ocean explorer
www.oceanexplorer.noaa.gov

Image captions/credits on Page 2.

lesson plan

Cradle of the Earthquake:
Exploring the Underwater San Andreas Fault 2010 Expedition

Sonar Simulation

(adapted from the Bonaire 2008: Exploring Coral Reef Sustainablility with New Technologies Expedition)

Focus

Side-scan sonar

Grade Level

7-8 (Earth Science/Physical Science)

Focus Question

How can side-scan sonar be used to locate objects underwater?

Learning Objectives

- Students will be able to describe side-scan sonar.
- Students will be able to compare and contrast side-scan sonar with other methods used to search for underwater objects.
- Students will be able to make inferences about the topography of an unknown and invisible landscape based on systematic discontinuous measurements of surface relief.

Materials

- ❑ Shoeboxes, one for each student group
- ❑ Plaster of Paris, 1 – 2 lb for each student group
- ❑ Woodworking awl or sharp nail, 3 – 4 mm diameter
- ❑ Masking tape
- ❑ Pingpong balls, 2 for each student group
- ❑ Wooden dowel, approximately 3 mm diameter, 30 cm long, one for each student group
- ❑ Colored pencils, five colors for each student group
- ❑ Ruler, one for each student group
- ❑ Graph paper
- ❑ Copies of *Sonar Simulation Activity*, one copy for each student group

Audio-Visual Materials

- ❑ Chalkboard, marker board, or overhead projector with transparencies for group discussions

Teaching Time

One 45-minute class period

Seating Arrangement

Groups of 2-4 students

Maximum Number of Students

32

Key Words

San Andreas Fault
Sonar
Topography

Background Information

NOTE: Explanations and procedures in this lesson are written at a level appropriate to professional educators. In presenting and discussing this material with students, educators may need to adapt the language and instructional approach to styles that are best suited to specific student groups.

At 5:12 am on April 18, 1906, Ernest Adams was thrown violently from his bed and watched in disbelief as the side of his San Francisco home crumbled to the ground. "I fell and crawled down the stairs amid flying glass and timber and plaster. When the dust cleared away I saw nothing but a ruin of a house and home that it had taken twenty years to build. I saw the fires from the city arising in great clouds and it was no time to mourn my loss so getting into what clothing I could find, I started on a run for Kearny St., five miles away... " (Adams, 1906).

In 1906, modern plate tectonic theory was several decades in the future, so no one who lived through the Great San Francisco Earthquake could know that their terrifying experience resulted from interaction between two large pieces of Earth's crust now known as the Pacific and North America Plates. These tectonic plates are portions of the Earth's outer crust (the lithosphere) about 5 km thick, as well as the upper 60 - 75 km of the underlying mantle. They move on a hot flowing mantle layer called the asthenosphere, which is several hundred kilometers thick. Heat within the asthenosphere creates convection currents (similar to the currents that can be seen if food coloring is added to a heated container of water). Movement of convection currents causes tectonic plates to move several centimeters per year relative to each other.

Where tectonic plates slide horizontally past each other, the boundary between the plates is known as a transform plate boundary. As the plates rub together, huge stresses are set up that can cause portions of the rock to break, resulting in earthquakes. Places where these breaks occur are called faults. The San Andreas fault exists along the transform plate boundary between the Pacific and North America Plates in California. The 1906 San Francisco Earthquake was caused by a 296 mile-long rupture along the San Andreas fault from the Mendocino Triple Junction to San Juan Bautista. A triple junction is a place where three of Earth's tectonic plates intersect. At the Mendocino

Images from Page 1 top to bottom:
San Francisco, California, Earthquake April 18, 1906. Downtown San Francisco showing residents watching fire after the 1906 earthquake. Photo by Ralph O. Hotz. April 1906. Image courtesy USGS.
http://libraryphoto.cr.usgs.gov/cgi-bin/show_picture.cgi?ID=ID.%20Hotz%2C%20P.E.%20%20104

A small bush of tubeworms. When tubeworm bushes are young, only endemic species of animals can colonize them. The presence of the mussels (*Bathymodiolis childressi*) in the center of the bush means that methane is seeping just below. Image courtesy Gulf of Mexico 2002, NOAA/OER.
http://oceanexplorer.noaa.gov/explorations/02mexico/background/communities/media/2tubesmussels.html

