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Research

50-Year-Old Mystery Solved: Seafloor Mapping Reveals Cause of 1964 Tsunami that Destroyed Alaskan Village

By Helen Gibbons and Leslie Gordon

Minutes after the 1964 magnitude-9.2 Great Alaska Earthquake (<**http://earthquake.usgs.gov/earthquakes/events/alaska1964/**>), a series of tsunami waves swept through the village of Chenega in Prince William Sound, destroying all but two of the buildings and killing 23 of the 75 inhabitants. Fifty years later, detailed seafloor images revealed the likely cause of the tsunami: a large set of underwater landslides. U.S. Geological Survey (USGS) scientists and their colleagues from Boise State University and the Alaska Department of Fish and Game collected the images while mapping the seafloor in May 2014 (see sidebar, page 2). Their findings, published in January 2016 in the journal *Earth and Planetary Science Letters* (<**http://dx.doi.org/10.1016/j.epsl.2016.01.008**>), underscore the tsunami hazard that submarine landslides can pose in fjords around the world where communities and ports are commonly located.

USGS geologists who investigated Alaska's south coast shortly after the 1964 earthquake speculated that an underwater landslide might have triggered the Chenega tsunami, just as landslides triggered tsunamis that devastated the Alaskan towns of Valdez, Seward, and Whittier. But an undersea survey just after the earthquake "didn't show evidence of a landslide in nearby Dangerous Passage or the other waterways around Chenega," explained **Daniel Brothers**, USGS geophysicist and lead author of the study. "Alternate explanations involving seafloor movement during the earthquake didn't fit the timing and severity of the Chenega tsunami as described by eyewitnesses." The tsunami origin remained uncertain until a team led by Brothers mapped a large underwater

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Scientists aboard the Alaska Department of Fish and Game (ADFG) research vessel (R/V) Solstice *collaborated in seafloor mapping to support ADFG studies of rockfish habitat and USGS studies of underwater earthquake and tsunami hazards. USGS photograph by* ***Danny Brothers****.*

The team on the R/V Solstice *(left to right):* ***Gerry Hatcher*** *(USGS),* ***Jimmy Osga*** *(Alaska Department of Fish and Game [ADFG]),* ***Lee Liberty*** *(Boise State University),* ***Dave Anderson*** *(ADFG),* ***James Weise*** *(ADFG),* ***David Finlayson*** *(Chesapeake Technology), and* ***Danny Brothers*** *(USGS). USGS photograph by* ***Gerry Hatcher****.*

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landslide complex in Dangerous Passage, mostly in water deeper than that studied in 1964.

"What makes this slide unusual is that much of the material that slid was at 250 to 350 meters [820 to 1,150 feet] water depth," said **Peter Haeussler**, USGS geologist and a coauthor of the report. "The depth made it particularly good at generating a tsunami."

The scientists used multibeam sonar technology to collect high-resolution bathymetric (seafloor depth) data, and a single-channel seismic-reflection system to collect sub-bottom profiles (cross-sectional views of sediment layers and other features beneath the seafloor).

The researchers calculated the time it would take for a tsunami produced by a large landslide in the mapped areas to reach the village of Chenega and found a good fit with eyewitness reports. A tsunami triggered in the areas where the scientists found landslide evidence would take three to four minutes to reach the village, consistent with the arrival time of the most destructive waves.

"It's exciting to see the technology evolve so we can now get high-resolution images of the seafloor [and] pinpoint the most likely source for the waves," said USGS geologist emeritus **George Plafker**. "After 50 years, this new work confirms our original inference that it was probably landslide-generated waves that devastated Chenega so many years ago." Plafker and colleague **Larry Mayo** were among the first scientists on the scene and wrote some of the early geological field reports on surface effects of the Chenega waves (<**http://pubs.usgs.gov/pp/0542g/**>).

The newly collected bathymetric data reveal three sedimentary basins at progressively deeper levels toward the open waters of Prince William Sound. Glaciers carved these basins when sea level was lower. After the last ice age, as sea level rose and the

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Weather Detour Leads to Landslide Discovery

Bad weather can take some credit for the discovery of underwater landslides that triggered the 1964 Chenega tsunami. Scientists aboard the R/V *Solstice* were actually focused on Cape Cleare, a rocky shoal southwest of Montague Island. Geophysicists **Danny Brothers** (USGS) and **Lee Liberty** (Boise State University) wanted to learn more about the Patton Bay fault, which cuts through the shoal. Rupture of the Patton Bay fault during the 1964 Great Alaska Earthquake lifted parts of Montague Island by as much as 10 meters. Many scientists believe the fault's movement on the seafloor was a major contributor to a tsunami that struck Seward, Kodiak Island, and the U.S. west coast after the quake. Its offshore extent was poorly known, and the scientists on the *Solstice* wanted to change that. The team collected some stunning data during eight days of clear, calm weather. But on the ninth day, the wind picked up. "It happened quickly," said Brothers. "The data quality was severely compromised, and we were really getting knocked around. We had to head in behind Montague Island for cover and think about our options." The researchers had charted backup locations to survey in case the weather turned nasty. One of those was Dangerous Passage, near the abandoned Chenega village site. "We knew it had never been mapped with the type of tools we had on board," Brothers said, "and it was only a two-hour detour." Outer islands sheltered Dangerous Passage from the wind, enabling the scientists to work for about eight hours before they had to return to port. That was just long enough to collect the landslide evidence. "It took 50 years and crummy weather to finally uncover what happened," said Brothers.

—Helen Gibbons

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Aerial view of the Chenega village site in Alaska. Lower limits of snow, as shown by arrows, indicate the approximate limits of the tsunami; the schoolhouse is circled. The earthquake occurred March 27, 1964; the photograph was taken two days later. (Figure 5 from 1969 report at <**http://pubs.usgs.gov/pp/0542g/**>.)

Main part of the Chenega village site in Alaska. Pilings in the ground mark the former locations of homes swept away by tsunami waves. Schoolhouse on high ground was undamaged. Photograph taken 1964. (Figure 6 from 1969 report at <**http://pubs.usgs.gov/pp/0542g/**>.)

glaciers retreated, the basins filled with sediment washed off the land. The basins are separated by ridges, likely terminal glacial moraines, and bounded by steep, rugged slopes. The new images reveal other features typical of landslides, including scarps, blocks, and lumpy surfaces. Similarly, the sub-bottom profiles show that fine-grained sediment fills the basins, with distorted layers that indicate multiple landslides.

When the researchers compared their 2014 bathymetric data with data collected in 1957 by the U.S. Coast and Geodetic Survey, they discovered dramatic differences in the seafloor in Dangerous Passage. In 2014, the lowermost basin was shallower by an average of about 11 meters (33 feet), yet the basin just above it was deeper by an average of about 21 meters (63 feet). The differences suggest that sediment moved from the higher basin into the lower basin between 1957 and 2014. The new study's authors concluded that the sediment movement took place during the 1964 earthquake. "Once mobilized," they wrote, "landslide debris poured over the steep, 130-m [430-foot] face of a deeper moraine and then blanketed the [lowermost] basin."

