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Learning Ocean Science through Ocean Exploration

Section 2

Mapping the Ocean Floor: Bathymetry

Why Bathymetry?

Exploring the ocean starts with getting some idea of what the bottom topography is like. Thanks to satellites and a variety of measuring stations—both fixed and drifting, we have a pretty good idea of the surface of the sea, but have seen only bits of the bottom. Ship and submersible time for ocean exploration are expensive. Expeditions need to be carefully planned in order to produce the maximum amount of information in the least amount of time. For that to happen, scientists need to have a general idea of where interesting features might be located and then develop site information for those areas. Detailed maps are rare for areas other than shallow, near shore areas. Towing a remotely operated vehicle (ROV) or diving in a manned submersible without a clear understanding of the bottom topography risks losing the equipment or even losing human life. Consequently, mapping the sea floor—bathymetry—is an important part of many OE expeditions. With good maps, the researchers can focus their time and energy.

GPS and Computers

Global Positioning System (GPS) data are combined with the input from latest bottom-topography technology available, including ship-based swath mapping systems, side-scan sonar, and seismic reflection, as well as submersible and ROV dives to reveal exciting new details about the geology and the flora and fauna of the ocean. Computers with digital acquisition systems process masses of data and create three-dimensional views of the ocean bottom. The OE web site includes many of these maps, enabling students to visualize the structure of interesting underwater features such as seamounts, canyons and mid-ocean ridges.

What We Can Learn from Mapping

Surprisingly fine scale details are evident in observations of near shore depths. Sea stacks, beaches, sea cliffs, lagoons, shore faces, wave cut platforms, and sand ripples, all formed about twenty thousand years ago when the accumulation of ice on land lowered the ocean level, show up clearly. Future exploration and mapping may reveal more about climate and the geological and biological conditions of periods of lowered sea level, as well as information on the indigenous people who lived along that ancient shore.

Farther from shore, swath mapping systems, side-scan sonar, seismic reflection, and exploration by submersible and ROVs reveal details about underwater volcanic rifts in the Pacific Ocean, seamounts in the Pacific and the Atlantic, submarine canyons off US shores and deep vents and cold water seeps in many sites.

Classroom Activities on Mapping in this Section

The following three exercises give students an introduction to the techniques used to create maps of the underwater world—bathymetric maps. Of particular content relevance are the *Mission Plan* and *Mapping the Unknown* from Hudson Canyon 2002, as well as several of the seamount expeditions from the OE CD or web site.

- *A Watered Down Topographic Map* from Submarine Ring of Fire 2002
- *Mapping the Canyon* on Deep East 2001 and Hudson Canyon 2002
- *Mapping Deep-sea Habitats* from Northwest Hawaiian Islands Exploration 2002

Where to Find More Activities on Mapping

Mapping exercises in the OE 2001-2002 database on the OE CD or web site include:

- *Come on Down* from Galapagos Rift and Deep East 2001
- *An Ocean of Weather* in Islands in the Stream 2002

- *Finding the Way* from Deep East 2001
- *At the Edge of the Continent* in Islands in the Stream 2002
- *Mapping Seamounts in the Gulf of Alaska* from Exploring Alaska's Seamounts 2002

Lesson Plan 2

A Watered-down Topographic Map

Focus Questions

How can a two-dimensional map be created showing the three-dimensional nature of a landform?

What are topographic maps and bathymetric charts?

Learning Objectives

Students will create a bathymetric map of a model underwater feature.

Students will interpret a simple topographic or bathymetric map.

Students will explain the difference between topographic and bathymetric maps.

Students will create models of some of the undersea geologic features studied in ocean explorations.

