests
- Learn about DOI science needs and the DOI Ocean Action Plan (see URL **http://www.doi.gov/initiatives/oceanfr.html**)
- Share information on coastal-zone-management issues and stakeholders, including the West Coast Governors' Agreement on Ocean Health (URL **http://westcoastoceans.gov/**)
- Strategize on how to maximize the scientific impact of current work
- Identify and develop new multidisciplinary-research opportunities and collaborations consistent with the USGS Science Strategy (URL **http://www.usgs.gov/science_strategy/**)
- Discuss expanded collaboration in the Southern California Bight

The workshop featured 26 presentations organized in six sessions: (1) Introduction; (2) Geologic, Sea-Floor, and Habitat Mapping; (3) Coastal Watersheds; (4) the Nearshore Coastal Zone; (5) Island Ecosystems; and (6) the Coastal Ocean. Several major multidisciplinary themes were raised and reinforced repeatedly throughout the workshop; they are summarized below.

Santa Barbara Channel area.

Important DOI/Federal land-management responsibilities are numerous in the Santa Barbara Channel—DOI has specific land-management responsibilities in the Santa Barbara Channel because of Channel Islands National Park (NPS), ongoing petroleum production and infrastructure in Federal waters (MMS), and responsibilities for managing and monitoring endangered species (FWS). The Santa Barbara Channel is also host to Channel Islands National Marine Sanctuary, managed by the National Oceanic and Atmospheric Administration (NOAA). No other part of the densely populated Southern California Bight has this DOI/Federal land-management focus. This Federal role commonly requires scientific information to inform decision making, and the USGS has a long history of partnering with other Federal agencies to conduct scientific work in the Santa Barbara Channel. Given increasing environmental stress due to onland development, climate change, and significant natural hazards, the scientific role of the USGS should continue to grow in this area.

The Santa Barbara Channel area is a natural laboratory—For the workshop, we defined the "Santa Barbara Channel" as extending from the steep Santa Ynez Mountains on the north to the Channel Islands and adjacent continental shelf on the south, and from Point Conception on the west to Mugu Submarine Canyon (about 20 km east of Anacapa Island) on the east. This highly dynamic landscape is characterized by diverse ecosystems, intensive resource management, varying human impacts, and dense population centers. It is thus an ideal and stimulating place to conduct investigations of the links between ecosystems, hazards, climate change, wildlife and human health, natural-resource management (water, mineral, wildlife), and landscape-scale human impacts.

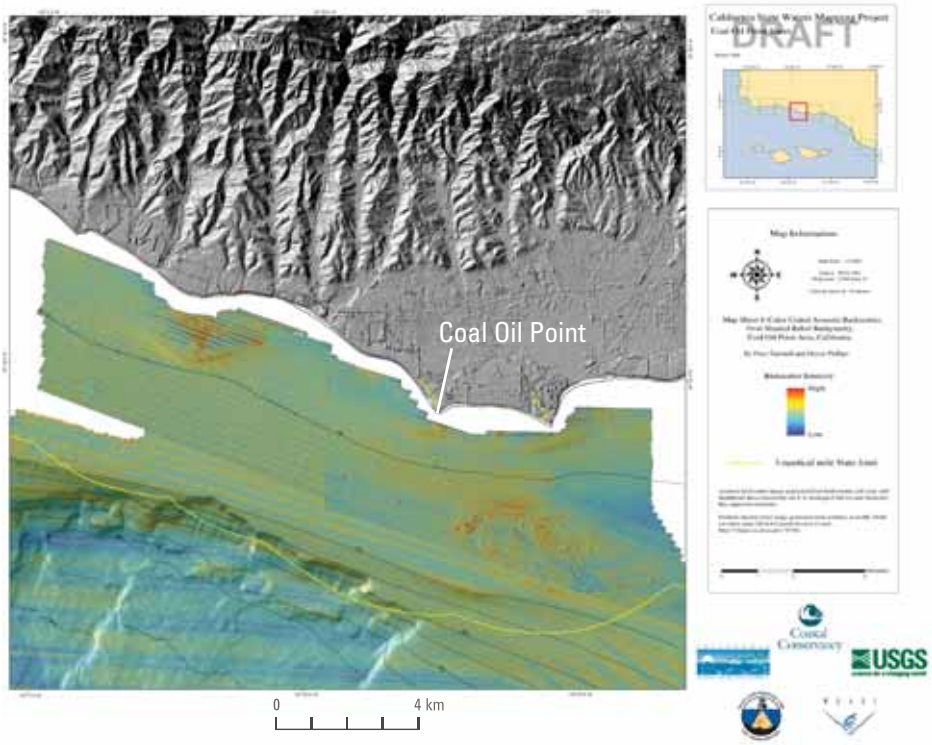
Scientific partnerships and collaboration are extremely important—Maximizing the impact of scientific studies in the Santa Barbara Channel area will require developing and maintaining long-term relationships with other active and ongoing scientific efforts.

