



## Aegean and Black Sea 2006 Expedition

# Ping!

*(adapted from the 2003 Steamship Portland 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 lbs for each student group
- Container and mixing stick for plaster of Paris, 1 for each student group (paper containers and stirring sticks for mixing paint are ideal)
- 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

- Marker board and markers or overhead projector and transparencies for group discussions

### TEACHING TIME

Three 45-minute class periods – one to build and dry, one to explore and graph, one for reports

### SEATING ARRANGEMENT

Groups of two to four students

### MAXIMUM NUMBER OF STUDENTS

30

### KEY WORDS

Marine archaeology  
Shipwreck  
Sonar  
Side-scan sonar  
Topography

### BACKGROUND INFORMATION

The geographic region surrounding the Aegean and Black Seas has been the stage for many spectacular performances in Earth's geologic and human history. Human activities on the region's stage began during Paleolithic times; artifacts discovered near Istanbul are believed to be at least 100,000 years old. Well-known Aegean

cultures include the Minoans (ca 2,600 – 1,450 BC), Mycenaeans (ca 1,600 – 1,100 BC), Ancient Greeks (776 – 323 BC), and Hellenistic Greeks (323 – 146 BC). Istanbul—"the only city that spans two continents"—has been a crossroads of travel and trade for more than 26 centuries. Mariners have traveled the Aegean and Black Seas since Neolithic ("Stone Age" times; 6,500 – 3,200 BC), probably for a combination of purposes, including trading, exploration, and warfare.

Interactions between these cultures and many others were often violent and destructive. So, too, were interactions with geological processes. One of the most dramatic and destructive events was the eruption of a volcano in a small group of Aegean islands called Thera (also known as Santorini), sometime between 1,650 and 1,450 BC. Estimated to be four times more powerful than the Krakatoa volcano of 1883, the eruption left a crater 18 miles in diameter, spewed volcanic ash throughout the Eastern Mediterranean, and may have resulted in global climactic impacts. Accompanied by earthquakes and a tsunami, the volcano destroyed human settlements, fleets of ships, and may have contributed to the collapse of the Minoan civilization on the island of Crete, 110 km to the south.

Interactions with other geological processes may have been equally disastrous. In 1997, geologists William Ryan and Walter Pitman published a theory in which the Black Sea was inundated around 5,600 BC by flood waters from the Mediterranean passing through the Straits of Bosphorus at Istanbul. Such a deluge, if it occurred, would have been disastrous for human settlements along the Black Sea shoreline and might have provided an origin for accounts of cataclysmic floods in Christianity and other cultures. Subsequent research has neither proved nor disproved the Black Sea deluge theory, but in 2000, Robert Ballard discovered remains of a wooden structure that may have been part of an ancient seaport 95 meters below the surface of the Black Sea. This may be one of

the best places in the world to look for remains of ancient civilizations, because the deep waters of the Black Sea contain almost no oxygen, so the biological organisms that normally attack such relicts cannot live in this environment. Additional support for the idea comes from radiocarbon dating of the shells of freshwater molluscs sampled at the "ancient shoreline" site. These analyses show the age of the freshwater molluscs to be about 7,500 years, while saltwater species from the same area appeared about 6,900 years ago. In other words, the transition from fresh to saline conditions was fairly rapid. More recent analyses of other data conclude that while this flood did occur, it was not as catastrophic as suggested by Ryan and Pitman, and a more severe flooding event took place 16,000 - 13,000 years ago (see [http://gsa.confex.com/gsa/2003AM/finalprogram/abstract\\_58733.htm](http://gsa.confex.com/gsa/2003AM/finalprogram/abstract_58733.htm)).

Notwithstanding debate about the relative significance of ancient floods, the anoxic waters of the Black Sea may still reveal a great deal about seafaring activities of "Stone Age" peoples. Finding well-preserved marine archaeological sites, studying ancient maritime trade, and exploring the history of the Thera volcano are the primary goals of the Aegean and Black Sea 2006 Expedition. Major Expedition activities are divided into two segments. In the first segment, side-scan sonar, subbottom profiling, and multibeam bathymetric technology are used to survey selected portions of the Aegean, Black, and Eastern Mediterranean Seas. The second segment uses remotely operated vehicles (ROVs) for direct visual observation of promising sites located during the first segment. 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 "Shoebathymetry" activity on the Ocean World Web site, [http://oceanworld.tamu.edu/educators/props\\_of\\_ocean/activities/PO\\_systems.htm](http://oceanworld.tamu.edu/educators/props_of_ocean/activities/PO_systems.htm).]

