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PHAEDRA 2006:
Partnership for Hellenic-American Exploration in the Deep Regions of the Aegean

Where Am I?
(adapted from the 2003 Steamship Portland *Expedition)*

Focus
Marine navigation and position-finding

Grade Level
9-12 (Earth Science)

Focus Question
What instruments and techniques can be used for marine navigation and position-finding?

Learning Objectives
Students will be able to identify and explain at least seven different techniques that have been used for marine navigation and position-finding.

Students will be able to explain the purpose of a marine sextant.

Students will be able to use an astrolabe to solve practical trigonometric problems.

Materials
- ❒ Heavy poster board
- ❒ Drinking straws

Audio/Visual Materials
- ❒ Marker board and markers or overhead projector and transparencies for group discussions

Teaching Time
One to three 45-minute class periods, plus time for student research

Seating Arrangement
Groups of 2-4 students

Maximum Number of Students
30

Key Words
Aegean Sea
Global positioning system
Astrolabe
Sextant
Longitude
Navigation

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.

Precision undersea mapping shares at least one thing with the earliest mariners to sail the Aegean: the need for a way to accurately determine where a vessel is on the surface of the Earth. In this lesson, students will investigate tools used for navigation and position-finding, from techniques used thousands of years ago to modern GPS technology.

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.

   Tell students that to be most useful, precise bathymetric maps and photographic images require some way to accurately determine a vessel's position. During the PHAEDRA 2006 Expedition, scientists will use a global positioning system (GPS) to find their position. Tell students that their assignment is to research various methods used for marine navigation and position finding, and to construct and use a simple navigation instrument.

3. Have each student group prepare a brief report that describes at least three different navigation techniques or instruments used more than 2,000 years ago, two techniques or instruments used between 100 and 2,000 years ago, and three techniques or instruments currently in use. Have each group make a brief presentation of their research results, and tabulate the various instruments and techniques on a marker board or overhead projector transparency.

4. You may want to have your students watch the NOVA program, Lost at Sea: The Search for Longitude (available from http://www.pbs.org/wgbh/nova/novastore.html).

5. Have students construct the astrolabe described by James E. Morrison in the file http://astrolabes.org/mariner.exe. This is a self-extracting archive that includes a file named "Mariner.doc," which is a Microsoft Word® file containing directions for constructing an astrolabe, and a second file named "MarinerPS," which is a Postscript® file that is a full-size template for a home-made astrolabe. If the .exe file does not self-extract, try opening the file with a file expansion program such as StuffitExpander®. If you are not able to open the Postscript® file, you may be able to print it by dragging the file icon and dropping it onto the icon for a Postscript® printer on your desktop. Alternatively, look for a printer utility file in your operating system that will allow you to open Postscript® files. If these options don't work (or are not available) there are several Postscript printing programs that can be downloaded at no cost from the internet, including Drop*PS, PrintFile, and GhostScript. Use a search engine to locate sources for these programs. You may also want to visit http://astrolabes.org/individual.htm for examples of astrolabes made by individuals.

   Have each group solve the following problem using their astrolabe:

   "You are walking along a beach and see a boat drifting some distance away. A man on board yells that his engine is dead, and he needs help getting to shore. Fortunately, you have 500 feet of nylon line and are a strong swimmer. Unfortunately, you aren't sure whether 500 feet is enough to reach the boat. Fortunately, you have your trusty astrolabe and a book of trigonometric functions as well. How can you use the astrolabe to find the distance to the boat?"

ANSWER: You mark a spot on the beach with a stick, and pace off a known distance, perpendicular to an imaginary line joining the stick with the boat (about 100 ft would be good). Then, you use your astrolabe to find the angle between the path you have just paced and the boat. From your vast knowledge of trigonometry, you know that the tangent of that angle is the distance from the stick to the boat divided by the distance you have paced. So, the distance to the boat is the distance you paced multiplied by the tangent of the angle measured with your astrolabe.

6. To wrap up, you may want to have your students do NOVA's GPS exercise (http://www.pbs.org/wgbh/nova/longitude/gps.html), and/or circumnavigation activity (http://www.pbs.org/wgbh/nova/teachers/activities/2511_longitud.html)

The Bridge Connection

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

The "Me" Connection

Have students write a short essay describing how their lives are affected by tools and technologies that allow for precise navigation and position-finding.