Coastal watersheds have significant impacts on the coastal ocean—Given the varying geomorphology and land-use practices described above, the Santa Barbara Channel is an ideal place to study the impacts of coastal watersheds on the coastal ocean.

USGS mapping provides an important multidisciplinary opportunity—The USGS Western Coastal and Marine Geology Team (WCMG) is in the middle of a significant mapping campaign in the Santa

(Santa Barbara Channel continued on page 16)

(Santa Barbara Channel continued from page 15)



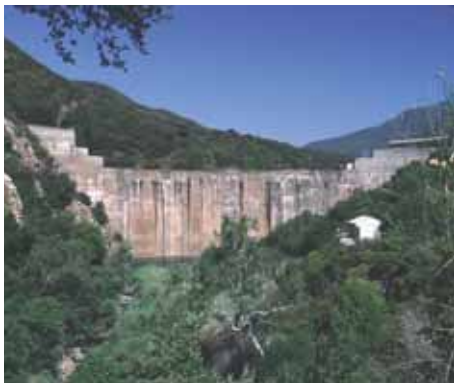
Color-coded backscatter values offshore Coal Oil Point. (Enlarged scale and Coal Oil Point label added for greater visibility.)

Barbara Channel. This important effort will result in several map folios, including map sheets and geographic-information-system (GIS) layers that show high-resolution bathymetry, bathymetric perspective views, backscatter (the strength of sound energy reflected by the sea floor, which yields information about sea-floor composition), sea-floor characteristics, ground-truthing imagery of the sea floor, benthic habitats, and shallow stratigraphy and structural geology as revealed by seismic-reflection data. Other USGS disciplines have an opportunity to add to this landmark effort by contributing additional spatial data, such as land-use data from geographers and information about flora and fauna from biologists.

Climate change may significantly affect humans and ecosystems in the Santa Barbara Channel—Potential changes in ocean temperature, upwelling, and currents will likely affect basal marine food webs and upper-trophic-level predators. Sea-level rise will likely result in increased coastal erosion, beach loss, increased inundation from coastal storms, wetland loss and degradation, and associated negative impacts on nearshore marine and adjacent terrestrial ecosystems. Potential changes in rainfall (and important coastal moisture from fog) could significantly affect water availability and terrestrial-ecosystem function. Changes in local and regional rainfall patterns and local ground-water levels are all expected to result from climate change. Forecasts and modeling of these impacts, which link processes across geographic and temporal scales, are needed to inform public planning and policy.

Removal of Matilija Dam presents an important scientific opportunity—Matilija Dam in the Ventura River watershed is slated for decommissioning and removal in the next 3-5 years. The dam currently serves no practical purpose, and the lake behind the dam is almost completely filled with sediment. Investigation

(Santa Barbara Channel continued on page 17)



*Matilija Dam in the upper part of the Ventura River watershed is slated for removal. Photograph by **Paul Jenkin**, Matilija Coalition.*

Rising sea level associated with climate change could exacerbate coastal-erosion problems.

(Santa Barbara Channel continued from page 16)

and monitoring of this dam removal is an important opportunity because (1) anticipated increased sediment loads may affect watershed and coastal ecosystems, and (2) the pace of dam removal in the Western United States is expected to grow significantly in coming years, and policy makers will need information to develop science-based forecasts of dam-removal impacts. Designing a coordinated research plan will require significant collaboration with numerous agencies and entities: the FWS, the U.S. Army Corps of Engineers, the California Department of Fish and Game, the U.S. Forest Service, Regional Water Quality Boards and Water Districts, and local county and city governments.