Materials Per Group Of Four Students

- ❒ A square quart plastic food storage container at least 7 cm deep
- ❒ 500-700 ml of water in measuring cup or bottle
- ❒ Small plastic funnel
- ❒ 10 cm plastic ruler (can be made by photocopying a ruler repeatedly on an overhead acetate)
- ❒ Overhead projector acetate cut to fit food container top
- ❒ Felt tip waterproof marker
- ❒ 12 inches of masking tape
- ❒ Scissors
- ❒ Two sticks of modeling clay – two colors
- ❒ Student Handouts

Audio/visual Equipment

- ❒ Overhead projector

Teaching Time

Two 45-minute periods

Seating Arrangement

Cooperative groups of up to four students

Key Words

Topographic
Bathymetric
Contour line
Contour interval
Relief
Elevation
Depth
Submarine canyon
Seamount
Ridge/bank
Rift/mid-ocean ridge
Continental shelf

Background Information

This activity serves two purposes: it introduces your students to contour maps—both bathymetric and topographic—and it introduces them to the geologic features that many explorers study. Bathymetric mapping is a major part of many of the OE expeditions since our understanding of the ocean floor starts with knowing what it looks like. We do not know much at this point.

Topographic maps are tools used by anyone in need of knowing his/her position on Earth in relation to surrounding surface features. A topographic map is a two-dimensional map portraying three-dimensional landforms. Geologists, field biologists, and hikers are just a few who routinely use topographic maps.

Bathymetric maps (also called charts) are topographic maps of the bottom features of a lake, bay or ocean. They are very similar to topographic maps in their terminology and interpretation. The primary difference is that bathymetric maps show depth below sea level while topographic maps show elevation above sea level. Another difference is the limited data available to create a bathymetric map when compared to a topographic map.

The skill needed to see two dimensions on a map and visualize three dimensions can be a difficult for students. Interpreting familiar topographic maps provides practice in this skill. This exercise will build an understanding of the relationship between a two-dimensional representation and a three-dimensional landform.

Both topographic and bathymetric maps use contour lines to show elevation or depth. Contour lines are imaginary lines connecting points of the same elevation or depth. A contour interval is the predetermined difference between any two contour lines. A contour interval of 100 feet means that the slope of the land or sea bottom has risen or declined by 100 feet between two contour lines. A map that shows very close contour lines means the land is very steep. A map that has wide spacing between contour lines has a gentle slope. The smaller the contour interval, the more capable a map is of depicting finer features and details of the land. A contour interval of 100 feet will only pick up details of features larger than 100 feet. It also means that a seamount could be 99 feet higher in elevation than the map depicts.

Because one cannot usually easily see beneath the water, the difference between what is mapped and the reality of what actually exists is greater on bathymetric maps. With the advent of new, more sophisticated ocean floor sensing technology, bathymetric maps are becoming much more detailed, revealing new information about ocean geology.

Learning Procedure

1. Distribute the plastic food storage containers and sticks of clay to each group, along with a card describing an underwater feature (these same features also occur on dry land). Each group should read the card and build a clay model to match the description written on the card. The model may not extend above the top of the container. For ease of construction, they may assemble them on the desk and then install them in the container. Allow them to consult the OE web site or CD or oceanography texts if they need help visualizing the descriptions.

2. Challenge the students to create a two-dimensional map of their three-dimensional underwater feature that would visually interpret it for other groups of students.

3. Help them think this through as a group. Draw a large circular shape on the board. Ask the students what they think the drawing represents. Guide the answers, if necessary, toward maps of landforms, such as a pond, an island, a race track circuit, and so on. Could it be the base of an underwater mountain? Draw a side view of an undulating mountain directly below and matching the horizontal margins of the circle. Tell the students the two drawings represent the same thing, but from a different perspective. Ask the students again what they think the circular shape and the new side view of the circular shape represents. A mountain should be one of the obvious answers. How can we combine the two dimensions of the circle with the third dimension—height—in the second drawing on a flat map?

4. Hand out the *Student Handouts* and ask them to follow the instructions. When the equipment is

ready, have the students check with you to make sure they set up correctly. Depending on your students' abilities you may have all setups complete and proceed as a class through drawing of the contour line. Some classes will take off and do this very well on their own. Having completed the first contour line, have the class add water to the first centimeter mark on the ruler, reminding them to take care when pouring the water into the funnel. Remind them about accuracy in measurement also. Once they draw the second contour line they may work at their own speed.

5. When the "maps" are completed, introduce the terms topographic and bathymetric maps and discuss contour lines to make sure the concept is clear.

6. Have the students remove the water from their models and display the models with the maps. Pass around a model and challenge the students to pick the map that represents it from the maps displayed on the overhead projector.