San Francisco, California, Earthquake April 18, 1906. Fault trace 2 miles north of the Skinner Ranch at Olema. View is north. 1906. Plate 10, U.S. Geological Survey Folio 193; Plate 3-A, U.S. Geological Survey Bulletin 324. Image courtesy USGS. (*Note: you may need to paste the link below into your browser to get to the image.*)
http://libraryphoto.cr.usgs.gov/cgi-bin/show_picture.cgi?ID=ID.%20Gilbert%2C%20G.K.%202933

Iceworms (*Hesiocaeca methanicola*) infest a piece of orange methane hydrate at 540 m depth in the Gulf of Mexico. During the Paleocene epoch, lower sea levels could have led to huge releases of methane from frozen hydrates and contributed to global warming. Today, methane hydrates may be growing unstable due to warmer ocean temperatures. Image courtesy Ian MacDonald.
http://oceanexplorer.noaa.gov/explorations/06mexico/background/plan/media/iceworms_600.jpg

Triple Junction, the Pacific Plate and North American Plate intersect with the Juan de Fuca Plate. Other types of plate boundaries include convergent boundaries, which are formed when tectonic plates collide more or less head-on; and divergent boundaries, which occur where plates are moving apart. View animations of different types of plate boundaries at: http://www.seed.slb.com/flash/science/features/earth/livingplanet/plate_boundaries/en/index.html.

Understanding that the 1906 quake resulted from the movement of tectonic plates leads quickly to the realization that these plates are still in motion; in fact, the San Andreas fault is the fastest moving fault in western North America. This realization inevitably leads to the question, "When will a major earthquake like the 1906 quake strike again?"

To help answer this question, geologists study the history of past earthquakes along the San Andreas fault system. These studies, as well as thousands of years of historical records from China and Japan, tell us that giant earthquakes on faults like the San Andreas tend to occur every few hundred years. This interval is thought to be the time required for motion between tectonic plates to build stresses to levels that produce large quakes. In general, this evidence suggests that a 1906-size earthquake is not likely to strike Northern California for at least 100 years. Still, studies also show that stress has built up again along the San Andreas Fault system. For 70 years following the 1906 earthquake, there were only low levels of seismic activity in Northern California. Then, between 1979 and 1984, there were three quakes with magnitudes of about 6; and in 1989 a major (Loma Prieta) earthquake with a magnitude of 6.9. A similar pattern of earthquake activity took place during the 70 years prior to the 1906 quake.

The Cradle of the Earthquake: Exploring the Underwater San Andreas Fault 2010 Expedition will improve our understanding of the history of great earthquakes and how they are interrelated by investigating portions of the great plate boundary fault that lie offshore; areas that have virtually never been observed or explored. The first step in this exploration is to prepare detailed maps of the entire offshore fault using multibeam and side-scan sonar. These maps, in turn, will help scientists identify areas within the fault to be investigated in greater detail using an autonomous underwater vehicle and a remotely operated vehicle to obtain high resolution photographs as well as samples of sediments and hard corals.

Sonar (which is short for SOund NAvigation and Ranging) systems are used to determine water depth, as well as to locate and identify underwater objects. In use, an acoustic signal or pulse of sound is transmitted into the water by a sort of underwater speaker known as a transducer. The transducer may be mounted on the hull of a ship, or may be towed in a container called a towfish. If the seafloor or other object is in the path of the sound pulse, the sound bounces off the object and returns an echo to the sonar transducer. The system measures the strength of the signal and the time elapsed between the emission of the sound pulse and the reception of the echo. This information is used to calculate the distance of the object, and an experienced operator can use the strength of the echo to make inferences about some of the object's characteristics. Hard objects, for example, produce stronger echoes that softer objects. This is a general description of active sonar. Passive sonar systems do not transmit sound pulses. Instead, they "listen" to sounds emitted from marine animals, ships, and other sources. Subbottom profiler systems are another type of sonar system that emits low frequency sound waves that can penetrate up to 50 meters into the seafloor. Visit http://oceanexplorer.noaa.gov/technology/tools/sonar/sonar.html for more information about sonar systems.