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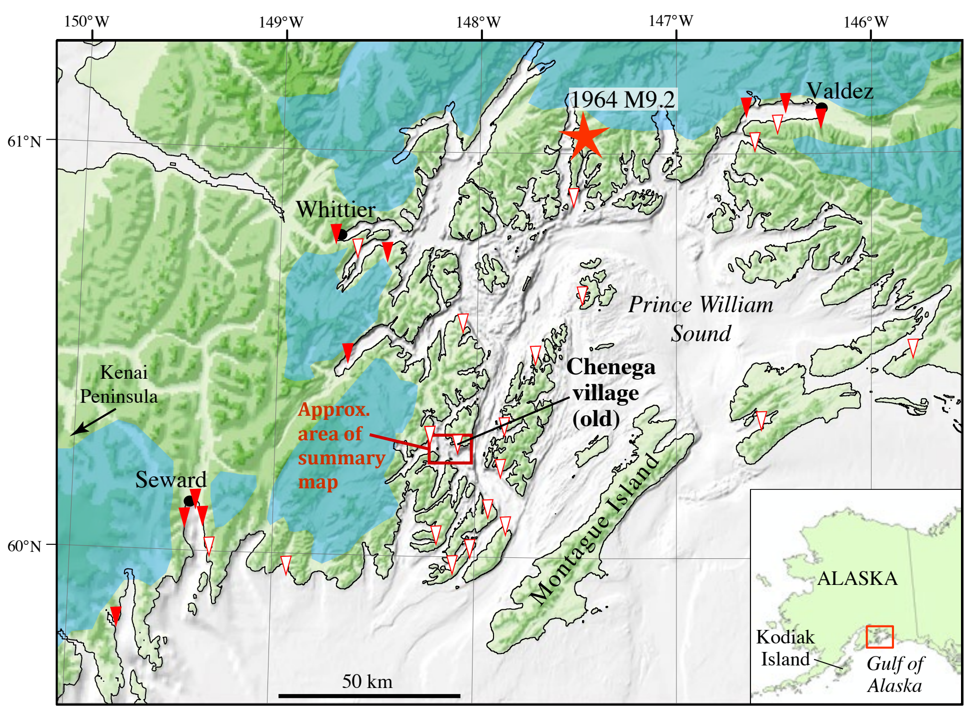

Shaded-relief map of Prince William Sound and surrounding region. Triangles are locations of local tsunamis that occurred during the 1964 Great Alaska Earthquake (red star marks the epicenter). Red triangles mark tsunamis linked to submarine landslides; white triangles mark tsunamis of unexplained origin. Blue shading indicates areas of large ice fields and active glaciers. (Modified from figure 1 in 2016 paper, <**http://dx.doi.org/10.1016/j.epsl.2016.01.008**>.)

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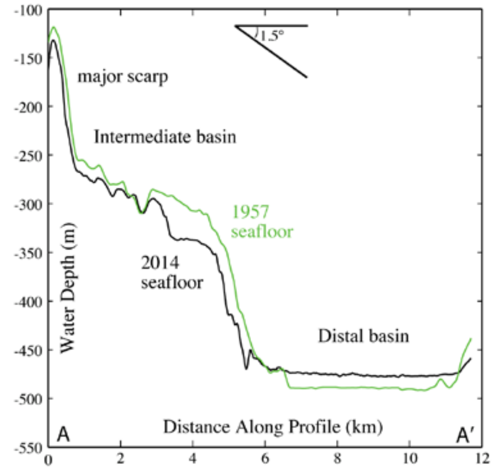
Most known landslides in fjords occur in shallow water along the fronts of submerged deltas formed by sediment washing out of upstream glaciers—areas known to be prone to sliding during earthquakes. Such landslides triggered the tsunamis that struck Seward, Valdez, and Whittier during the 1964 earthquake. The Chenega landslides, in contrast, occurred in much deeper water, where unstable deposits of glacial sediment were hidden. Their discovery implies that similar deep landslides were a likely source for unexplained local tsunamis throughout southern Alaska during the 1964 earthquake and may be an overlooked hazard for fjords globally.

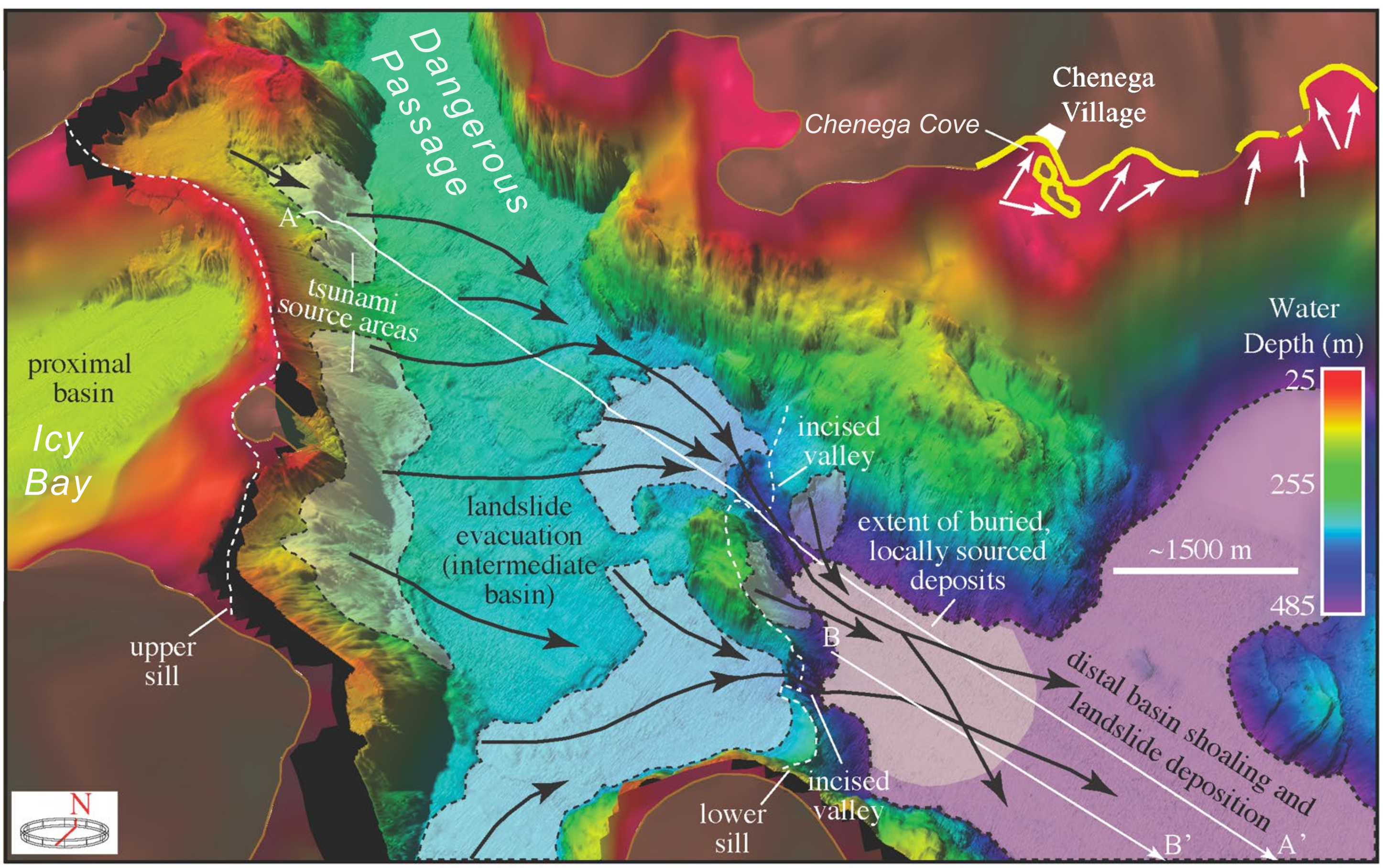
The full citation for the new paper is: Brothers, D.S., Haeussler, P.J., Liberty, L., Finlayson, D., Geist, E., Labay, K., and Byerly, M., 2016, A submarine landslide source for the devastating 1964 Chenega tsunami, southern Alaska: Earth and Planetary Science Letters, v. 438, p. 112–121 [<**http://dx.doi.org/10.1016/j.epsl.2016.01.008**>].