Beach health and the role of submarine-ground-water discharge are important issues—Beach closures and warnings triggered by high bacterial levels are becoming increasingly common in the Santa Barbara Channel area and elsewhere. USGS multidisciplinary studies can help determine the relative importance of such factors as shorebirds, submarine groundwater discharge, sewage infrastructure, and coastal circulation.

Multidisciplinary science is needed to understand and manage ocean ecosystems—The USGS can bring a multidisciplinary, holistic approach to understanding marine ecosystems, collecting and synthesizing important information about physical, chemical, and biological/ecological processes. Some specific issues that the USGS could address are:

- More detailed understanding of marine food webs
- Monitoring of selected "sentinel species," such as sea otters and certain seabirds, to understand and model the impacts of contaminants, pathogens, and natural oil and gas seeps
- Monitoring to evaluate the effectiveness and connectivity of Marine Protected Areas (URL **http://mpa.gov/**)
- Development of statistical approaches that relate biota to benthic habitats
- Understanding the viral, bacterial, and parasite ecology links to physical and biological systems
- Biologic importance of systems that deliver sediment and contaminants from watersheds to the coastal ocean (for example, hyperpycnal [density driven] flows)
- Fate of sediment and contaminant loads in the coastal ocean, including the importance of submarine canyons as "sinks"
- Determination of baseline prehistoric sediment and contaminant loads to evaluate human impacts, incorporating high-resolution dating
- Identification of physical processes in the marine environment that are controlling ecological processes
- Assessment of offshore geologic hazards, including evaluation of earthquake and tsunami sources
- Determining the effects of land use on sediment, contaminant, and nutrient loads to project effects of future land-use changes❁

Santa Barbara has recently had significant issues with beach health. This image shows Santa Barbara's West Beach and Stearns Wharf. Copyright (C) 2002-2008 ***Kenneth & Gabrielle Adelman,*** *California Coastal Records Project, URL* ***http://www.Californiacoastline.org/****.*

Sea otters and certain seabirds are important "sentinels" of ecosystem health. Photograph of southern sea otters courtesy of the U.S. Fish and Wildlife Service.

USGS is Part of Law of the Sea Delegation Visiting Australia

By Debbie Hutchinson

U.S. Geological Survey (USGS) scientists **Jon Childs** and **Debbie Hutchinson** were part of a U.S. delegation that visited Geoscience Australia—the country's national agency for geoscience research and geospatial information—in Canberra on April 28-30, 2008. The purpose of their visit was to talk with the principal members of the Australian Extended Continental Shelf Group about the lessons they learned as they defined their extended-continental-shelf boundaries, how they organized the 10-year effort to define their boundaries, and whether they had any recommendations for the United States in using Article 76 of the United Nations Convention on the Law of the Sea (the Convention) to define our extended continental shelf.

*U.S. delegation with some of their hosts from Geoscience Australia. **Jon Childs** and **Debbie Hutchinson** are second and fifth from right, respectively.*

Although most geologists think of the continental shelf as those shallow-water parts of the continental margin covered by less than about 200 m of water, the legal continental shelf can extend across the entire morphologic continental margin. In the Convention, every coastal nation has a right to a legal continental shelf that goes either to 200 nautical miles from the shore or to a shared maritime boundary with another nation. The Convention also allows for an extended continental shelf beyond 200 nautical miles if a nation can show that it meets the conditions set forth in Article 76. Within the extended continental shelf, a nation has exclusive sovereign rights over natural resources, as well as exclusive control of marine research, on the sea floor and sub-sea floor.

The United States is just at the beginning stages of defining its extended continental shelf beyond 200 nautical miles. In contrast, Australia in late April received recommendations from the Commission on the Limits of the Continental Shelf on the positions of its final boundaries and is therefore nearly done with its delimitation process. The visit by the Law of the Sea delegation was not planned to coincide with the final recommendations; however, this coincidence allowed the U.S. delegation to talk with the Australians about strategies that proved to be successful. One of the most important outcomes was that geology and seismic-reflection data played a prominent role in every step of the delimitation process.

Other members of the delegation included **Margaret Hayes**, **Brian Van Pay**, **Mark Simonoff**, **Larry Mayer**, and **Barbara Moore** from the U.S. Department of State and **Christopher Fox** and **Heather Allen** from the National Oceanic and Atmospheric Administration.

