Lesson 3: Wet Maps

Focus
Bathymetric mapping

Grade Level
5-6 (Physical Science/Earth Science)

Focus Question
What kinds of maps are used for ocean exploration, and how are these maps made?

Learning Objectives
- Students will explain how multibeam sonar is an example of advances in engineering that have extended the measurement, exploration, modeling, and computational capacity of scientific investigations.
- Students will analyze data from a simulated multibeam sonar system to create a three-dimensional map that shows ocean sea floor ridges and trenches, and explain how tectonic processes produce these features.

Materials
For each student group:
- Copies of *Multibeam Mapping Simulation Activity Guide* and *Multibeam Mapping Simulation Activity Preparation Guide* (if you decide to have the students do the preparation)
- Cardboard box with lid, approximately 10 x 10 x 6 inches (at least 6 inches deep)
- Pencils, unsharpened; or wood dowels approximately 1/4-inch diameter x 8 inches; two for each student
- Copies of Sounding Rod Scale (Figure 2); two for each student
- Clear tape
- Plaster of Paris, 1 – 2 lb, or plaster wrapcloth (from craft stores)
- Masking tape
- Colored pencils, six colors
- Ruler, one for each student group
- Graph paper

Audio Visual Materials
Optional – Images of exploration technologies and animations (see Learning Procedure, Step 1c)

Teaching Time
Three to four 45-minute class periods, depending upon the availability of resources and activities assigned for out-of-class completion
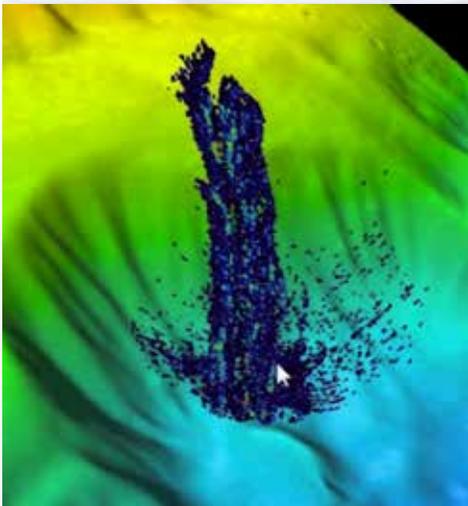
Multibeam image of Mendocino Ridge Plume taken with the Kongsberg EM302 multibeam bathymetric mapping system. Image courtesy INDEX-SATAL 2010 Expedition.
http://oceanexplorer.noaa.gov/okeanos/media/movies/mendocino_ridge_plume_video.html

Seating Arrangement

Groups of three to four students

Maximum Number of Students

30

Key Words and Concepts

Ocean Exploration
*Okeanos Explorer*
Bathymetric map
Multibeam sonar

Background

Multibeam sonar is one of the most powerful tools available for modern deep-sea exploration, and can create high-resolution maps, three dimensional models, or even "fly-through" videos that simulate a trip across the area being mapped.

For more information about how multibeam sonar is used aboard the NOAA Ship *Okeanos Explorer*, please see *Introduction to Multibeam Sonar* on page 49. In this lesson, students will learn about multibeam sonar, and use mock sonar set-ups to create a three-dimensional model of a simulated ocean floor.

Learning Procedure

1. To prepare for this lesson:
   a) Review:
      - Introductory essays for the INDEX-SATAL 2010 Expedition (*http://oceanexplorer.noaa.gov/okeanos/explorations/10index/welcome.html*);
      - Minding the Multibeam at Midnight by Colleen Peters (*http://oceanexplorer.noaa.gov/okeanos/explorations/10index/logs/aug05/aug05.html*); and
      - State of the Art Seafloor Survey by Meme Lobecker and Elaine Stuart (*http://oceanexplorer.noaa.gov/okeanos/explorations/10index/logs/july31/july31.html*).
   (b) Review background information about the *Okeanos Explorer* exploration strategy and technologies.
   (c) If desired, download images to accompany discussions in Step 2. You may also want to download this "before and after" image to illustrate the capabilities of multibeam sonar:
      > *http://oceanexplorer.noaa.gov/okeanos/explorations/10index/background/hires/em302_before_after_hires.jpg*,