Side-scan sonar systems use transducers housed in a towfish, usually dragged near the sea floor, to transmit sound pulses directed toward the side of the ship, rather than straight down. Return echoes are continuously recorded and analyzed by a processing computer. These data are used to construct images of the sea floor made up of dark and light areas. These images can be used to locate seafloor features and possible obstructions to navigators, including shipwrecks. Multibeam sonar systems are used to make bathymetric maps and create three-dimensional images of the seafloor. Multibeam sonars send out multiple, simultaneous sonar beams in a fan-shaped pattern that is perpendicular to the ship's track. This allows the seafloor on either side of the ship to be mapped at the same time as well as the area directly below. In addition to information about bottom topography, sonar can also be used to obtain information about the water column above the bottom. The multi-frequency water column sonar can detect fishes and other organisms, and can be used to construct a three-dimensional image of biomass in survey areas. When combined with information from other sensors, this can reveal relationships between the geology, substrate, gas and fluid vents, and water column biota.

In this lesson, students will learn about side-scan sonar, and use mock sonar set-ups to experience some of the difficulties encountered when trying to locate objects or map the ocean floor.

Learning Procedure

Note: This lesson is adapted from the "Shoebox Bathymetry" activity on the Ocean World Web site, http://oceanworld.tamu.edu/educators/props_of_ocean/activities/PO_systems.htm.

1. To prepare for this lesson:
   - Review background essays for the Cradle of the Earthquake: Exploring the Underwater San Andreas Fault 2010 Expedition

(http://oceanexplorer.noaa.gov/explorations/10sanandreas)

- Prepare mystery bathymetry shoeboxes. Mix plaster of Paris, and pour a 1 – 2 cm thick layer into the bottom of each shoebox. Make irregular mounds of plaster in one area to simulate rough topography. Embed one pingpong ball somewhere in the rough topography, and another pingpong ball in a smoother area. Allow plaster to harden. Punch five rows of holes 3 – 4 mm in diameter in the lid of the shoebox with an awl or nail. Space the holes 2 cm apart over the surface of the lid. Temporarily fasten the lids to the boxes with masking tape.

2. Lead an introductory discussion of the Cradle of the Earthquake: Exploring the Underwater San Andreas Fault 2010 Expedition. You may want to show students some images from the U.S. Geological Survey's Photographic Library (http://libraryphoto.cr.usgs.gov/; click on "Earthquakes" in the left column). Discuss the importance of studying the timing and impacts of past earthquakes to help prepare for similar events in the future.

   Describe the role of underwater robots and side-scan sonar in surveying underwater portions of the San Andreas Fault. Explain that sonar is short for "sound navigation ranging," and uses sound waves to locate underwater objects by measuring the time it takes for a transmitted sound wave to be reflected back to its source. The sound wave is transmitted through a transducer, which is analogous to a speaker in a radio. Side-scan uses a transducer housed in a hollow container called a towfish that is towed through the water 10 to 20 feet above the bottom. The transducer emits sound waves to either side of the towfish, and measures the time it takes for the waves to be reflected back to the towfish. These measurements are processed into an image that resembles an aerial photograph, and can be viewed in real-time on a computer monitor aboard the towing vessel. A differentially corrected global positioning system (DGPS) is used to guide the towing vessel along predetermined search paths, as well as to identify points of interest on the side-scan image. This allows searchers to return to any point on the image for further investigation. Side-scan sonar does not depend upon light and can be used under conditions that would make searching by divers dangerous or impossible. Because it typically covers a swath of 60 to 120 feet at about 2 miles per hour, it is a very efficient way to search large areas. For these reasons, side-scan sonar has been used increasingly over the last few years to search for drowning victims.

3. Tell students that their assignment is to map an unexplored and invisible landscape. Distribute one copy of the *Sonar Simulation Activity* to each student group. When students have completed their bathymetry graphs, have each group show their graphs to the entire

class and report their conclusions about the mystery landscape. After each group has reported their conclusions, have them open their box, and compare the actual topography with their predictions.

4. When all groups have made their presentations, ask students how their investigations could be improved. Students should realize that this activity does not simulate side-scan sonar, or even conventional sonar; it is more like the centuries-old method used by mariners who lowered a lead weight attached to a measured line until the weight touched the bottom (or some object resting on the bottom). A conventional sonar system would provide a continuous record of depth directly beneath a ship. This would improve resolution along the search path, but there would still be gaps between the paths that are much greater than the area actually imaged. Side-scan sonar would fill in these gaps, and give an almost continuous picture of the search area. Students should also realize that rough topography can obscure other topographic features, so better resolution is especially important when there are boulders, reefs, or other irregular objects in a search area.