USGS Sponsors Meeting on Carolinas Coastal Change Processes Project

By John C. Warner

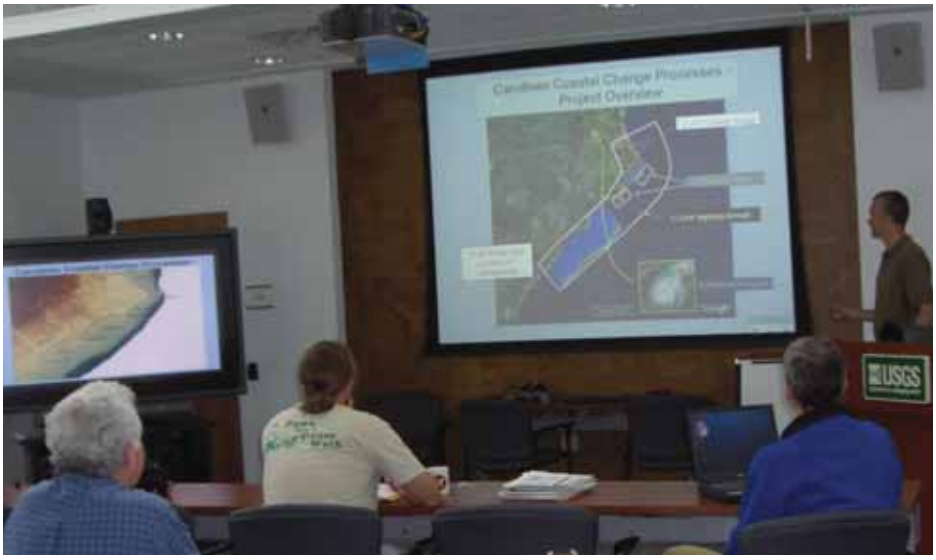
A meeting was convened on April 29-30, 2008, at the U.S. Geological Survey (USGS) Woods Hole Science Center in Woods Hole, Massachusetts, to plan science objectives for the USGS Carolinas Coastal Change Processes Project. The meeting was attended by about 15 scientists from several organizations, including **George Voulgaris** from the University of South Carolina; **Ruoying He** from the University of North Carolina; **Lynn Leonard** from the University of North Carolina Wilmington; **Jesse McNinch** from the Virginia Institute of Marine Sciences and the U.S. Army Corps of Engineers; **Kevin Haas** from Georgia Tech Savannah; **Dave Thompson** from the USGS Florida Integrated Science Center office in St. Petersburg; and **John Warner**, **Rob Thieler**, **Jeff List**, **Brad Butman**, **Chris Sherwood**, **Rich Signell**, **Brandy Armstrong**, **Marinna Martini**, and **Ellyn Montgomery** from the USGS Woods Hole Science Center.

Several attendees gave presentations related to current research activities in the study area, which focuses on the Outer Banks and cuspate forelands of North and South Carolina. The Carolinas project theme is to investigate the interactions of shoreline, nearshore, and offshore sediment-transport processes driv-

(Carolinas Meeting continued on page 19)

(Carolinas Meeting continued from page 18)

ing coastal change in the Carolinas by using geophysical surveys, oceanographic studies, and predictive models. The meeting was held in the USGS Woods Hole Science Center's new Tilley Conference Room, which includes a multimedia center that allowed outside investigators to log in via WebEx and presenters to display concurrent multiple images on the plasma screen and overhead projector system. The well-equipped meeting center facilitated the scientists' development of an integrated science plan to address issues of coastal-change hazards.

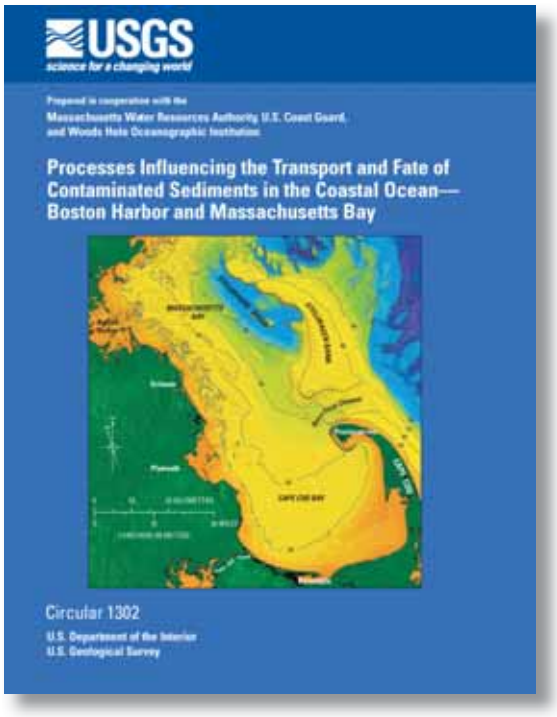


Several scientists preparing for the Carolinas project meeting use the new Tilley Conference Room's multimedia display and state-of-the-art visualization capabilities.

