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PHAEDRA 2006:

Partnership for Hellenic-American Exploration in the Deep Regions of the Aegean

Mapping the Aegean Seafloor

(adapted from the 2002 Northwestern Hawaiian Islands Expedition)

Focus
Bathymetric mapping of deepsea bottom features

Grade Level
7-8 (Earth Science)

Focus Question
How can deep-sea areas of the Aegean Sea be mapped to locate shipwrecks and unusual geologic features?

Learning Objectives
Students will be able to create a two-dimensional topographic map given bathymetric survey data.

Students will be able to create a three-dimensional model of landforms from a two-dimensional topographic map.

Students will be able to interpret two- and three-dimensional topographic data.

Materials
- ❒ Copies of "Aegean Submarine Volcano Bathymetric Data;" one for each student group
- ❒ Copies of "Bathymetric Data Reduction Sheet;" one for each student group
- ❒ Tracing paper
- ❒ Pieces of foamcore display board, seven for each student group; 8-1/2" x 11" x 5/32" thick or 11" x 17" x 1/4" thick if students' maps are enlarged 200% (see Learning Procedure, Step 2; these thicknesses will approximate the correct vertical scale)
- ❒ Glue, preferably spray type used for mounting photographs
- ❒ Sharp scissors or X-Acto knives for cutting foam-core

Audio/Visual Materials
- ❒ None

Teaching Time
Two 45-minute class periods

Seating Arrangement
Groups of four students

Maximum Number of Students
32

Key Words
Volcano
Shipwreck
Underwater archaeology
Aegean
Bathymetry

Background Information
"Man hoisted sail before he saddled a horse. He poled and paddled along rivers and navigated the open seas before he traveled on wheel along a road. Watercraft were the first of all vehicles." Thor Heyerdahl, *Early Man and the Ocean* (Doubleday, 1979)

Mariners have travelled the Aegean Sea since Neolithic times (the Stone Age: 6,500 – 3,200 BC). Motives for their voyages ranged from trading to exploration to warfare, making seafaring prominent in the history of cultures that 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). Remnants of ancient ocean voyages (i.e., shipwrecks) can provide information about trading patterns, sociopolitical networks, technological development and many other unique insights into these cultures, but a variety of factors makes it difficult to find such remnants. One problem is that interactions between cultures were not always peaceful, and destroying important shipping assets would have been an obvious step toward conquering an opponent.

Another obstacle is the same feature that makes ancient shipwrecks so valuable: their age. In addition to increasing the severity of deterioration by biological and chemical processes, the passage of time also increases the likelihood that ancient shipwrecks will be impacted by natural disasters. The southern Aegean region has experienced numerous severe volcanic events and tsunamis, including the eruption of a volcano near a small island called Thera (also known as Santorini), sometime between 1,650 and 1,450 BC. This eruption is estimated to have been four times more powerful than the Krakatoa volcano of 1883, left a crater 18 miles in diameter, spewed volcanic ash throughout the Eastern Mediterranean, and may have resulted in global climatic impacts. Coupled with earthquakes and a tsunami, the volcano destroyed human settlements, fleets of ships, and may have contributed to the collapse of the Minoan civilization. More recently, the 1650 AD eruption of the Columbo volcano—7 km to the northeast of Thera—produced ash, pumice, toxic gases, and a tsunami that devastated the coasts of surrounding islands.

Even if ancient shipwrecks survive natural disasters (and those caused by humans), finding, exploring and scientifically studying these sites are complicated by the fact that much of the Aegean Sea is relatively deep. Total darkness and an environment that is extremely hostile to humans have, until recently, been obstacles that are virtually insurmountable. Technological advances over the past decade, though, have made deep water archaeology a much more feasible endeavor. The PHAEDRA 2006 Expedition will use the SeaBED Autonomous Underwater Vehicle to search for deepwater shipwrecks, as well as conduct precise geological and chemical surveys in the vicinity of underwater volcanoes in the Aegean Sea. "Autonomous Underwater Vehicle" (AUV) means that this is a self-contained underwater robot that operates without a physical cable or tether such as those used on remotely operated vehicles (ROVs). SeaBED is designed specifically to provide precise maps and high-resolution three-dimensional color images of seafloor features, as well as to carry equipment for measuring physical and chemical properties of the surrounding seawater. Using SeaBED to map and document survey sites frees archaeologists from tedious measuring and sketching tasks and allows them to concentrate on interpreting survey results. For more information about SeaBED, visit http://www.whoi.edu/institutes/doei/general/news_seabed.pdf.