7. During this oral assessment of understanding, show an overhead projection which is 180 degrees opposite in perspective to the view the students have of the respective feature. This not only tests the students understanding of topography with respect to the orientation but also reinforces the value of compass directions on maps.

8. Have students use the Ocean Exploration CD or web site to find and list the expeditions that explore each of the geologic features listed here: ridge/bank, submarine canyon, seamount or mid-ocean ridge/rift. Have them finds maps and/or illustrations of the features in this exercise, print them out, label them and put them up in the bulletin board. Also look for bathymetric maps that show the same features.

The BRIDGE Connection

www.vims.edu/bridge

The "Me" Connection

Have you ever been lost? What is it that helps you find your way? A familiar landmark is what most people need to find. A topographic map is all about finding landmarks even if you have never seen the landmark before.

Connections To Other Subjects

Mathematics, Geography

Evaluation

Teacher reviews maps created by students for accuracy and understanding. Teacher performs summative assessment by showing mapped objects and topographic map representations for class to relate to each another. Teacher performs formative assessment test questioning on key terms and topographic/bathymetric interpretations.

Extensions

Have students find landmarks and important features on a topographic map of their own area. "Topo" maps are sold at places that sell hiking and camping gear. Take a topographic map on the next field trip. Have students locate where they are on the map, what elevation they are at, and what distance they are from a prominent landmark.

National Science Education Standards

Content Standard A – Science as Inquiry
- Ability necessary to do 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 G – History and Nature of Science
- Nature of science

Activity developed by Bob Pearson, Eddyville School, Philomath, Oregon

Student Handout

Read ALL of the instructions first!

Materials:

- Model in quart plastic container: follow the instructions on the Underwater Feature cards to build the clay model in a square plastic food storage box using modeling clay
- Measuring cup or liter beaker of water
- Plastic funnel
- Centimeter ruler
- Overhead projector acetate
- Waterproof felt tip marker
- Masking tape
- Scissors

Procedure:

Read these instructions carefully. They contain new terms you will need for the Student Analysis Worksheet.

1. Build and install your model underwater feature in your plastic container.

2. Place the centimeter ruler inside the container against a side wall near a corner. Make sure that the highest number mark is at the bottom. Use the tape to attach the centimeter ruler to the container side, taking care not to make the measurement lines unreadable.

3. Cut the overhead acetate to a size that completely covers the container. On one corner of the acetate, cut away enough material so that the funnel spout can just fit through.

4. Tape the acetate to the top of the container. Attach the tape only at a few edges of the overhead and not completely across the container opening. You will need to remove the acetate later so use only enough tape to hold it firmly.

5. Insert the funnel into the opening and tape it so it is securely in place.

6. Check your setup for approval by your teacher.

7. Draw a line on the acetate that correlates with the place the object meets the bottom of the container.

Student Handout

8. Take the beaker of water and carefully add water through the funnel until the water level rises to the one centimeter mark on the ruler.

9. View the model by placing your eyes directly above it, looking downward. Focus on the outline of where the model and the water meet. Using the felt tip pen, very carefully draw this outline on the acetate. Label it with the cm shown at that depth on the ruler. The line that you draw is called a "contour line."

10. Add another centimeter of water to 2 cm in depth. Again, look directly downward at the object. Focus on where the object and water line meet. Draw this contour line in the same way you drew the first one, following the line where the water meets the object. You now have two contour lines which represent a one-half centimeter change in depth. Label it from the ruler measurement.

11. Continue adding water at centimeter intervals and drawing the contour lines at each centimeter rise until the model is completely covered with water. You have created a bathymetric map of the model.

Note: If you have a feature with high relief like a tall seamount, use 1 cm intervals. If you have a flat feature like a bank, use 0.5 cm intervals.

Student Handout

Underwater Feature Cards

Seamount

Volcanoes occur in the ocean too. If they build high enough above the ocean floor, they may form islands. The islands may weigh so much they eventually sink into the Earth's crust. Or they may not ever break the surface of the water. Either way, they may become seamounts—mountains under the ocean. Use your clay to make a volcano-shaped model mountain that is 6 cm high and not wide enough at the base to touch the sides of the plastic container.