Acknowledgments

The paper's authors wish to thank USGS ocean engineer **Gerry Hatcher** for his dedication and skill in maintaining and operating the mapping equipment, and the crew of the R/V *Solstice* for their hard work and exceptional support. ☸



*Seafloor profiles from 1957 (green) and 2014 (black) show that sediment was lost from the intermediate basin and gained in the distal (lowermost) basin. (Modified from figure 6 in 2016 paper at <**http://dx.doi.org/10.1016/j.epsl.2016.01.008**>.)*



*Perspective view of the seafloor offshore Chenega village. Light-blue patches in the intermediate basin outline sites of sediment loss between 1957 and 2014; the light-tan patch in the distal (lowermost) basin is a site of sediment deposition. Black arrows are interpreted sediment-flow pathways. White arrows near Chenega Village show the inferred 1964 tsunami travel direction, and yellow lines mark areas struck by high tsunami waves. (Modified from figure 7 in 2016 paper at <**http://dx.doi.org/10.1016/j.epsl.2016.01.008**>.)*

Local Research with Global Effects: Coastal Scientists Study El Niño in Northern California

By Rex Sanders

Coastal research can be hard work. That's what U.S. Geological Survey (USGS) oceanographer **Dan Hoover** thought one cold and foggy night as he trudged a couple of miles north on San Francisco's Ocean Beach. A specially equipped off-road vehicle (ORV) had broken down. While his beach survey partner waited in the gloom, Hoover retrieved their four-wheel-drive SUV to tow the busted ORV back to the shop. Then the SUV got stuck on a partly buried timber, forcing the scientists to dig through shifting sand to free both vehicles.

"It was miserable," said Hoover. "Every time you go out, especially at Ocean Beach, there's always something." Hoover and his colleagues have surveyed Ocean Beach over 200 times as part of a series of research projects. This year, they'll find out what happens during a major El Niño winter.

Researchers with the USGS Coastal and Marine Geology Program (<**http://marine.usgs.gov/**>) study coastal hazards like beach erosion and cliff collapse at many locations over years and decades. By comparing conditions before, during, and after this year's very strong El Niño, these scientists hope to improve forecasts of coastal changes during future events.

El Niño is the common name for warm ocean temperatures that appear around Christmas off the west coast of South America. The weather pattern warms or cools other parts of the Pacific Ocean, and changes weather around the world. El Niño seasons typically last about one year and return at irregular intervals every two to seven years. Every winter is different, and so is every El Niño. The most recent very strong seasons occurred in 1982–1983 and 1997–1998. Sea surface temperature differences measured during this year's El Niño have set new records.

For the mainland United States, El Niño winters typically bring more rain to southern states from California to Florida, and stronger storms with bigger waves to the West Coast. In some other years, La Niña brings colder waters offshore of South America and drought to the southern U.S. Scientists refer to the irregular patterns of El Niño, La Niña, and neutral years as the El Niño-Southern Oscillation, or ENSO.

This year's very strong El Niño should show up in USGS coastal studies from Guam to Florida, and Panama to Washington State, including Northern California, home to the USGS Pacific Coastal and Marine Science Center (<**http://walrus.wr.usgs.gov/**>).

*USGS geologist **Patrick Barnard** tells Secretary of the Interior **Sally Jewell** and San Francisco Mayor **Ed Lee** about the coastal hazards facing Ocean Beach. Credit: **Tami Heileman**, U.S. Department of the Interior.*

*Off-road vehicle with a precision GPS receiver, driven by a USGS scientist surveying a beach. These surveys require special training and permits. Credit: **Andrew Stevens**, USGS.*

San Francisco's Main Beach Disappears and Reappears

Ocean Beach is San Francisco's 5.6-kilometer (3.5 mile)-long "front yard" on the Pacific Ocean, part of the Golden Gate National Recreation Area (<**http://www.nps.gov/goga/planyourvisit/oceanbeach.htm**>). The sky is often overcast or foggy, the water is too cold for most swimmers, and the waves challenge even expert surfers. The sandy beach expands in the summer and autumn thanks to gentle waves and currents that carry sand onshore. During unusually stormy winters, up to 150 meters (490 feet) of beach washes away, and large waves can damage the

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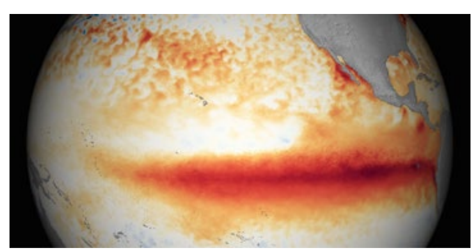


Pacific Ocean surface temperature differences measured in December 2015. Dark red areas along the equator are 9° C (16° F) warmer than average. Credit: National Oceanic and Atmospheric Administration.

(El Niño Study continued from page 5)

Map of Northern California, with Ocean Beach, Pacifica, and Santa Cruz marked. Source: ***http://coastalmap.marine.usgs.gov/***.

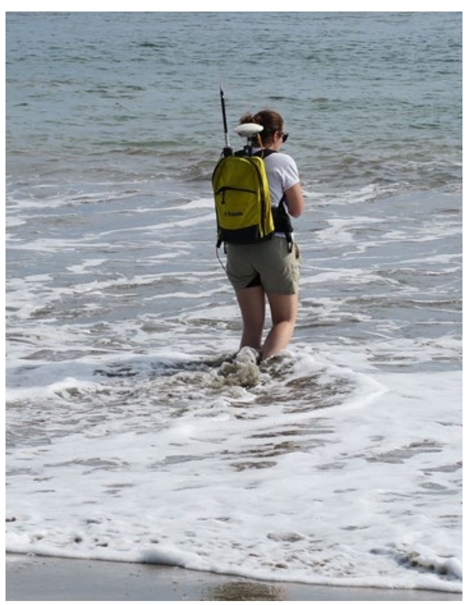
Great Highway running beside the beach. San Francisco's Oceanside sewage treatment plant (<**http://sfwater.org/index.aspx?page=622**>) sits underground, just inland from the south end of Ocean Beach, protected from waves and erosion by a rock wall and a constantly shifting sandy shore.

Ocean Beach, San Francisco. Credit: ***Kirke Wrench****, National Park Service.*

That's one of the reasons USGS scientists keep going back—the beach helps protect critical infrastructure. Every month since 2004, teams survey the sand using precision GPS receivers in backpacks or mounted on ORVs. A few times each year, and if the surf's not too rough, they use personal watercraft to measure the ocean floor just beneath the waves. Intensive beach surveys over many years like this are rare. "There's a curse in doing time series work, because once you start you can't stop," said Hoover. "The longer it is, the more valuable it is, and then it's harder and harder to let it go."

Severe bluff erosion along Ocean Beach. Storm damage to the Great Highway during the moderate 2009–2010 El Niño required $5 million in repairs and new protection. Credit: ***Jeff Hansen****, USGS.*

Using the precision surveying data, USGS researchers calculate how much sand moves on and off Ocean Beach. Combined with data on weather, swells, tides, and currents, they can link ocean conditions to beach erosion. Scientists use the long-term Ocean Beach data to improve computer forecasts of coastal hazards due to El Niño and climate change. The National Park Service (<**http://www.nps.gov/**>) wants to know what could happen to Ocean Beach and other areas they manage. The city of San Francisco can use those forecasts to help protect the sewage treatment plant from extreme storms.



USGS scientist surveying a beach using a backpack-mounted precision GPS receiver. Credit: ***Andrew Stevens****, USGS.*

A personal watercraft ready to survey the surf zone, with custom waterproof displays linked to an echo sounder and a precision GPS receiver. These surveys require special training and permits. Credit: ***Andrew Stevens****, USGS.*

The residents of cliff-top homes in Pacifica worry about the future, too.

Crumbling Cliffs in Pacifica

Unfortunately, Pacifica, California, has become the poster child for coastal cliff erosion. The small seaside town is on a section of the coast with the highest erosion rates in the state. Since the 1980s, shoreline erosion along that stretch has increased 50 percent. Even during calm years, big chunks of bluffs fall into the ocean, endangering or destroying roads, homes, and other buildings on top of those cliffs.

USGS research geologist and Mendenhall post-doctoral fellow **Patrick Limber** knows Pacifica's cliffs well. He studied the rocks that form those bluffs (and others) for his thesis, and he's continuing his research at USGS to forecast cliff erosion due to climate change and El Niño. The erosion process is a lot more complicated than waves bashing weak rocks and triggering spectacular collapses. The beach plays a critical role.