The BRIDGE Connection

www.vims.edu/bridge/ - Click on "Ocean Science Topics" in the navigation menu to the left, then "Geology" for resources on marine geology and plate tectonics.

The "Me" Connection

Ask students to imagine that they are asked to locate a small boat that has sunk in a nearby body water, and write a short essay describing the procedures and equipment they would use to complete this task.

Connections to Other Subjects

English/Language Arts, Earth Science

Assessment

Experimental notes and oral reports prepared in Step 3 provide opportunities for assessment.

Extensions

See the Cradle of the Earthquake: Exploring the Underwater San Andreas Fault 2010 Expedition Education Module for additional information, activities, and media resources about deepwater ecosystems and earthquakes associated with the San Andreas Fault.

Multimedia Discovery Missions

http://oceanexplorer.noaa.gov/edu/learning/welcome.html - Click on the link to Lessons 1, 2, and 4 for interactive multimedia presentations and Learning Activities on Plate Tectonics, Mid-Ocean Ridges, and Subduction Zones.

Other Relevant Lesson Plans from NOAA's Office of Ocean Exploration and Research

Mapping the Deep Ocean Floor (PDF, 1.5 Mb)
(from the INSPIRE: Chile Margin 2010 Expedition)
http://oceanexplorer.noaa.gov/explorations/10chile/background/edu/media/mapping.pdf

Focus: Bathymetric Mapping

Students create a two-dimensional topographic map from bathymetric survey data, create a three-dimensional model of seafloor topography from a two-dimensional topographic map, and interpret two- and three-dimensional topographic data.

I, Robot, Can Do That! (PDF, 315 kb)
(from the Lost City 2005 Expedition)
http://oceanexplorer.noaa.gov/explorations/05lostcity/background/edu/media/lostcity05_i_robot.pdf

Focus: Underwater Robotic Vehicles for Scientific Exploration (Physical Science/Life Science)

Students describe and contrast at least three types of underwater robots used for scientific explorations, discuss the advantages and disadvantages of using underwater robots in scientific explorations, and identify robotic vehicles best suited to carry out certain tasks.

Other Resources

The Web links below are provided for informational purposes only. Links outside of Ocean Explorer have been checked at the time of this page's publication, but the linking sites may become outdated or non-operational over time.

http://oceanexplorer.noaa.gov/explorations/10sanandreas – Web site for the Cradle of the Earthquake: Exploring the Underwater San Andreas Fault 2010 Expedition

http://celebrating200years.noaa.gov/edufun/book/welcome.html#book - A free printable book for home and school use introduced in 2004 to celebrate the 200th anniversary of NOAA; nearly 200 pages of lessons focusing on the exploration, understanding, and protection of Earth as a whole system

http://earthquake.usgs.gov/regional/nca/1906/18april/index.php – U.S. Geological Survey Web page about the 1906 San Francisco earthquake

Adams, E. 1906. Letter to Reed and Barton. The Virtual Museum of the City of San Francisco; http://www.sfmuseum.net/1906/ew3.html

http://www.ess.washington.edu/SEIS/PNSN/HAZARDS/CASCADIA/cascadia_event.html – Web page about the January, 1700 Cascadia Subduction Zone earthquake and tsunami from the Pacific Northwest Seismic Network; includes discussion of various lines of evidence that help pinpoint the date of past earthquakes

http://www.sciencecourseware.com/eec/Earthquake/ – Web site for Virtual Earthquake, an interactive activity designed to introduce concepts of how an earthquake epicenter is located and how the magnitude of an earthquake is determined

Paull, C.K., B. Hecker, C. Commeau, R.P. Feeman-Lynde, C. Nuemann, W.P. Corso, G. Golubic, J. Hook, E. Sikes, and J. Curray. 1984. Biological communities at Florida Escarpment resemble hydrothermal vent communities. Science 226:965-967 – Early report on cold seep communities.