This expedition is an unusual collaboration between four U.S. research institutions and the Greek Ephorate of Underwater Antiquities (Hellenic Ministry of Culture) and Hellenic Centre for Marine Research. Scientists from Woods Hole Oceanographic Institution, Massachusetts Institute of Technology, Franklin W. Olin College of Engineering, and Johns Hopkins University will work with their Greek counterparts to use underwater robots to make detailed archaeological surveys of two ancient shipwrecks in deep water. One of these is believed to be the wreck of a Classical or Hellenistic ship that lies in a depth of about 500 m off the island of Hythnos in the central Aegean Sea. The other is believed to be the remains of a Byzantine period vessel that sank in 110 m of water off Porto Kuofo in the northern Aegean.

A third survey area will focus on a portion of the Aegean seafloor that scientists believe was unaffected by the Theran eruption and may consequently contain very ancient shipwrecks that have not yet been discovered. This area is close to the Columbo volcano, but has never been explored. To learn more about volcanic processes in this area, surveys will precisely map the seafloor and gather chemical data that will provide clues about volcanic activity as well as unusual geologic features such as cold seeps and volcanic vents.

Bathymetric maps of these areas will be created with multibeam and side scan sonars mounted on the SeaBED AUV or towed behind a research vessel. These sonars use transducers (a sort of combination microphone/loudspeaker) to send out pulses of sound in a fan-shaped pattern, and then record sounds reflected from the seafloor. These systems collect high resolution water-depth data as well as the amount of sound energy returned from the seafloor (called "backscatter"), which can help identify different materials (such as rock, sand, or mud) on the seafloor. All data are collected in digital form, which allows them to be processed by computer to produce maps, three dimensional models, or even "fly-by" videos that simulate a trip across the area being mapped in a high-speed submersible! Topographic maps are one of the most common outputs from these systems. On these maps, areas with the same depth are connected by lines, so that mountains (or valleys) are shown as a series of concentric, irregular closed curves. Curves that are close together indicate steep topography, while curves that are farther apart show more gentle slopes.

This activity focuses on how topographic maps are created from bathymetric data. Students will construct a three-dimensional model of a hypothetical Aegean submarine volcano from their topographic maps to help visualize the actual form of the volcano.

Learning Procedure

1. To prepare for this lesson, review the background essays for the PHAEDRA 2006 Expedition at http://oceanexplorer.noaa.gov/explorations/06greece/. If students will not have access to the internet for research, you will also need to download suitable materials, or confirm that such materials are available in libraries to which students have access.

2. Introduce the PHAEDRA 2006 Expedition, and discuss some of the reasons that scientists are interested in finding shipwrecks in the Aegean Sea.

3. Distribute copies of "Aegean Volcano Bathymetric Data" and "Bathymetric Data Reduction Sheet" to each student group. Tell the students that the bathymetric data are part of a data set that was produced by a research vessel using multibeam bathymetry. Be sure students understand that each data point represents the depth of water below the research vessel when the vessel was at the location described by the grid coordinates. Each grid cell interval corresponds to one minute of latitude or longitude. Note that for the purposes of this exercise, we are not dealing with all of the side-scan data, which would include more than a hundred additional depth readings in each grid cell and would be much more difficult to process without computer analysis.