1. To prepare for this lesson
  - a. review the background essays for the Aegean and Black Sea 2006 Expedition at <http://oceanexplorer.noaa.gov/explorations/06blacksea/>. You may also want to review information about side-scan sonar at <http://oceanexplorer.noaa.gov/technology/tools/sonar/sonar.html>.
  - b. 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. Introduce the Aegean and Black Sea 2006 Expedition, emphasizing some of the reasons that scientists are interested in the Black Sea, and the probable existence of undiscovered marine archeological sites that could reveal a great deal about the history of the Aegean/Black Sea area. Tell students that the first phase of the Expedition will involve searching large areas of the seafloor for promising archaeological sites using side-scan sonar.

Say that sonar is short for “sound navigation ranging,” and uses sound waves to locate underwater objects by analyzing the echo that is bounced off the seafloor or other objects and reflected back to the sound’s source. Sound waves are 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 continuously the strength of the return echo to create an of the ocean bot-

tom. 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. Images produced by echoes from hard objects (such as rocks or shipwrecks) are darker than images produced by echoes soft objects (such as sediments).

- 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.

Most side scan systems do not provide information about depth. Multibeam sonar systems measure and record the time for an acoustic signal to travel from the transducer to a reflecting object and back to the receiver (rather than measuring the strength of the return echo as in sidescan systems. Transducers for multibeam sonars are generally attached to a vessel, rather than a towfish, so the area of seafloor covered by these systems depends upon the depth of the water.

3. Tell students that their assignment is to map an unexplored and invisible landscape. Distribute one copy of “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 what is being searched for, so better resolution is especially important when there are boulders, reefs, or other irregular objects in a search area.

#### THE BRIDGE CONNECTION

<http://www.vims.edu/bridge/archive1200.html/>

#### THE "ME" CONNECTION

Ask students to imagine that they are to locate a small boat that has sunk in a nearby body of 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 4 provide opportunities for assessment.

#### EXTENSIONS

Have students visit <http://oceanexplorer.noaa.gov/explorations/06blacksea> to keep up to date with the latest Aegean and Black Sea 2006 Expedition discoveries.

#### RESOURCES

##### NOAA Learning Objects

<http://www.learningdemo.com/noaa/> – Click on the links to Lessons 1, 2, and 4 for interactive multimedia presentations and Learning Activities on Plate Tectonics, Mid-Ocean Ridges, and Subduction Zones.

##### Other Relevant Lessons from the Ocean Exploration Program

##### Mapping Deep-sea Habitats in the Northwestern Hawaiian Islands

[http://www.oceanexplorer.noaa.gov/explorations/02hawaii/background/education/media/nwhi\\_mapping.pdf](http://www.oceanexplorer.noaa.gov/explorations/02hawaii/background/education/media/nwhi_mapping.pdf)

(7 pages, 80kb) (from the 2002 Northwestern Hawaiian Islands Expedition)

Focus: Bathymetric mapping of deep-sea habitats (Earth Science - This activity can be easily modified for Grades 5-6)

In this activity, students will be able to create a two-dimensional topographic map given bathymetric survey data, will create a three-dimensional model of landforms from a two-dimensional topographic map, and will be able to interpret two- and three-dimensional topographic data.

##### How Does Your Magma Grow?

[http://www.oceanexplorer.noaa.gov/explorations/05galapagos/background/edu/media/05galapagos\\_magma.pdf](http://www.oceanexplorer.noaa.gov/explorations/05galapagos/background/edu/media/05galapagos_magma.pdf)

(6 pages, 224k) (from the 2005 Galapagos: Where Ridge Meets Hotspot Expedition)

Focus: Hot spots and midocean ridges (Physical Science)

In this activity, students will identify types of plate boundaries associated with movement of the Earth's tectonic plates, compare and contrast volcanic activity associated with spreading centers and

hot spots, describe processes which resulted in the formation of the Galapagos Islands, and describe processes that produce hydrothermal vents.

### It's Going to Blow Up!

[http://oceanexplorer.noaa.gov/explorations/05fire/background/edu/media/rof05\\_explosive.pdf](http://oceanexplorer.noaa.gov/explorations/05fire/background/edu/media/rof05_explosive.pdf)

(10 pages, 1.6Mb) (from the New Zealand American Submarine Ring of Fire 2005 Expedition)

Focus: Volcanism on the Pacific Ring of Fire (Earth Science)

Students will be able to describe the processes that produce the "Submarine Ring of Fire;" will be able to explain the factors that contribute to explosive volcanic eruptions; will be able to identify at least three benefits that humans derive from volcanism; will be able to describe the primary risks posed by volcanic activity in the United States; and will be able to identify the volcano within the continental U.S. that is considered most dangerous.