"For example, if you have a really wide beach in front of the cliff, the cliff is pretty well protected because the waves break farther offshore," said Limber. "If you have no beach in front of the cliff, the waves can really get in there and, when they break, they break very close to the

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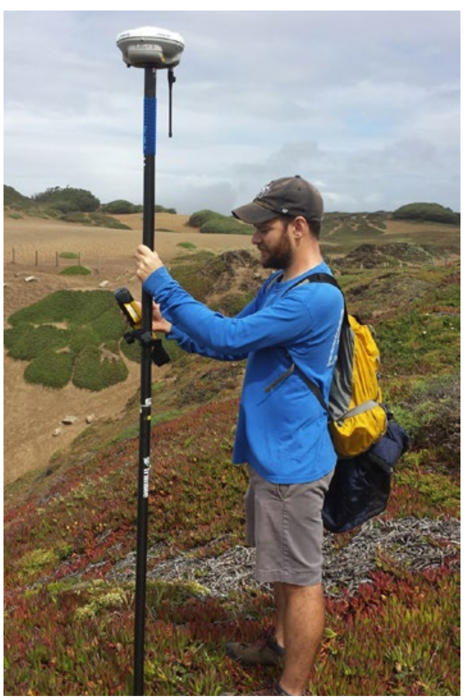
Apartments on the edge of a crumbling cliff in Pacifica, California. Credit: USGS.

cliffs. There's a lot of energy at the toe of the cliff, so cliffs tend to erode faster." During especially stormy seasons, like this year's El Niño, waves and currents can wash all the sand away.

It gets worse. As the last of the sand is washing away, the mixture of sand and ocean water beating against the cliffs acts like a belt sander. "There's a sweet spot between having too much beach and having no beach, where the cliffs actually erode the fastest," said Limber.



*USGS research geologist **Patrick Limber** measuring bluff heights near Ocean Beach. Credit: USGS.*

*USGS scientist surveying the ocean floor in front of the Santa Cruz Beach Boardwalk, October 20, 2014. Credit: **Andrew Stevens**, USGS.*

Some years, cliffs collapse even without big storms. Many factors affect the longevity of these coastal precipices. "Bluffs are complicated geologically," oceanographer Hoover told local TV station KRON4 (<**http://kron4.com/2016/01/12/video-powerful-el-nino-storms-could-lead-to-erosion/**>). "They're hard to measure, and there's a lot of them. And there's a lot of differences in local geology and hydrology that affect how bluffs are going to fail."

Measuring the strength of cliff rocks is one of Limber's specialties. Some cliffs are little more than slightly compacted sand dunes, porous and easily crumbled in your hand. Others are made of much tougher stuff, like granite. Limber measures hardness using a small spring-loaded device called a Schmidt hammer, then figures out how likely the rock unit will crumble while under attack by waves, sand, and debris. Using these data and long-term location measurements, Limber plans to add cliff erosion to the Coastal Storm Modeling System (CoSMoS; <**http://walrus.wr.usgs.gov/coastal_processes/cosmos/**>) computer forecasts of coastal hazards. Like all cutting-edge research, it won't be easy.

"There's no handbook for it," Limber said. "We're developing our own methods." He also plans to include well-accepted forecasts of rising sea levels and altered weather patterns due to climate change.

Scientists often measure and forecast cliff erosion as a long-term average, such as 30 centimeters (1 foot) per year. However, most cliffs don't erode that much every single year. "It's a sort of stop-start process," said Limber. A cliff-side home could be fine for 99 years and then, boom. That's what we see in Pacifica, and that's why USGS research on coastal bluff erosion is so important.

Ocean Beach and Pacifica are not the only places with eroding beaches and cliffs.

Taking Advantage of El Niño near Santa Cruz

You might remember that weather forecasters called for an El Niño in 2014–2015. USGS researchers in the Pacific Coastal and Marine Science Center wanted to take advantage of that uncommon event, and began monitoring beaches and cliffs in their own backyard—Santa Cruz County, California. "We got it going, and then El Niño didn't happen," said **Patrick Barnard**, USGS coastal geologist and project chief. "It was a nice baseline data collection, so now we're ready for this El Niño. We can understand how these shorelines vary seasonally due to normal summer-winter oscillations and then during El Niño."

Besides using GPS receivers mounted on backpacks, ORVs, and personal watercraft, the scientists also measure beaches and bluffs with ground-based and airborne lidar. Lidar stands for light detection and ranging. It's like radar, but instead of radio signals, lidar uses invisible (and harmless) laser beams to precisely determine the distance to millions of points. A tripod-mounted ground-based lidar rotates rapidly to measure buildings and roads, beaches

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*USGS geographer **Josh Logan** sets up a ground-based lidar scanner. Credit: **Amy West**, USGS.*

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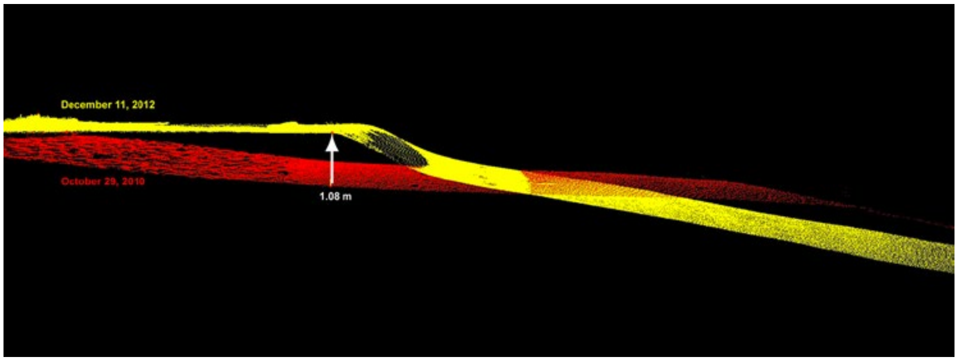


Lidar data collected in 2010 and 2012 showing a change in the beach profile. Spot marked by vertical arrow was about 1 meter (3 feet) higher after two years. Credit: ***Josh Logan****, USGS.*

and cliffs, both vertically and horizontally out to 1,400 meters—more than three-quarters of a mile. If scientists repeat those measurements before, during, and after a series of El Niño enhanced storms, they can measure how the beaches and cliffs have changed.

These devices are expensive, though, and take a long time to set up at each location. For the best results, you need scans from several spots along each stretch of beach. To quickly scan broad areas, USGS scientists use lidar mounted in airplanes flown by contractors. Airborne lidar can't measure beneath overhanging cliffs, but it can cover far more ground in far less time than its ground-based counterparts. Researchers

Special camera rig and precision GPS receiver (right) designed to take Structure from Motion photos from a small airplane. Credit: ***Jonathan Warrick****, USGS.*

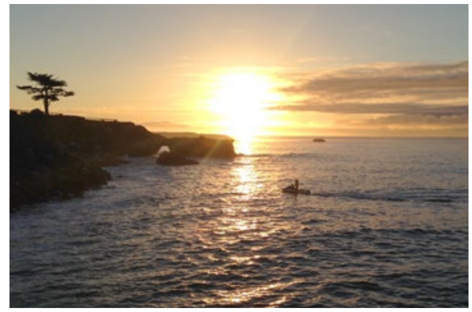
get a "bird's eye" view of the coast that's impossible to get from the beach.

Hilary Stockdon is a USGS research oceanographer stationed in St Petersburg, Florida, who's used airborne lidar for years. She's helping her colleagues in Santa Cruz collect data along the entire the West Coast later this year. "We'll compare it to a survey that was collected in 2014 and start to document the changes along the coastline," she said. "El Niño is giving us a great opportunity to look at coastal change on the West Coast and test [computer forecasts] that we've been developing."

Many USGS scientists are excited about a new technique for precisely measuring landscapes, called Structure from Motion. **Jonathan Warrick**, a USGS research geologist, is spearheading that effort along the coast. "I'm a data geek," said Warrick. "A geo-geek nerd who loves science."

In some ways, Structure from Motion is a throwback to mapping techniques from the middle of the 20th century. Cartographers made maps of remote locations using air photos. By carefully examining pairs of images using special lenses, they could trace the contours of the land. "One of the ideas behind photogrammetry and Structure from Motion is that you get a three-dimensional perspective from having multiple views of an object," said Warrick. "It's just like your eyes. You have two eyes, and if they both work well, you can understand the three-dimensional environment."