Ridge/Bank

Hard bottom features may rise above the continental shelf. Since many organisms need a hard surface to attach and grow, ridges or banks may be unusually rich areas. They may be large or small and may be quite irregular in shape. Use your clay to make a low mound that ranges from 0.5 to 2 cm high, covers about two thirds of the container bottom and has an irregular shape.

Submarine Canyon

Along the edges of the North American continent, the sea floor is shallow—forming an underwater plain that is very wide in some places and less so in others. Where rivers empty into the sea, canyons were cut into this plain when sea level was much lower during the Ice Ages. As sea level rose, the canyons became flooded. Use your clay to make a shallow sloping platform 4 cm high filling two sides of the container with the third side diagonal across the middle—the continental shelf. From the middle to the other two sides, create a slope down to a clay bottom that is 0.5 cm. Use a tool (dissecting needle or pencil) to cut a canyon that starts at the highest point in the corner between the two high sides and gradually gets deeper as it crosses the shelf. At the slope it should reach all the way to the bottom.

Mid-Oceanic Ridge/Rift

Make a flat bottom of clay about 1 cm deep from one color of clay. Make a thin rope about 1 cm in diameter of the same clay, rolling it in your hands. Lay a strip of the rope across the middle of the clay floor in the model ocean container. It should be about 1 cm higher than the floor. Use the second color of clay to make two flat sheets a little less than ½ the area of the container floor. Place one sheet down each side of the central "ridge" coming up to the middle but not touching so that the clay below shows through the middle. If the lower layer is red, you can think of it as glowing volcanic magma that flows up through the rift in the Earth's crust. In cross-section, there will be a small valley at the top of the ridge.

Lesson Plan 3

Mapping the Canyon

Focus
Bathymetry of Hudson Canyon

Focus Question
What are bathymetric and topographic maps, and what are the differences between them?

Learning Objectives
Students will compare and contrast a topographic map and a bathymetric map.

Students will investigate the ways in which bathymetric maps are made.

Students will interpret a bathymetric map.

Materials for Each Group
Part I:
- ❒ 1 Hudson Canyon Bathymetry map transparency from http://www.photolib.noaa.gov/ships/ship3201.htm
- ❒ 1 local topographic map
- ❒ 1 USGS Fact Sheet on Sea Floor Mapping from http://pubs.usgs.gov/fs/fs039-02/fs039-02.html

Part II:
- ❒ 1 local topographic map per group
- ❒ 1 Hudson Canyon Bathymetry map per group
- ❒ Hudson Canyon Bathymetry map transparency
- ❒ *Contour Analysis Worksheet*

Part III:
Internet access

Audio/visual Equipment
Overhead Projector

Teaching Time
Two 45-minute periods

Seating Arrangement
Cooperative groups of four

Key Words
Topography
Bathymetry
Map
Multi-beam sonar
Canyon
Contour lines
Sonar
Side-scan sonar
GLORIA
Echo sounder

Background Information
A map is a flat model of all or part of Earth's surface drawn to a specific scale. A map is a model of the real world. The better maps communicate information, the more effective they are as a model.

Topographic maps show elevation of landforms above sea level. Bathymetric maps show depths of landforms below sea level. The topographic elevations and the bathymetric depths are shown with contour lines. A contour line is a line on a map representing a corresponding imaginary line on the surface of the land or bottom of the sea that has the same elevation or depth along its entire length.

Since the ocean floor is not visible to us, it is difficult to map. Scientists use various techniques to gather data for a bathymetric map. In the early 1800s, mariners recorded depths of shallow water features with a weighted line. Then in 1854, a depth-sounding device was attached to the line instead of the weight. This made determining when the line hit the bottom of the ocean easier. However, measuring a small section of shallow ocean still took hours or days and was restricted to shallow depths.

The difficulty and technical limitations meant mapping the sea floor took place much later than the production of good maps of dry land. Much of the ocean remains unmapped, even today. During World War II, when submarine warfare was the highly effective against Allied shipping, sonar (sound navigation ranging) was developed. Active sonar devices use returning echo times to measure distance to the object that is being studied.