   Have each group enter the depth readings from the bathymetric data sheet into the corresponding grid cells on the "Bathymetric Data Reduction Sheet." Next, have the students draw contour lines on the Data Reduction Sheet for depths of 1,000 m, 2,000 m, 3,000 m, and 4,000 m. Tell the students to assume that the depth reading was taken at the center of each grid cell (indicated on the Data Reduction Sheet by the light crossed diagonal lines). In most cases, students will have to interpolate the position of the contour lines; for example, if one grid cell has a depth reading of 2,800 m and an adjacent cell has a depth reading of 3,200 m, students should assume that the 3,000 m contour line passes halfway between the center points of the two cells. Once these three contour lines are drawn, have students draw intermediate contour lines at 500 m intervals (i.e., 1,500 m, 2,500 m, and 3,500 m). When students have completed their contour maps, have them make a master tracing, and seven photocopies. If you want them to make larger models, they can enlarge their master tracing on the photocopier.

4. Have the students mount each copy of their contour map onto a piece of foamcore. Be sure to use enough glue to cover the entire surface of the foamcore. Next, students should prepare the seven layers of their three-dimensional model by cutting along the 4,000 m contour line on one mounted map, then cutting along the 3,500 m contour on the next mounted map, and so on until seven layers have been cut out corresponding to each of the seven contour lines constructed on the Data Reduction Sheet. If students are using X-Acto knives, be sure to have a suitable backing (heavy cardboard, cutting board, etc.) to protect work surfaces.

5. Starting with the 4,000 m contour, carefully glue successive contours together to build the three-dimensional model of the volcano.

6. Using the models the students have produced, discuss the advantages of various locations on the volcano for diving missions: flat regions are more likely to have accumulations of sediment, and will provide different habitats than very steep areas. On the other hand, steep areas obviously have a greater range of depths within a short distance, so these are better sites to study how depth influences the distribution of various species. Identify areas that are likely to offer a variety of habitat types within a short distance. These offer some of the best opportunities to get the most out of limited diving time.

The Bridge Connection

http://www.vims.edu/bridge/archive1200.html – Activities and links about shipwrecks

www.vims.edu/bridge/ – Click on "Ocean Science Topics" then "Marine Geology." Enter http://www.vims.edu/bridge/archive0799.html for directions for preparing a three-dimensional plot of any part of the Earth's surface.

The "Me" Connection

Have students write a first-hand account of an exploratory mission to the Aegean volcano, referring to topographic features revealed by their model.

Connections to Other Subjects

English/Language Arts, Mathematics

Assessment

Volcano models and group discussions (Step 6) provide opportunities for assessment.

Extensions

Have students visit http://oceanexplorer.noaa.gov/explorations/06greece/ to keep up with the latest discoveries from the PHAEDRA 2006 Expedition.

Resources

NOAA Learning Objects

http://www.learningdemo.com/noaa/ – Click on the links to Lessons 1, 2, 4 and 5 for interactive multimedia presentations and Learning Activities on Plate Tectonics, Mid-Ocean Ridges, Subduction Zones and Chemosynthesis and Hydrothermal Vent Life.

Other Relevant Lessons from the Ocean Exploration Program

Ping!

http://oceanexplorer.noaa.gov/explorations/06blacksea/background/edu/media/06blacksea_ping.pdf
(from the Aegean and Black Sea 2006 Expedition)

Focus: Side scan sonar (Earth Science/Physical Science)

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

My Friend, The Volcano

http://oceanexplorer.noaa.gov/explorations/06blacksea/background/edu/media/06blacksea_friendvol.pdf
(from the Aegean and Black Sea 2006 Expedition)

Focus: Ecological impacts of volcanism (Life Science/Earth Science)

Students will be able to describe at least three beneficial impacts of volcanic activity on marine ecosystems, and will be able to explain the overall tectonic processes that cause volcanic activity.

Come on Down!

http://oceanexplorer.noaa.gov/explorations/02galapagos/background/education/media/gal_gr7_8_l1.pdf
(6 pages, 464k) (from the 2002 Galapagos Rift Expedition)

Focus: Ocean Exploration

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.

It's Going to Blow Up!

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.

How Does Your Magma Grow?

http://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)

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.