Structure from Motion combines air photos from digital cameras and positions from GPS receivers, analyzing them with powerful computers instead of a



Coastal research can be beautiful, too. Personal watercraft survey offshore of Santa Cruz, California. Credit: ***Andrew Stevens****, USGS.*

brain. Feeding precisely located digital images into special software can produce landscape measurements as good as, and sometimes better than, lidar or GPS—with an angled view of the entire cliff face and far more measurement points.

"Aerial lidar typically gets a few points per meter," said Warrick. "We're getting ten, 100 times more data density." Data collection is fast, too. "From Año Nuevo to Monterey, [we] took 1,800 photos and it took us an hour and a half total." Gathering so much data comes with a cost: processing all that information took several weeks.

Scientists can almost travel back in time to make Structure from Motion measurements. "One of the exciting things that we're finding is that historic imagery can be used quite well, if the imagery has enough overlap," said Warrick. "We're finding, for example, the California Coastal Records Project (<**http://californiacoastline.org**>) images have plenty of overlap in most places." Those images go back to 1928 along some stretches of coast.

Preparing for a Changing World

All these measurements from Ocean Beach, Pacifica, and Santa Cruz should help researchers tune their computer forecasts, and help people concerned about coastal hazards caused by climate change and El Niño to make better plans for the future, everywhere.

"There are many reasons to work in your backyard," said Warrick. "Often you can do fantastic science that is nationally or internationally recognized, and yet locally important at the same time." ❅

Second Phase of Photo and Video Portal Completed

by Jessica Fitzpatrick, Nadine Golden, and Seth Ackerman

The U.S. Geological Survey (USGS) has completed the second phase of releasing thousands of photos and videos of the seafloor and coastline through their Coastal and Marine Video and Photography Portal (**<http://dx.doi.org/10.5066/F7JH3J7N>**).

Most of these marine and coastal scenes have never been seen before or mapped at this level of detail. A more accurate perspective of these areas helps coastal managers make important decisions that range from protecting habitats to understanding hazards and managing land use.

This USGS portal is unique, due to the sheer quantity and quality of data presented. It is the largest database of its kind, providing detailed and fine-scale representations of the coast and seafloor. The "geospatial context" is also unique, with maps that display imagery in the geographic location where the images were recorded.

Prior to development of the data portal, retrieving this imagery most often required internal USGS access with specific hardware and software. Furthermore, it was difficult to manage and challenging to share such a large amount of information.

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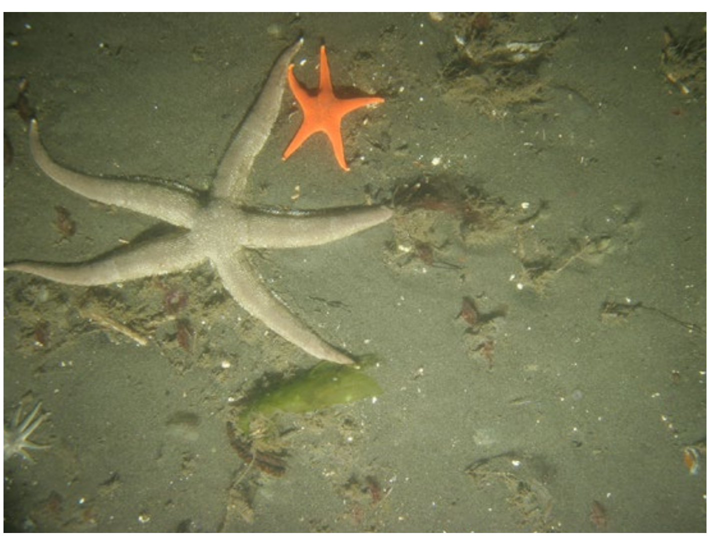
This photograph is of the seafloor off the Massachusetts coast and shows a lobster as well as boulders and sediment covered in seaweed, bubblegum algae and red filamentous algae. This photograph was collected as part of USGS research in collaboration with the Massachusetts Office of Coastal Zone Management to support development of the Massachusetts Ocean Management Plan and management of the state's waters.



This photograph is of the Puget Sound seafloor and shows a sandy area with partial hydroid and algae cover occupied by sea stars and small filter feeding worms. This image was collected as part of USGS efforts to help with rockfish recovery in the Puget Sound. Scientists are mapping their ecosystem and habitat to understand population distribution.

*This photograph shows ice-wedge polygons and an eroding shoreline at Cape Halkett on the Beaufort Sea coast of Alaska. Coastal erosion along the Arctic coast is chronic, widespread and potentially accelerating, posing threats to infrastructure important for defense and energy purposes, natural shoreline habitats and nearby Native communities. To help address these concerns, the USGS is collecting information on past and present shoreline changes along the conterminous United States and parts of Alaska and Hawaii. Photo credit: **Bruce Richmond/Ann Gibbs**.*

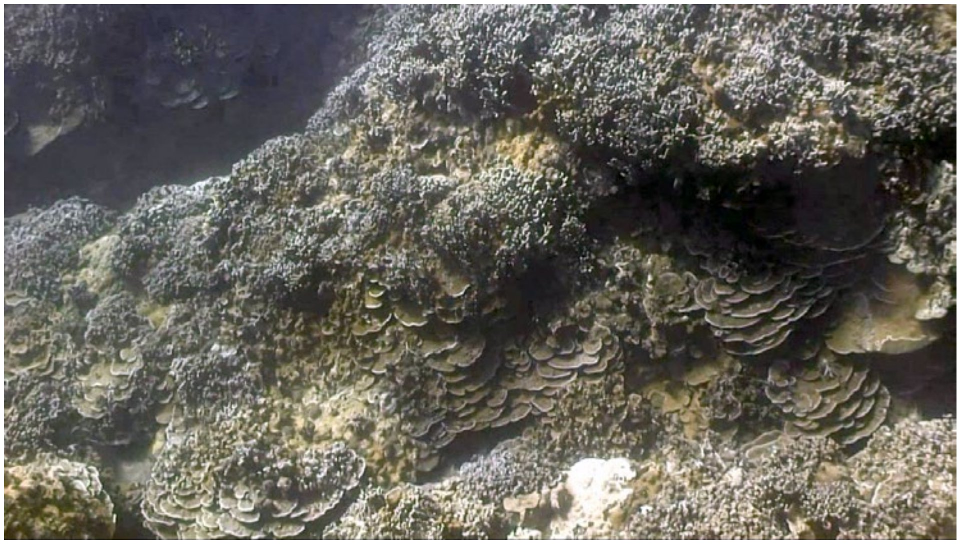
(Second Phase of Portal continued from page 9)

In early 2015, the USGS published imagery and video of California, Massachusetts, the Gulf of Mexico and the mid-Atlantic coasts. This second phase, now complete, includes Puget Sound, Hawaii, Alaska, Rhode Island, Connecticut, and Long Island Sound, as well as additional products from Massachusetts and nine pre-storm and post hurricane photo datasets from the Gulf and Atlantic Coasts. Video and photographs will be continuously added as they are collected; archived imagery will also be incorporated soon.

In total, approximately 165,500 photographs have been collected as well as 1,210 hours of trackline video covering almost 3,200 miles of coastline.

Online tutorials are available to explain how to navigate the portal (<**https://www.youtube.com/watch?v=f4qXf0Txu-w&feature=youtu.be**>) and also how to search the data catalog and work with multiple data layers (<**https://www.youtube.com/watch?v=t5N4k6WuVp0&feature=youtu.be**>).

For additional information about the portal, read about the completion of the first phase in *Sound Waves* article "Dive In! Explore Thousands of Coastal and Seafloor Images along U.S. Coasts," (<**http://soundwaves.usgs.gov/2015/02/outreach.html**>).