USGS Circular on Massachusetts Bay-Boston Harbor Project Wins National Association of Government Communicators Blue Pencil Award

By Bradford Butman and Michael H. Bothner

At a ceremony in Albuquerque, New Mexico, on April 29, 2008, U.S. Geological Survey (USGS) Circular 1302, "Processes Infuencing the Transport and Fate of Contaminated Sediments in the Coastal Ocean—Boston Harbor and Massachusetts Bay," was awarded a 2008 Blue Pencil Award of Excellence in the Technical or Statistical Report category by the National Association of Government Communicators. The Blue Pencil Awards recognize the Government's best in writing and print materials, video, and multimedia communications.



Cover of USGS Circular 1302, which recently won a Blue Pencil Award of Excellence from the National Association of Government Communicators. See the report online at URL ***http://pubs.usgs.gov/circ/2007/1302/****. A copy of the printed report may be ordered by calling 1-888-ASK-USGS or ordering online at URL* ***http://store.usgs.gov/*** *(product number 207752).*

The Circular, edited by **Michael Bothner** and **Bradford Butman**, contains 11 independently authored sections that summarize the results of an 18-year multidisciplinary research program designed to develop a predictive capability for sediment and contaminant transport and fate in Massachusetts Bay. The program, one of the first pollution studies carried out by the USGS Coastal and Marine Geology Program, included high-resolution mapping of the sea floor, an 18-year time series of geochemical and oceanographic observations, and numerical modeling of sediment transport and fate. The results of this program contributed to what has become the environmental success story of the Boston Harbor cleanup by providing scientific information that informed the public debate, guided management decisions, and saved taxpayer dollars. The USGS program demonstrates how an understanding of regional geology is important to addressing the fate of contaminated sediment in the coastal ocean, and how scientists and managers can partner to address a serious public issue. The program was carried out in cooperation with the Massachusetts Water Resources Authority, the Woods Hole Oceanographic Institution, and the U.S. Coast Guard.

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The design and layout of the publication were chosen to effectively convey scientific results even to those who only browse the report. The USGS Circular design—of both the printed and the online version—enabled 19 investigators to describe the results of their multiyear research studies in a single reviewed publication that includes an introduction to the issues, a description of the program, a summary of results, and a complete bibliography. The goal for the printed version was to make it sufficiently interesting at first glance to encourage reading and discussion among participants at workshops and scientific meetings and in classrooms. Thus, the Circular includes many full-color figures, maps, and photographs, all in striking detail and with informative captions. Each section was peer reviewed for scientific content; and all contributions were edited, reformatted, and arranged to achieve a consistent appearance throughout the entire document.

A printed book and a set of online PDF files (download from URL **http://pubs.usgs.gov/circ/2007/1302/**) were the formats selected for delivery. The printed book presents the highlights of the research program in a single, high-quality publication that is attractive for distribution and promotes face-to-face discussions. The online PDF version provides free and unlimited worldwide availability. Approximately 650 copies of the printed Circular have been distributed or ordered, and the online version of the report has received more than 24,000 hits since it was posted in July 2007. Requests for pages from the online version have come predominantly from six domains: unknown (26 percent), Networks (.net, 24 percent), U.S. Government (.gov, 21 percent), Commercial (.com, 8 percent), U.S. Higher Education (.edu, 7 percent), and China (.cn, 5 percent). The report has been enthusiastically received when distributed and used in national, regional, and local venues; and the format has become a publication template for similar USGS research programs seeking to summarize results for a broad audience.

Editing and production of the report were carried out by a team of editors and graphics specialists at the Pembroke Publishing Service Center of the USGS Enterprise Publishing Network. The publications team included **Debra Foster**, **Mary Ashman**, **Mark Bonito**, **Ann Marie Squillacci**, **Christine Mendelsohn**, and **Barbara Korzendorfer**.

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