National Science Education Standards

Content Standard A: Science As Inquiry
- Abilities necessary to do scientific inquiry
- Understandings about scientific inquiry

Content Standard D: Earth and Space Science
- Structure of the Earth system

Content Standard E: Science and Technology
- Abilities of technological design

Content Standard F: Science in Personal and Social Perspectives
- Natural hazards
- Risks and benefits

Ocean Literacy Essential Principles and Fundamental Concepts

Essential Principle 1.
The Earth has one big ocean with many features.
Fundamental Concept h. Although the ocean is large, it is finite and resources are limited.

Essential Principle 6.
The ocean and humans are inextricably interconnected.
Fundamental Concept b. From the ocean we get foods, medicines, and mineral and energy resources. In addition, it provides jobs, supports our nation's economy, serves as a highway for transportation of goods

and people, and plays a role in national security.

Fundamental Concept e. Humans affect the ocean in a variety of ways. Laws, regulations and resource management affect what is taken out and put into the ocean. Human development and activity leads to pollution (such as point source, non-point source, and noise pollution) and physical modifications (such as changes to beaches, shores and rivers). In addition, humans have removed most of the large vertebrates from the ocean.

Fundamental Concept f. Coastal regions are susceptible to natural hazards (such as tsunamis, hurricanes, cyclones, sea level change, and storm surges).

Fundamental Concept g. Everyone is responsible for caring for the ocean. The ocean sustains life on Earth and humans must live in ways that sustain the ocean. Individual and collective actions are needed to effectively manage ocean resources for all.

Essential Principle 7.
The ocean is largely unexplored.

Fundamental Concept a. The ocean is the last and largest unexplored place on Earth—less than 5% of it has been explored. This is the great frontier for the next generation's explorers and researchers, where they will find great opportunities for inquiry and investigation.

Fundamental Concept b. Understanding the ocean is more than a matter of curiosity. Exploration, inquiry and study are required to better understand ocean systems and processes.

Fundamental Concept c. Over the last 40 years, use of ocean resources has increased significantly, therefore the future sustainability of ocean resources depends on our understanding of those resources and their potential and limitations.

Fundamental Concept d. New technologies, sensors and tools are expanding our ability to explore the ocean. Ocean scientists are relying more and more on satellites, drifters, buoys, subsea observatories and unmanned submersibles.

Fundamental Concept f. Ocean exploration is truly interdisciplinary. It requires close collaboration among biologists, chemists, climatologists, computer programmers, engineers, geologists, meteorologists, and physicists, and new ways of thinking.

Send Us Your Feedback

We value your feedback on this lesson.
Please send your comments to:
oceanexeducation@noaa.gov

For More Information

Paula Keener, Director, Education Programs
NOAA's Office of Ocean Exploration and Research
Hollings Marine Laboratory
331 Fort Johnson Road, Charleston SC 29412
843.762.8818 843.762.8737 (fax)
paula.keener-chavis@noaa.gov

Acknowledgements

This lesson was developed by Mel Goodwin, PhD, Marine Biologist and Science Writer. Design/layout by Coastal Images Graphic Design, Charleston, SC. If reproducing this lesson, please cite NOAA as the source, and provide the following URL: http://oceanexplorer.noaa.gov/

Student Worksheet
Sonar Simulation Activity

1. Assign a different color to each of the five rows of holes on your shoebox.

2. Select one row (it doesn't matter which one). Insert the wooden dowel into each hole in the row and measure the depth from the surface (lid) by marking it with your finger, pulling the dowel out, and measuring the distance with your ruler. Record this measurement on your graph paper in the appropriate color. The x-axis of your graph paper should correspond to the numbers of the holes in each row (the first hole should correspond to number 1 on the x-axis, the second hole to number 2, etc.). The y-axis of your graph should correspond to the depth measurements.

3. Continue doing Step 2 until the depth through all holes in the first row has been measured. Connect the dots on your graph with the appropriate color.

4. Based on this one row of measurements, predict what the topography is like inside your shoebox. Record your predictions.

5. Repeat Step 2 on the next row of holes using a different color pencil. Record data on the same graph used for the first row, using the appropriate color.

6. Examine your data for the second row. Are they the same? What does this new information reveal? Record any changes in your predictions.

7. Repeat Steps 5 and 6 for the remaining three rows of holes. Now wait for further instructions from your teacher.