Coral growth offshore of the Hawaiian Island of Kaho'olawe has been significantly impacted by the island's deforestation and resulting erosion and sediment run-off into the nearshore environment. This image is of a coral reef in deeper waters offshore of Kaho'olawe. Photo credit: ***Ann E. Gibbs, Susan A. Cochran, Joshua B. Logan****, and* ***Eric E. Grossman****.*

Learn more about USGS science by visiting the USGS Coastal and Marine Geology Program website (<**http://marine.usgs.gov/**>). ☸

Awards

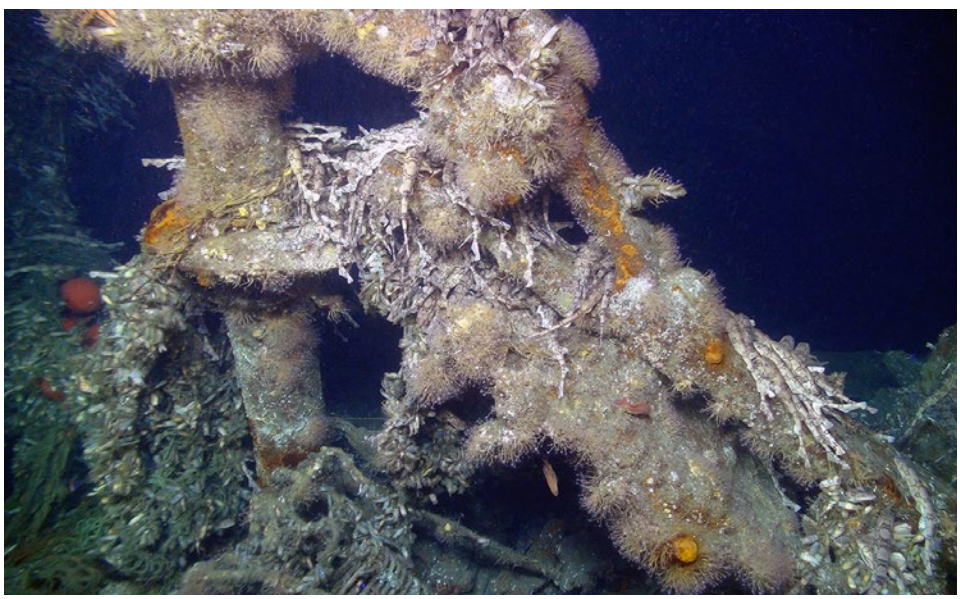
"Atlantic Canyons" Interagency Study Team Receives Excellence in Partnering Award

By Ann Tihansky

The Bureau of Ocean Energy Management (BOEM), National Oceanic and Atmospheric Administration (NOAA), and the U.S. Geological Survey (USGS) were awarded the National Oceanographic Partnership Program (NOPP) 2015 Excellence in Partnering Award at the Ocean Sciences Meeting in New Orleans on February 23, for their work in conceiving, managing and conducting the "Atlantic Canyons: Pathways to the Abyss" project.

Through collaboration, all three Federal agencies accomplished what none could have done alone. This multi-year effort leveraged the resources of BOEM, USGS, NOAA's Office of Ocean Exploration and Research, 12 universities and research institutions, and two companies, to explore Baltimore and Norfolk Canyons about 60 miles offshore of Maryland and Virginia.

("Atlantic Canyons" continued on page 11)



Hundreds of catsharks, or chainlink dogfish, rest on one of the "Billy Mitchell" Fleet shipwrecks. The shipwreck has also been occupied by colonies of anemones, starfish, and hydroids. Image courtesy of Deepwater Canyons 2013 - Pathways to the Abyss, NOAA-OER/BOEM/USGS.

("Atlantic Canyons" continued from page 10)

U.S. Geological Survey scientists (left to right) ***Jennifer McClain-Counts***, ***Jill Bourque***, *and* ***Amanda Demopoulos*** *prepare to extract a sediment sample from one of the push cores deployed by the* Jason II *remotely operated vehicle. Image courtesy of Deepwater Canyons 2013 - Pathways to the Abyss, NOAA-OER/BOEM/USGS.*

The work took place under the NOPP research umbrella.

The research findings are significant and depict a biologically rich region that had not been fully explored in the past, including historically important shipwrecks, extensive deep-sea coral communities, and a vast methane-seep ecosystem. Learn more about the project's history and discoveries by watching the 23-minute high-definition video at **https://vimeo.com/128444694**.

Participating USGS scientists from across the nation and multiple research programs being recognized for their part of the Atlantic Canyon project include: **Matthew Andersen**, **Jonathan Borden**, **Jill Bourque**, **Colleen Charles**, **Olivia Cheriton**, **Hillary Close**, **Katharine Coykendall**, **Amanda Demopoulos**, **Michael Gray**, **Christina Kellogg**, **Stephanie Lawler**, **Jennifer McClain-Counts**, **Cheryl Morrison**, **Nancy Prouty**, **Kurt Rosenberger**, and **Pamela Swarzenski**.

The team received another major award in January 2014, when Secretary of the Interior Sally Jewell presented them with the Department of the Interior's (DOI) Partners in Conservation Award (<**https://www.doi.gov/news/pressreleases/secretary-jewell-presents-2013-partners-in-conservation-awards**>). ☸

Deep-sea coral communities can be very diverse. Here a squat lobster rests among a bubblegum coral, a red tree coral, and a sponge. A brisingid seastar arm is also visible. Image courtesy of Deepwater Canyons 2013 - Pathways to the Abyss, NOAA-OER/BOEM/USGS.

ROV Jason *is launched from NOAA Ship* Ronald H. Brown*. Image courtesy of Deepwater Canyons 2013 - Pathways to the Abyss, NOAA-OER/BOEM/USGS (<**http://www.boem.gov/press02042016/**>).*

USGS Scientist Takes Post with the International Atomic Energy Agency in Monaco

By Amy West

"Atoms for Peace" is the mission of the International Atomic Energy Agency (IAEA, <**https://www.iaea.org/about**>), where U.S. Geological Survey (USGS) research oceanographer **Peter Swarzenski** will take a post as head of the Radioecology Laboratory in Monaco.

Swarzenski has spent nearly two decades at the USGS, split almost evenly between the Coastal and Marine Geology teams in St. Petersburg, Florida, and Santa Cruz, California. Now his background in isotopes and oceanography will take him to IAEA's Radioecology Laboratory (<**https://www.iaea.org/nael/page.php?page=2010**>) in Monaco. The lab investigates coastal and marine issues that can be tracked using radioactive isotopes. Projects include climate change impacts to coastal systems, ocean acidification, metal pollution, harmful algal blooms, and deep-sea corals. Swarzenski will live in nearby Menton, France, with his wife and children.

Big life moves are not new to Swarzenski. Born in Pakistan, he moved to Santa Barbara, to Kenya, and then to Switzerland, before returning to the U.S. to attend high school. A connection to water and travel runs in the family; his dad, **Wolf Swarzenski**, was a pioneer in groundwater research, working in the U.S. and abroad as a research hydrologist for the USGS.

Many associate IAEA with its efforts to promote the peaceful use of nuclear energy, or with world-class radioisotopic calibration standards. Swarzenski, however, sees a clear connection between oceanography and IAEA. He believes they have some of the best oceanographers on staff, and their strong interests in climate change and coastal ecosystems resonate with him. The global aspect to IAEA's work and connecting with IAEA's member states, which encompass 167 countries, appeal especially to Swarzenski, whose father instilled in him that "science should stand in service to man and not become an end to itself."

"IAEA strives to help make the ocean and coastal communities more resilient to future pressures," Swarzenski says. "It's not enough to just study something, we have to strive to make things better."

Swarzenski's USGS contributions have ranged from developing the former "Leaky Coastal Margins" project in St. Petersburg to starting the Coastal Aquifers project at the USGS Santa Cruz office. So, naturally, it's his USGS colleagues and their science he will miss the most. "Working for the Coastal and Marine Geology Program has been an incredible experience—I've never had a bad day in the office," says Swarzenski. Always bright and smiling, he's humbled by this opportunity to expand his scientific horizons with IAEA. He will start his new position in the spring of 2016 but plans to stay connected to his USGS colleagues and projects. ☸

***Peter Swarzenski** doing fieldwork on Alaska's Barter Island, summer 2015 (<**http://soundwaves.usgs.gov/2016/01/fieldwork2.html**>).*

A Childhood Love for Plants Becomes a Career in Wetland Science

By Kaitlin Kovacs

On September 12, 2015, in Lafayette, Louisiana, **Beth Middleton**, a botanist and research ecologist for the U.S. Geological Survey (USGS), stood in the bright spotlight on a darkened stage to share her experiences as a wetland biologist and her observations of climate change.