Using sonar, scientists were able to map ocean trenches, ridges, plains, and submerged islands, creating more accurate ocean floor maps. Today, scientists are working on advances that make sonar more accurate, including a side-scan sonar device called GLORIA (Geologic Long-Range Inclined Asdic). Sidescan sonar is towed behind a vessel and is able to scan the depth along the sides of the vessel as well as the depth directly below it. GLORIA is making detailed maps of the continental margin along the North American coasts. Another sonar advance is multi-beam sonar. By emitting signals of different frequencies, multi-beam sonar produces a detailed three-dimensional map of the sea floor.

Even with new advances in bathymetric mapping, only a limited portion of the vast sea floor has actually been mapped. Consequently, sea floor mapping is an important part of Ocean Exploration expeditions.

Learning Procedure

See Resources for web sites and sources of maps.

Part I:

1. Introduce topographic maps and bathymetric maps.
2. Hand out USGS Fact Sheet on Sea Floor mapping for them to read and study.

Part II:

1. Use the following materials to answer the worksheet questions: a local topographic map, the Hudson Canyon bathymetry map, and the *Contour Analysis Worksheets*.

Part III:

1. Have student groups research and give presentations on the different techniques used to collect depth data for bathymetric mapping. Topics could include:
   a. Echo sounder
   b. Seismic reflection profiles
   c. Multi-beam sonar
   d. Weighted wires
   e. Sonar
   f. GLORIA
   g. World War II and sonar

The BRIDGE Connection

http://woodshole.er.usgs.gov/epubs/openfiles/ofr98-616/titlepage.html

Connection To Other Subjects

Mathematics, English/Language Arts

Evaluations

Have students write a paragraph summarizing what they learned about the bathymetry of the Hudson Canyon.

Teacher review of each student's *Contour Analysis Worksheet*

Teacher review of presentations given by students on the various techniques used to map the bottom of the ocean floor

Extensions

Ask students to write a short essay comparing the Grand Canyon to the Hudson Canyon.

Make a clay model of the Hudson Canyon.

Ask students to identify all of the deep-sea canyons found along the Atlantic Coast.

Visit the Ocean Exploration Web Site at www.oceanexplorer.noaa.gov

Visit the National Marine Sanctuaries web page for a GIS fly-through of the Channel Islands National Marine Sanctuary at http://www.cinms.nos.noaa.gov/

References:

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Metzger, Ellen P., 1999, "Submarine Mountains Teachers Guide". www.ucmp.berkeley.edu/fosrec/Metzger2.html

Tarbuck, E.J., and Lutgens, F.K., 1999, EARTH An Introduction to Physical Geology (6th ed.): Prentice Hall, Inc., Upper Saddle River, New Jersey, p. 450-452

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
- Understandings about science and technology

Content Standard F – Science in Personal and Social Perspectives
- Science and technology in society

Content Standard G – History and Nature of Science
- Nature of science
- History of science

Activity developed by Tanya Podchaski, Bernards High School, Bernardsville, New Jersey

Student Handout

Contour Analysis Worksheet

1. Collect the following materials from your teacher:
    a. 1 local topographic map
    b. 1 bathymetric map of Hudson Canyon

2. What is the scale on the topographic map?

3. What is the scale on the bathymetric map?

4. Why do you think the scales are so different?

5. What is the contour interval on the topographic map?

6. What is the contour internal on the bathymetric map?

7. What do the two contour intervals indicate?

8. What do the colors represent on a topographic map?

9. What do the colors represent on a bathymetric map?

10. Why do these color schemes differ?

Student Handout

11. What is the highest feature on the topographic map? What is its elevation?

12. What are the latitude and longitude coordinates of this feature?

13. Locate Hudson Canyon on the bathymetric map. What is the depth of the deepest part?

14. What are the latitude and longitude coordinates of the Hudson Canyon?

15. Why is it important for the submarine *Alvin* to know the bathymetry of Hudson Canyon?

16. Write a two-paragraph summary comparing and contrasting topographic maps to bathymetric maps.

Lesson Plan 4

Mapping Deep-sea Features

Focus
Bathymetric mapping of deep-sea habitats

Focus Question
How can deep-sea areas be mapped to facilitate exploration with a manned submersible?