### Come on Down!

[http://oceanexplorer.noaa.gov/explorations/02galapagos/background/education/media/gal\\_gr7\\_8\\_11.pdf](http://oceanexplorer.noaa.gov/explorations/02galapagos/background/education/media/gal_gr7_8_11.pdf)

(6 pages, 464k) (from the 2002 Galapagos Rift Expedition)

Focus: Ocean Exploration

In this activity, students will research the development and use of research vessels/vehicles used for deep ocean exploration; calculate the density of objects by determining the mass and volume; and construct a device that exhibits neutral buoyancy.

### OTHER RESOURCES AND LINKS

<http://oceanexplorer.noaa.gov/explorations/06blacksea> – Web site for the Aegean and Black Sea 2006 Expedition

<http://www.immersionpresents.org/> – Immersion Presents Web site; click on "Ancient Eruptions!" for more information about the Aegean and Black Sea 2006 Expedition, images, and educational activities

<http://www.ngdc.noaa.gov/paleo/ctl/clihis10k.html> – Timeline for last 10,000 years from NOAA's Paleoclimatology Web site

<http://pubs.usgs.gov/pdf/planet.html> – "This Dynamic Planet," map and explanatory text showing Earth's physiographic features, plate movements, and locations of volcanoes, earthquakes, and impact craters

[http://disc.gsfc.nasa.gov/oceancolor/scifocus/oceanColor/dead\\_zones.shtml](http://disc.gsfc.nasa.gov/oceancolor/scifocus/oceanColor/dead_zones.shtml) – Web page from NASA about "Creeping Dead Zones," including SeaWiFS satellite imagery

<http://news.nationalgeographic.com/news/2000/12/122800blacksea.html> – National Geographic Web site, "Ballard Finds Traces of Ancient Habitation Beneath Black Sea"

<http://blacksea.orlyonok.ru/blacksea.shtml> – Web site of the Living Black Sea Marine Environmental Education Program in the Russian Federal Children Center Orlyonok

Friedrich, W. L.. 2000. *Fire in the Sea. The Santorini Volcano: Natural History and the Legend of Atlantis*. Translated by Alexander R. McBirney. Cambridge University Press. 258 pp.

Ryan, W. and W. Pitman. 1999. *Noah's Flood: The New Scientific Discoveries About the Event That Changed History*. Simon and Schuster. New York.

Yanko-Hombach, V. 2003. "Noah's Flood" and the late quaternary history of the Black Sea and its adjacent basins: A critical overview of the flood hypotheses. Paper presented at the Geological Society of America Annual Meeting, November 2–5, 2003, Seattle, WA (abstract available online at [http://gsa.confex.com/gsa/2003AM/finalprogram/abstract\\_58733.htm](http://gsa.confex.com/gsa/2003AM/finalprogram/abstract_58733.htm)).

[http://ina.tamu.edu/ub\\_main.htm](http://ina.tamu.edu/ub_main.htm) – Web site with information about the excavation of a Bronze Age shipwreck at Uluburun, Turkey

[http://projectsx.dartmouth.edu/history/bronze\\_age/](http://projectsx.dartmouth.edu/history/bronze_age/) – Dartmouth University Web site, “Prehistoric Archaeology of the Aegean,” with texts, links to other online resources, and numerous bibliographic references

<http://score.rims.k12.ca.us/activity/bubbles/> – Marine archaeology activity guide based on investigations of the wreck of a Spanish galleon; from the Schools of California Online Resources for Education Web site

<http://www.gomr.mms.gov/homepg/lagniapp/shipwreck/>  
– US Department of the Interior Minerals Management Service publication, “Historic Shipwrecks of the Gulf of Mexico: A Teacher’s Resource”

### NATIONAL SCIENCE EDUCATION STANDARDS

#### Content Standard A: Science As Inquiry

- Abilities necessary to do scientific inquiry
- Understanding 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 2.

**The ocean and life in the ocean shape the features of the Earth.**

- *Fundamental Concept b.* Sea level changes over time have expanded and contracted continental shelves, created and destroyed

inland seas, and shaped the surface of land.

- *Fundamental Concept e.* Tectonic activity, sea level changes, and force of waves influence the physical structure and landforms of the coast.

#### Essential Principle 6.

**The ocean and humans are inextricably interconnected.**

- *Fundamental Concept a.* The ocean affects every human life. It supplies freshwater (most rain comes from the ocean) and nearly all Earth’s oxygen. It moderates the Earth’s climate, influences our weather, and affects human health.
- *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 c.* The ocean is a source of inspiration, recreation, rejuvenation and discovery. It is also an important element in the heritage of many cultures.
- *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 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:

[oceaneducation@noaa.gov](mailto:oceaneducation@noaa.gov)

### FOR MORE INFORMATION

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## Student Handout

### 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.