Invited by the TEDxVermilionStreet coordinators, she emphasized to the audience that there are ways to decrease climate change impacts both on an ecological and a personal level (<**https://www.youtube.com/watch?v=8O72jOgTQPw**>).

"This is daunting," Middleton said to the TEDx audience. "But humans are good complex problem solvers."

Public speaking is one of Middleton's fortes. After teaching at the University of Southern Illinois for 12 years, she grew to be comfortable standing in front of an audience. But after years of scientific presentations and her current role as a member of the faculty of the University of Louisiana at Lafayette, the TEDx format was a bit different.

"The scientist in me wants to say, 'This is about climate change, not me,' but the TED format wants you to say, 'This is about me and why I think climate change is important,'" said Middleton. "The [audience] may not care about climate change, so I told them why I care about it. People attend these talks to be inspired, and they want to trust you, the speaker. They don't want to know *why* you think what you do, but instead, just that you think it's important."

Another thing that Middleton thinks is important, according to her TEDx talk, is the connection people have to the natural world.

"At some point everyone has a flower they love, or a nature spot they love, some tie to the land, but then they left it there in the past," she said.

Growing up on a farm in Wisconsin, immersed in nature, Middleton grew to love the grasses, flowers, and trees that surrounded her home. Her mother gardened; in fact, most of their family's food came from the garden. But even still, her parents didn't quite understand the fascination with plants, according to Middleton.

***Beth Middleton** in China.*

"They just let me be," she said.

As she grew up, her love for plants flourished.

"In junior high, I came to the conclusion that I wanted to be a botanist, and I don't think anyone realized up until that point that you could make a living studying plants," said Middleton. "But it's the only thing I ever considered doing."

Years later, Middleton continues her plant fascination by researching climate change and its effects on swamps, including baldcypress swamps, monsoonal wetlands, mangrove swamps, northern peatlands, prairie fens, and floodplain wetlands. With the USGS she was able to develop a research network in baldcypress swamps—the North American Baldcypress Swamp Network—that invites other researchers to work in these study sites to examine the long-term function of and climate change effects on some of the most pristine swamps in the southeastern United States.

Middleton's work also delves into the effects of hurricanes on coastal wetlands, flood pulsing in restoration sites, and biodiversity loss in fens around the world. She is interested in hydrology and water changes and projecting these changes into the future. Her work has spanned from India where she conducted both her PhD dissertation and USGS research (<**http://www.sciencedirect.com/science/article/pii/S030437701500073X**>), to China where she was awarded a visiting professorship (<**http://onlinelibrary.wiley.com/doi/10.1111/rec.12015/abstract**>), and throughout the United States (<**http://www.sciencedirect.com/science/article/pii/S0925857413000402**>).

"But no matter what I study, climate change always becomes part of the discussion," said Middleton.

Recently, Middleton was awarded a Sigma Xi Distinguished Lectureship from July 1, 2016, to June 30, 2018, for which she will present up to five lectures a year to university audiences around the world.

For more information on Middleton's research, visit **https://profile.usgs.gov/middletonb**. ☸

New Map Series Shows Physical Characteristics of the Seabed and the Distribution of Geologic Substrates off Boston, Massachusetts

By Page Valentine

The U.S. Geological Survey (USGS), in cooperation with the National Oceanic and Atmospheric Administration's National Marine Sanctuary Program, conducts seabed mapping and related research in the Stellwagen Bank National Marine Sanctuary region, an area of approximately 3,700 square kilometers (km^2) that is subdivided into 18 quadrangles. The region lies offshore of Boston, Massachusetts, extending from Cape Cod in the south to the southern part of Jeffreys Ledge in the north (see location map below).

Seven new online maps (see maps, right) portray the physical characteristics of the seabed in quadrangle 6 (211 km^2) at a scale of 1:25,000. The mapped region ranges in depth from 30 to 185 meters and includes the shallow eastern flank of Stellwagen Bank and a group of small banks and valleys of glacial origin that lie in deeper waters to the east. Interpretations of seabed substrates, topographic features, and geologic processes are based on: a) multibeam sonar bathymetric and backscatter imagery that show topography and the relative reflectivity (representing hardness and softness) of substrates; and b) sediment grain-size analyses and video and photographic imagery that provide data used to interpret the features and patterns observed in the sonar imagery. In all, data from 420 stations were analyzed, including sediment samples from 325 locations. The geology-based maps show the distribution of 10 substrate types. A geologic substrate is characterized not just by sediment grain-size composition (mud, sand, gravel), but also by surficial features (for example, ripples), sediment layering (for example, finer sediment partly covering coarser sediment), sediment movement, and water depth range. The methodology employed to delineate substrates is explained in the accompanying report.

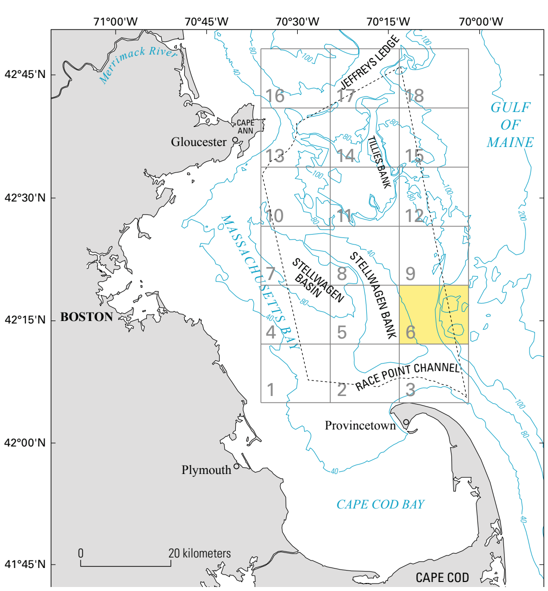
Three maps in this series focus on regional physical characteristics of the seabed such as topography (Map A), ruggedness (Map B), and backscatter (Map C). Four interpretive maps show the distribution of: geologic substrates, which range from boulder ridges to mobile, rippled, coarse-grained sand to immobile, muddy, fine-grained sand (Map D); substrate mobility (Map E); substrates dominated by fine- or coarse-grained sand (Map F); and substrate mud content (Map G).

The purpose of the map series is to provide a range of information about the distribution of physical attributes of the seabed at a scale of 1:25,000 (1 cm on the map represents 250 m on the seabed) that is justified by the density of data. High-resolution information will serve as a foundation for study of sediment transport and the ecology of vertebrate and invertebrate species that use these substrates as habitat, and for planning and managing development of this offshore region.

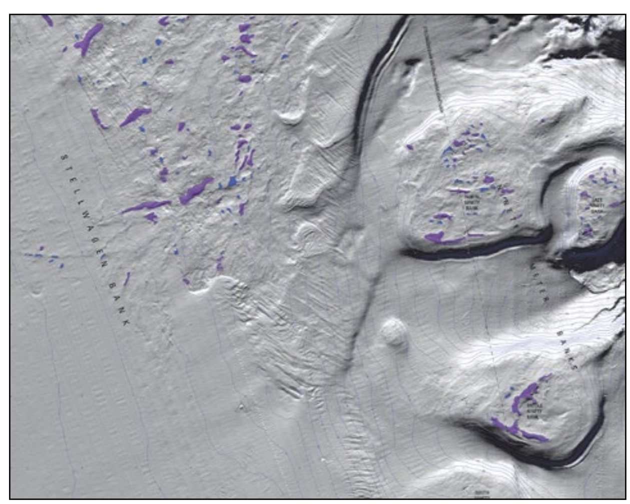
The maps were conceived and compiled by **Page Valentine**, **Leslie Gallea**, and **VeeAnn Cross**, all of the USGS Woods Hole Coastal and Marine Science Center, Woods Hole, Massachusetts.