Learning Objectives
Students will create a two-dimensional contour map from actual bathymetric survey data.

Students will create a three-dimensional model of the landform on the underwater contour map they created.

Materials
- ❒ Copies of *Loihi Submarine Volcano Bathymetric Data* for each student group
- ❒ *Bathymetric Data Reduction Sheet* enlarged to 11″ x 14 ″ for each student group
- ❒ 8 different colored makers, crayons or pencils in color range from purple to red; use in order of their appearance in the color spectrum
- ❒ *Bathymetric Data Reduction Sheet* enlarged for bulletin board (make as large as possible)
- ❒ Scissors for each group
- ❒ Colored modeling clay rolled into flat sheets – at least two colors
- ❒ 8 dissecting needles

Audio/Visual Materials
None

Teaching Time
Two 45-minute class periods

Seating Arrangement
Eight groups

Key Words
Seamount
Bathymetry
Transducer
Backscatter
Contour lines
False color

Background Information
This activity focuses on how bathymetric maps are created from multi-beam bathymetric data. Students will construct a three-dimensional model of the Loihi submarine volcano from bathymetric maps they make using real data. The model seamount will help visualize the translation of a two-dimensional model (a map) into three-dimensional model.

A chain of small islands and atolls stretches for more than 1,000 nautical miles northwest of the main Hawaiian Islands. While scientists have studied shallow portions of the area for many years, almost nothing is known about deeper ocean habitats below the range of SCUBA divers. Only a few explorations have been made with deep-diving submersibles and remotely operated vehicles (ROVs). These brief excursions led to the discovery of new species and species previously unreported in Hawaiian waters.

A major constraint to exploration of deepwater regions around the Northwestern Hawaiian Islands is the absence of accurate maps. In fact, recent expeditions found that some islands are not where they are supposed to be according to official nautical charts. Since time in submersibles is limited and expensive, every dive is carefully planned to ensure that the submersible goes to places of scientific interest. Good bathymetric maps are essential to good planning.

Scientists aboard the University of Hawaii's research vessel *Kilo Moana* used multi-beam swath bathymetry to create detailed pictures of the underwater topography around the Northwestern Hawaiian Islands. Multi-beam swath bathymetry, also called high-resolution multi-beam mapping, uses a transducer —a combination microphone/ loudspeaker —on the ship's hull to send out sound pulses in a fan-shaped pattern below the ship. It records sound reflected from the sea floor through receivers focused at different angles on either side of the ship. This system collects high-resolution water depth data, distinguishing differences of less than one meter. It also measures back scatter—the amount of sound energy returned from the sea floor—which identifies different materials such as rock, sand, or mud on the sea floor.

The multi-beam system, coupled with a global positioning system (GPS), pinpoints sea-floor locations within one meter. Data are collected in digital form for computer analysis which produces maps, three dimensional models, and even fly-by videos simulating a trip through the area in a submersible.

Bathymetric maps are the most common output. Points with the same depth are connected by lines, showing mountains and valleys as a series of concentric, irregular closed curves. Lines that appear close together indicate steep slopes while lines that are farther apart indicate more gentle slope.

Learning Procedure

1. Introduce the location of the Northwestern Hawaiian Islands and point out some features that make this area interesting to scientists. Discuss the need for accurate maps in planning deep-sea diving expeditions. Discuss the general concept of multibeam swath bathymetry. You may need to review the basic idea of topographic/bathymetric maps if students have not completed a previous activity using them.

2. Distribute copies of *Loihi Volcano Bathymetric Data* and an enlarged *Bathymetric Data Reduction Sheet* to each group. Tell the students that the bathymetric data are part of a real data set that was produced by a research vessel, using multi-beam 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 of the grid coordinates. If you wish to, relate the grid to the actual location. The lower left corner of grid cell 1,1 is latitude 18° 45'N, longitude 155° 20'W. Each grid cell is one minute of latitude or longitude. The students may assume that the depth reading was taken at the center of each grid cell, but they will color the entire cell as if it were in the depth range.