      as well as one or more of the following animations to accompany discussions in Step 3:
      > *http://oceanexplorer.noaa.gov/explorations/02fire/logs/jul08/media/sm2k.html*;
      > *http://oceanexplorer.noaa.gov/okeanos/media/movies/ex_podcast_video.html*
   (d) Review *Multibeam Mapping Simulation Activity Guide* and *Multibeam Mapping Simulation Activity Preparation Guide*, and decide how much preparation will be done by students. This activity may be varied, according to time available and individual teaching and learning styles. For example, students may be divided into "Beam Teams," each of which constructs a mystery landscape that is kept hidden from other teams. Teams then exchange boxes and perform the mapping procedure to reveal the "mystery topography."
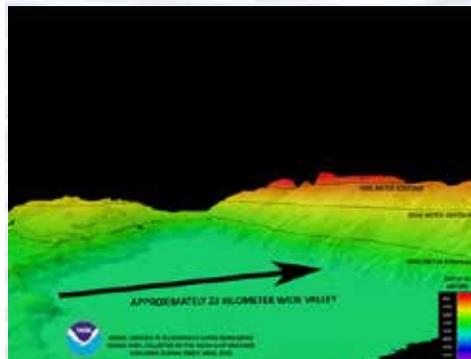
The EM302 gives us a high resolution "bird's eye" view of large areas. What we see underwater is similar to what we see around us every day. In the above image, a panorama of mountains and volcanoes sit majestically near a massive river delta surrounded by a soft sand beach. Since what we see here is actually underwater, there are, of course, no rivers or river deltas, or mountains and sand bars, but seeing these features makes one wonder how an area like this was formed. Image courtesy of NOAA *Okeanos Explorer* Program, INDEX-SATAL 2010.
http://oceanexplorer.noaa.gov/okeanos/explorations/10index/logs/july31/media/seamount_channels.html
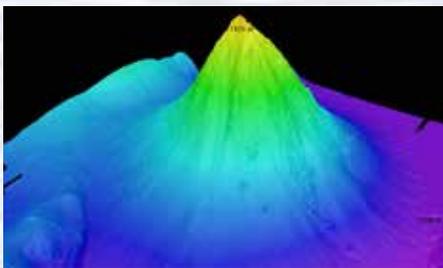
Okeanos Explorer's EM302 multibeam sonar mapping system produced this detailed image of the Kawio Barat seamount, which rises around 3800 meters from the seafloor. Image courtesy of NOAA *Okeanos Explorer* Program, INDEX-SATAL 2010.
http://oceanexplorer.noaa.gov/okeanos/explorations/10index/logs/hires/june26fig1_hires.jpg

A CTD is attached to a metal frame called a rosette, or carousel, along with numerous water sampling bottles and when deployed, provides information about the composition of the water column. Image courtesy of NOAA.
http://oceanexplorer.noaa.gov/technology/tools/sondectd/sondectd.html

Okeanos Explorer crew launch the vehicle during test dives off Hawaii. Image courtesy of NOAA *Okeanos Explorer* Program, INDEX-SATAL 2010.
http://oceanexplorer.noaa.gov/okeanos/explorations/10index/background/hires/launch_hires.jpg

ROV Team Lead, Commanding Officer, and Science Team Lead discuss operations at the Mid-Cayman Rise with participants located at both the Silver Spring ECC, and URI's Inner Space Center. Image courtesy of NOAA *Okeanos Explorer* Program, MCR Expedition 2011.
http://oceanexplorer.noaa.gov/okeanos/explorations/ex1104/logs/hires/daily_updates_aug9_1_hires.jpg

This can become a competition between teams if points are awarded to teams that accurately predict the topography in the shortest amount of time.