The full citation for the map series is: Valentine, P.C. and Gallea, L.B., 2015, Seabed maps showing topography, ruggedness, backscatter intensity, sediment mobility, and the distribution of geologic substrates in quadrangle 6 of the Stellwagen Bank National Marine Sanctuary region offshore of Boston, Massachusetts: U.S. Geological Survey Scientific Investigations Map 3341, 10 sheets, scale 1:25,000, and 21-p. pamphlet, **http://dx.doi.org/10.3133/sim3341**. ☸

(New Map Series continued on page 15)

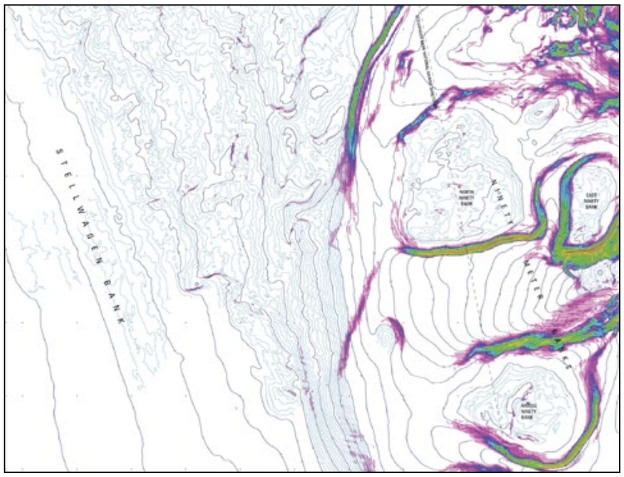


Shows the location of mapped area (highlighted in yellow) in the Stellwagen Bank region off Boston, Massachusetts.

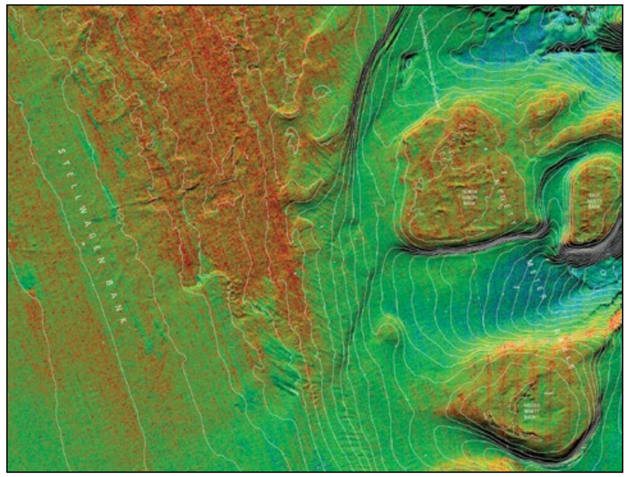


*From Map A: Sun-illuminated topographic imagery and boulder ridges (<**http://pubs.usgs.gov/sim/3341/downloads/sim3341_mapA.pdf**>).*

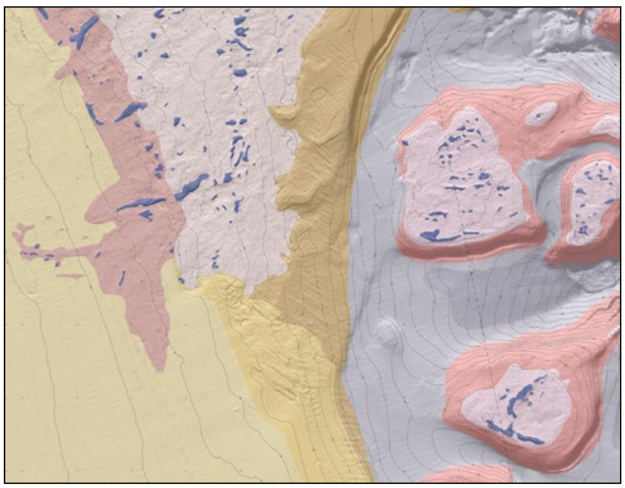
(New Map Series continued from page 14)



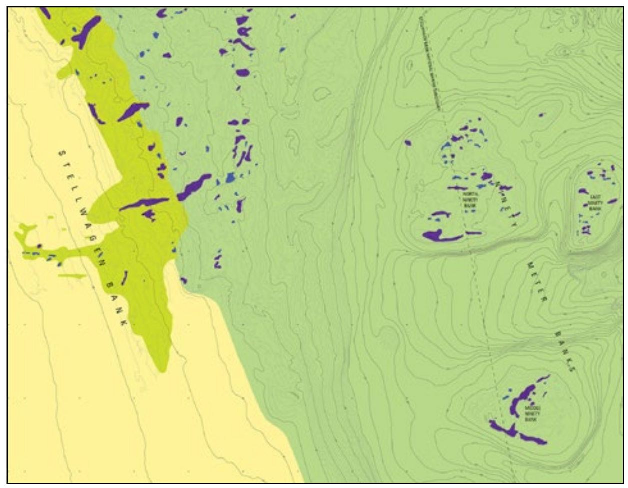
*From Map B: Seabed ruggedness (<**http://pubs.usgs.gov/sim/3341/downloads/sim3341_mapB.pdf**>).*



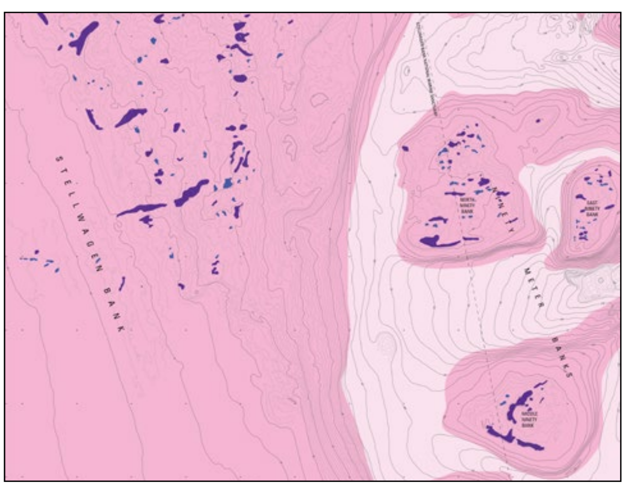
*From Map C: Seabed backscatter intensity (<**http://pubs.usgs.gov/sim/3341/downloads/sim3341_mapC.pdf**>).*



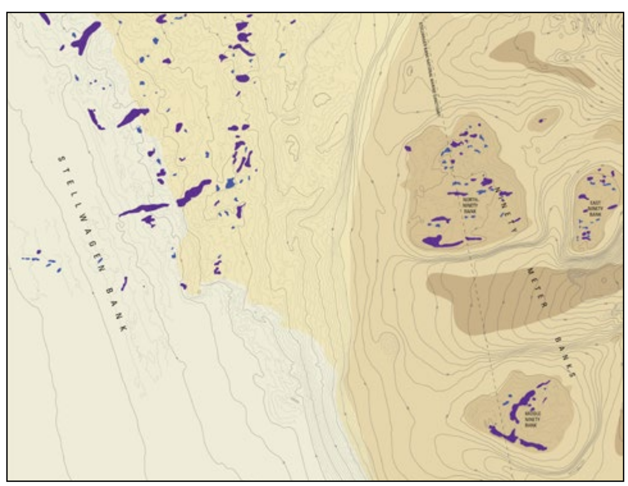
*From Map D: Geologic substrates (<**http://pubs.usgs.gov/sim/3341/downloads/sim3341_mapD_sheet4.pdf**>).*



*From Map E: Sediment mobility (<**http://pubs.usgs.gov/sim/3341/downloads/sim3341_mapE.pdf**>).*



*From Map F: Fine- and coarse-grained sand (<**http://pubs.usgs.gov/sim/3341/downloads/sim3341_mapF.pdf**>).*



*From Map G: Mud content (<**http://pubs.usgs.gov/sim/3341/downloads/sim3341_mapG.pdf**>).*

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Recent Publications continued on page 17)

Recent Publications continued from page 16)

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