Other Resources and Links

http://oceanexplorer.noaa.gov/explorations/06greece/ – Web site for the PHAEDRA 2006 Expedition

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://geopubs.wr.usgs.gov/fact-sheet/fs013-00/fs013-00.pdf – Fact sheet on multi-beam mapping

http://newton.physics.wwu.edu:8082/jstewart/scied/earth.html – Earth science education resources http://www.sciencegems.com/earth2.html – Science education resources

http://www-sci.lib.uci.edu/HSG/Ref.html – References on just about everything

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
- Understandings about science and technology

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

Ocean Literacy Essential Principles and Fundamental Concepts

Essential Principle 1.
The Earth has one big ocean with many features.
- *Fundamental Concept b.* An ocean basin's size, shape and features (such as islands, trenches, mid-ocean ridges, rift valleys) vary due to the movement of Earth's lithospheric plates. Earth's highest peaks, deepest valleys and flattest vast plains are all in the ocean.

Essential Principle 6.
The ocean and humans are inextricably interconnected.
- *Fundamental Concept f.* Coastal regions are susceptible to natural hazards (such as tsunamis, hurricanes, cyclones, sea level change, and storm surges).

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:
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For More Information

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Student Handout

Aegean Submarine Volcano Bathymetric Data

Grid Cell (row, column)	Depth (m)	Grid Cell (row, column)	Depth (m)	Grid Cell (row, column)	Depth (m)	Grid Cell (row, column)	Depth (m)
1,1	no data	3,10	2400	6,4	4000	8,13	3200
1,2	no data	3,11	2000	6,5	3400	8,14	3200
1,3	no data	3,12	1900	6,6	2700	8,15	2800
1,4	4600	3,13	2000	6,7	2000	9,1	4400
1,5	4400	3,14	2100	6,8	1800	9,2	4000
1,6	4400	3,15	2200	6,9	1600	9,3	3600
1,7	4000	4,1	no data	6,10	1300	9,4	3400
1,8	3800	4,2	no data	6,11	1200	9,5	3900
1,9	3600	4,3	4400	6,12	1700	9,6	4000
1,10	3300	4,4	3800	6,13	2000	9,7	3800
1,11	2700	4,5	3500	6,14	2200	9,8	3700
1,12	2400	4,6	3200	6,15	2000	9,9	3600
1,13	2500	4,7	2800	7,1	4500	9,10	3800
1,14	2600	4,8	2800	7,2	4400	9,11	3600
1,15	2800	4,9	2300	7,3	4000	9,12	3500
2,1	no data	4,10	1800	7,4	3800	9,13	3400
2,2	no data	4,11	1400	7,5	3000	9,14	3300
2,3	no data	4,12	1500	7,6	2400	9,15	3200
2,4	4200	4,13	1600	7,7	2400	10,1	4500
2,5	4100	4,14	1800	7,8	2300	10,2	4200
2,6	4100	4,15	1900	7,9	2300	10,3	4200
2,7	3900	5,1	no data	7,10	2500	10,4	4700
2,8	3400	5,2	no data	7,11	2500	10,5 - 10,15	no data
2,9	3200	5,3	4600	7,12	2700	11,1	4700
2,10	2800	5,4	4000	7,13	2900	11,2	4500
2,11	2400	5,5	3400	7,14	3000	11,3	4700
2,12	2200	5,6	2900	7,15	2500	11,4 - 11,15	no data
2,13	2300	5,7	2300	8,1	4500		
2,14	2300	5,8	1800	8,2	4000		
2,15	2400	5,9	1600	8,3	3600		
3, 1	no data	5,10	1000	8,4	3100		
3,2	no data	5,11	1100	8,5	3000		
3,3	no data	5,12	1200	8,6	3200		
3,4	4000	5,13	1400	8,7	3200		
3,5	3800	5,14	1600	8,8	3100		
3,6	3800	5,15	1800	8,9	3000		
3,7	3700	6,1	no data	8,10	3100		
3,8	3300	6,2	no data	8,11	3100		
3,9	2800	6,3	4500	8,12	3200		

Student Handout
Bathymetric Data Reduction Sheet