3. Assign each group a data range of 500 m (for example, 4600 – 4100 m) and a color. The maps they make are going to have 500 m contour lines. An example of the possible assigned color appears next to each below.
   Data Range:
   5000-4600 m - purple
   4500-4100m - blue violet
   4000-3600m - blue
   3500-3100m - blue green
   3000-2600m - green
   2500-2100m - yellow
   2000-1600m - orange
   1500-1100m - red

4. Each group will find ALL the recorded depths within its data range and color the entire square the assigned color for that depth. For example, if group 1 has 5000-4600 m and has been assigned purple, it will color the squares everywhere that there is a depth in the assigned range.

On the *Bathymetric Data Reduction Sheet* the square at row 1, column 4 would be purple.

5. Have the students translate their colors onto a single larger grid map on a bulletin board so that all colors are displayed. They have created a false color map showing depth with the purple deepest and the red most shallow. What is the object measured shaped like? Do they think they could draw it? Since digital imagining is common, ask students what would be needed to make this map more accurate. Better resolution would be achieved with more data points—more pixels and smaller ones.

6. Have each group use scissors to cut around the shape each group colored on the outside edges only. Each group will cut out their color and all shallower colors inside its color. Where a depth was skipped (sharp drop) go between the two colors on either side of the group's color.

7. Place the cut out shapes on a rolled out piece of modeling clay big enough to trace the outline of the contour and about 1/2-in thick. Use a dissecting needle to cut the clay to the shape of the grid. If you have several clay colors, alternate them for contrast.

8. Starting with the deepest contour (purple), lay the clay layers on top of each other in the orientation of the map to assemble a three-dimensional representation of the two-dimensional map. Now can they visualize its shape? This is a model of the Loihi Submarine Volcano.

9. Discuss the fact that a map is a model for a real place. The students have created two models of the same space. Which do they prefer? Using computers, bathymetric maps can be converted into three-dimensional pictures of spaces underwater.

10. Using the model the students produced, ask them to discuss the advantages of various sites on the volcano for diving missions. Integrate information on currents and sediment deposition. Flat regions are more likely to accumulate sediment, creating different habitats than steep places. On the other hand, steep areas have greater depth range within a short distance, so these are better places to study how depth influences the distribution of various species. Identify dive sites that are likely to offer a variety of habitats within a short distance. These offer good opportunities for getting the most benefit from limited diving time.

11. Have the students compare their models with the bathymetric image of the Loihi volcano at http://www.oar.noaa.gov/spotlite/archive/spot_loihi.html. This image provides much more detail than the students' topographic maps because it includes thousands of data points. This detailed mapping is only possible with computer analysis.

The BRIDGE Connection

www.vims.edu/BRIDGE/pacific.html

The "Me" Connection

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

Connections to Other Subjects

English/Language Arts, Mathematics

Evaluation

Have students write a description of the Loihi volcano based on their model, including geographic directions: north, south, east, and west, as well as latitude and longitude, topography such as steepness, and depth. Ask them to discuss the utility of two-dimensional vs. three-dimensional bathymetric maps in writing their descriptions.

Extensions

Have students visit http://oceanexplorer.noaa.gov to study real deep-sea mapping in the Northwestern Hawaiian Islands.

Resources

http://oceanexplorer.noaa.gov – Northwestern Hawaiian Islands Expedition documentaries and discoveries.

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

http://www.oar.noaa.gov/spotlite/archive/spot_loihi.html – Short article on the Loihi volcano

http://www.soest.hawaii.edu/GG/HCV/loihi.html – More extensive web site with information on Loihi and other volcanoes in Hawaii

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

Activity developed by Mel Goodwin, PhD, The Harmony Project, Charleston, SC

Student Handout

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

Use Colored Pencils, Markers or Crayons for Data Ranges:

5000-4600 m - purple

4500-4100m - blue violet

4000-3600m - blue

3500-3100m - blue green

3000-2600m - green

2500-2100m - yellow

2000-1600m - orange

1500-1100m - red

Student Handout

Bathymetric Data Reduction Sheet

16											
15											
14											
13											
12											
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7											
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4											
3											
2											
1											
	1	2	3	4	5	6	7	8	9	10	11