Connections to Other Subjects

English/Language Arts, Mathematics, Social Sciences

Assessment

Written reports prepared in Step 3 and astrolabe problem in Step 5 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

Lost City Chemistry Detectives

http://oceanexplorer.noaa.gov/explorations/05lostcity/background/edu/media/lostcity05_chemdetect.pdf
6 pages, 411k) (from the Lost City 2005 Expedition)

Focus (Chemistry/Earth Science) - Chemistry of the Lost City Hydrothermal Field

In this activity, students will be able to compare and contrast the formation processes that produce black smokers and the Lost City hydrothermal field, describe the process of serpentinization and how this process contributes to formation of chimneys at the Lost City hydrothermal field, and describe and explain the chemical reactions that produce hydrogen and methane in Lost City hydrothermal vent fluids.

The Big Balancing Act

http://oceanexplorer.noaa.gov/explorations/05fire/background/edu/media/rof05_balancing.pdf
(9 pages, 1.3Mb) (from the New Zealand American Submarine Ring of Fire 2005 Expedition)

Focus: Hydrothermal vent chemistry at subduction volcanoes (Chemistry/Earth Science)

In this lesson, students will be able to define and describe hydrothermal circulation systems, explain the overall sequence of chemical reactions that occur in hydrothermal circulation systems, compare and contrast "black smokers" and "white smokers," and use data on chemical enrichment in hydrothermal circulation systems to make inferences about the relative significance of these systems to ocean chemical balance compared to terrestrial runoff.

Where There's Smoke, There's ...

http://oceanexplorer.noaa.gov/explorations/05fire/background/edu/media/rof05_smoke.pdf
(6 pages, 680k) (from the New Zealand American Submarine Ring of Fire 2005 Expedition)

Focus: Hydrothermal vent chemistry at subduction volcanoes (Chemistry)

In this lesson, students will be able to use fundamental relationships between melting points, boiling points, solubility, temperature, and pressure to develop plausible explanations for observed chemical phenomena in the vicinity of subduction volcanoes.

Do You Have a Sinking Feeling?

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

Focus: Marine archaeology (earth science/mathematics)

In this activity, students plot the position of a vessel given two bearings on appropriate landmarks, draw inferences about a shipwreck given information on the location and characteristics of artifacts from the wreck, and explain how the debris field associated with a shipwreck gives clues about the circumstances of the sinking ship.

What's the Difference?

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

Focus: Volcanic processes at convergent and divergent tectonic plate boundaries (Earth Science)

Students will be able to compare and contrast volcanoes at convergent and divergent plate boundaries; identify three geologic features that are associated with most volcanoes on Earth; and explain why some volcanoes erupt explosively while others do not.

I, Robot, Can Do That!

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

Focus: Underwater Robotic Vehicles for Scientific Exploration

In this activity, students will be able to 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.

Designing Tools for Ocean Exploration

http://oceanexplorer.noaa.gov/explorations/02galapagos/background/education/media/gal_gr9_12_l1.pdf
(13 pages, 496k) (from the 2002 Galapagos Rift Expedition)

Focus: Ocean Exploration

In this activity, students will understand the complexity of ocean exploration; learn about the technological applications and capabilities required for ocean exploration; discover the importance of teamwork in scientific research projects; and develop the abilities necessary for scientific inquiry.

The Puzzle of the Ice Age Americans

http://oceanexplorer.noaa.gov/explorations/02fire/background/education/media/ring_puzzle_9_12.pdf
(8 pages, 100k) (from the 2002 Submarine Ring of Fire Expedition)

Focus: Anthropology, Earth Science - Origin of the first humans in the Americas

Students will be able to describe alternative theories for how the first humans came to the Americas and explain the evidence that supports or contradicts these theories, explain how exploration of a submerged portion of the North American west coast may provide additional insights about the origin of the first Americans, and describe the role of skepticism in scientific inquiry.

Other Resources and Links

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

http://www.pbs.org/wgbh/nova/longitude – NOVA Web site on the search for longitude

http://ina.tamu.edu/vm.htm – The Institute of Nautical Archaeology's Virtual Museum

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://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://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 E: Science and Technology
- Abilities of technological design
- Understandings about science and technology

Content Standard F: Science in Personal and Social Perspectives
- Natural and human-induced hazards
- Science and technology in local, national, and global challenges

Content Standard G: History and Nature of Science
- Historical perspectives

Ocean Literacy Essential Principles and Fundamental Concepts

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 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 d.* Much of the world's population lives in coastal areas.
- *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.

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