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
Bathymetric and topographic contour mapping.

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.

Additional Information for Teachers of Deaf Students
The words listed as Key Words are really the focus of the lesson. There are no formal signs in American Sign Language for many of these words and most are difficult to lipread. If some of this information has not already been covered in your class, you may need to introduce it prior to the activity and add additional class periods. Using the "Me" Connection activity first is also a good introduction to this activity.

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 Materials
- ❒ 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.

Resources

www.topozone.com
Interactive USGS topographic maps of the entire U.S.

egsc.usgs.gov/isb/pubs/booklets/symbols/
Topographic mapping and map symbols information

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

Additional information for teachers of deaf students developed by Denise Monte, Teacher of the Deaf and Audiologist, American School for the Deaf, West Hartford, Connecticut

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.

Student Handout

7. Draw a line on the acetate that correlates with the place the feature meets the bottom of the container. If it meets the side, do NOT draw a line.

8. Take the beaker of water and carefully add water through the funnel until the water level rises to 1 centimeter or 0.5 centimeters on the ruler.

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.

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." Do not draw a line where the water meets the sides of the container.

10. Add another 1.0 or 0.5 centimeters of water. Again, look directly downward at the feature. Focus on where the feature 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 feature. You now have two contour lines which represent a 1.0 or 0.5 centimeter change in depth. Label it from the ruler measurement.

11. Continue adding water at centimeter intervals and drawing the contour lines at each 1.0 or 0.5 rise until the model is completely covered with water. You have created a bathymetric map of the model.

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.

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 of the two sides, create a slope down to the bottom. 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.

Additional Information for Teachers of Deaf Students
There are no formal signs in American Sign Language for many of the Key Words and most are difficult to lipread. These words are the key to the lesson. Having the vocabulary list on the board as a reference during the lesson will be extremely helpful. The teacher may pick one of the topics in Part III and present it for the students in the form of a concept map. The students can then research the additional topics and add to the concept map. This allows them to see how each of these methods overlap.

Materials for Each Group
Part I:
- ❐ 1 Hudson Canyon bathymetry map transparency from pubs.usgs.gov/of/2004/1441/index.html
- ❐ 1 local topographic map
- ❐ 1 USGS Fact Sheet on Sea Floor Mapping from pubs.usgs.gov/fs/fs039-02/fs039-02.html

Part II:
- ❐ 1 local topographic map per group
- ❐ 1 Hudson Canyon bathymetry map per group pubs.usgs.gov/of/2004/1441/index.html
- ❐ Hudson Canyon Bathymetry map transparency
- ❐ *Contour Analysis Worksheet*

Part III:
Internet access

Audio/visual Materials
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 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://pubs.usgs.gov/of/1998/of98-616/ - Multibeam Bathymetric and Backscatter Maps of the Upper Hudson Shelf Valley and Adjacent Shelf, Offshore of New York, by Bradford Butman, William W. Danforth, William C. Schwab, and Marilyn Buchholtz ten Brink. Based on USGS Open File Report 98-616

The "Me" Connection

Have any students visited the Grand Canyon or other canyons? Have them bring in photos of trips to canyons or find pictures in books to share with the class, paying attention to the topography shown in the pictures. Challange students to make clay depictions of the portions of the canyons shown in the pictures.

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 oceanexplorer.noaa.gov

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

Resources

Metzger, Ellen P., 1999, "Submarine Mountains Teachers Guide". http://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

Additional information for teachers of deaf students developed by Denise Monte, Teacher of the Deaf and Audiologist, American School for the Deaf, West Hartford, Connecticut

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.

Additional Information for Teachers of Deaf Students

In addition to the words listed as Key Words, the following words should be part of the vocabulary list:

Atolls	Multibeam swath bathymetry
Nautical	Topography
SCUBA	GPS
Explorations	Topographic
Constraints	
Nautical charts	

The Key Words are integral to the unit but will be difficult to introduce prior to the activity. They are really the material of the lesson. There are no formal signs in American Sign Language for any of these words and many are difficult to lipread. Having the vocabulary list on board as a reference during the lesson will be extremely helpful. Also give the list as a handout to the students to refer to after the lesson.

If these topics have not already been covered in your class, you will need to add an additional class period to cover all the material. This activity is a bit involved and may require an additional period as well.

List all the steps required for the activity on the board so that students may follow step by step.

Materials

Copies of *Loihi Submarine Volcano Bathymetric Data* for each student group
Bathymetric Data Reduction Sheet for each group
8 different colored markers, crayons or pencils in the color spectrum from red to purple for each group
Bathymetric Data Reduction Sheet enlarged for bulletin board (make as large as possible)
Optional - 8 craft foam sheets in the color spectrum from red to purple and scissors for each group

Audio/visual Materials

None

Teaching Time

Two 45-minute class periods

Seating Arrangement

3-4 students per group

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 false color map of the Loihi submarine volcano, using real data. They will then make a model seamount from craft foam to 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 multi-beam 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 a *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 upper 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. Each group will find ALL the recorded depths and color the entire square the assigned color for that depth. Colors may vary with pen sets but use in sequence of the spectrum of light.

   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
   1500-1000m - red

4. Using the false color maps 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.

Optional:

1. Give each group 8 squares of craft foam (a 12x18" piece of foam yields 8 4x4.5" pieces). Craft foam can be purchased at craft store chains like Jo Ann's Fabrics and in the craft department of stores like Wal Mart.
2. Draw a cone shaped mountain (volcano) on the board and show one of the seamount bathymetric maps from Lesson Plan #2 on an overhead. Your drawing will basically be a series of concentric ovals, one inside the other.
3. Challenge the students to make a 3-dimensional model of a seamount using the craft foam in layers. Tell them to cut out the appropriate color of their craft foam sheets, following the general outline of your drawing on the board or the map on the overhead.
4. Starting with the deepest contour (purple), lay the foam layers on top of each other in the orientation of the map or drawing to assemble a three-dimensional representation of the two-dimensional map or drawing. Now can they visualize its shape? This is a model of a volcano such as the Loihi Submarine Volcano.
5. 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.
6. Have the students compare their models with the bathymetric image of the Loihi volcano at 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.
7. Additional data sets are available for creating false color maps of a ridge/bank, canyon, and mid-Atlantic ridge (all of the features dealt with in Lesson Plan #2, "A Watered-down Topographic Map") on the Ocean Explorer Web site at: oceanexplorer.noaa.gov/explorations/02hawaii/background/education/media/nwhi_mapping.pdf

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 oceanexplorer.noaa.gov to study real deep-sea mapping in the Northwestern Hawaiian Islands.

Resources

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

http://pubs.usgs.gov/fs/2000/fs013-00/ – Fact sheet on multi-beam mapping

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

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

www.sciencegems.com/earth2.html – Science education resources

http://www.martindalecenter.com/– References on just about everything

oceanexplorer.noaa.gov/explorations/02hawaii/background/education/media/nwhi_mapping.pdf – ridge/bank, canyon and mid-Atlantic ridge mapping extension activities

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

Additional information for teachers of deaf students developed by Denise Monte, Teacher of the Deaf and Audiologist, American School for the Deaf, West Hartford, Connecticut

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
1500-1000m - red

Student Handout

Bathymetric Data Reduction Sheet

COLUMNS

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