2. Briefly introduce the NOAA Ship *Okeanos Explorer* and the INDEX-SATAL 2010 Expedition. Briefly discuss why this kind of exploration is important (for background information, please see the lesson, *Earth's Ocean is 95% Unexplored: So What?*; *http://oceanexplorer.noaa.gov/okeanos/explorations/10index/background/edu/media/so_what.pdf*). Highlight the overall exploration strategy used by *Okeanos Explorer*, including the following points:
   - The overall strategy is based on finding anomalies;
   - This strategy involves
     - Underway reconnaissance;
     - Water column exploration; and
     - Site characterization;
   - This strategy relies on four key technologies:
     - Multibeam sonar mapping system;
     - CTD and other electronic sensors to measure chemical and physical seawater properties;
     - A Remotely Operated Vehicle (ROV) capable of obtaining high-quality imagery and samples in depths as great as 4,000 meters; and
     - Telepresence technologies that allow people to observe and interact with events at a remote location.

   You may want to show some or all of the images in the adjacent sidebar to accompany this review.

   Briefly review the mechanisms through which tectonic processes continually generate new seafloor at ridges and destroy old sea floor at trenches.

3. Ask students what they know about sonar, and provide additional information as necessary. (See *Introduction to Multibeam Sonar* on page 49). You may want to show one or more of the video clips referenced in Step 1c.

   Ask students how scientists and mariners made maps of underwater features before sonar was invented. For centuries, depth measurements were made with lead lines. A lead line is a rope or line with a 10-pound lead weight attached to the end. To make a depth measurement, the line is lowered into the water until the weight reaches the bottom. Markings on the line show how much line has been let out, which is equal to the depth of the water. Depth soundings made with lead lines are accurate, but they take a lot of time and only give information about single points of the sea bottom—so many lead line measurements are needed to accurately survey a given area.

   Nautical charts based on data collected with lead lines often consist of many small numbers scattered over the chart that correspond to the measured depth at the locations represented on the chart. The invention of sonar made it possible to collect many more data points, and this allowed scientists to construct bathymetric charts, which are similar to topographic maps that show the contour of landforms. Bathymetric charts, however, show the contour of the ocean floor. While they are a great improvement over charts made with lead line data, bathymetric charts are still two-dimensional representations of three-dimensional features and it takes practice to be able to accurately interpret these charts.
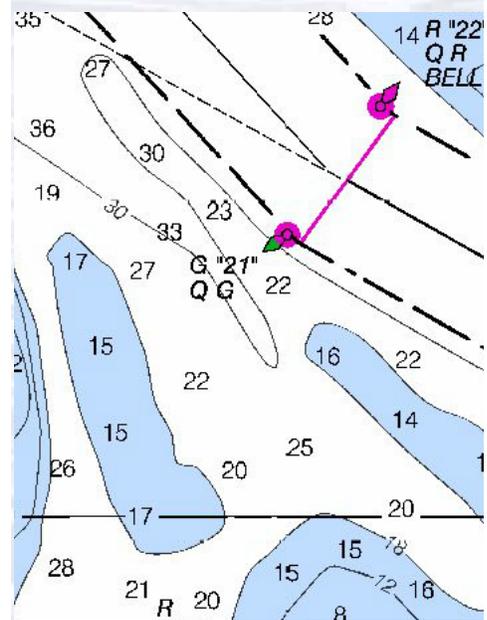
The development of multibeam sonar technology makes it possible to produce very detailed images of seafloor features, and to show the three-dimensional characteristics of these features. Point out that this is an example of how advances in engineering have extended the measurement, exploration, modeling, and computational capacity of scientific investigations.

Describe the role of multibeam sonar in ocean exploration aboard the *Okeanos Explorer*. Students should realize that this is the key technology for the "reconnaissance" component of the overall exploration strategy, and provides the "big picture" view as explorers look for anomalies. You may wish to have students read the log entry "Minding the Multibeam at Midnight" (Step 1a). This image shows how much *Okeanos Explorer*'s EM302 mapping system adds to what we know about seafloor terrain: *http://oceanexplorer.noaa.gov/okeanos/ explorations/10index/background/hires/em302_before_after_hires.jpg*.

Section of a typical nautical chart showing depth in feet. Image courtesy NOAA.
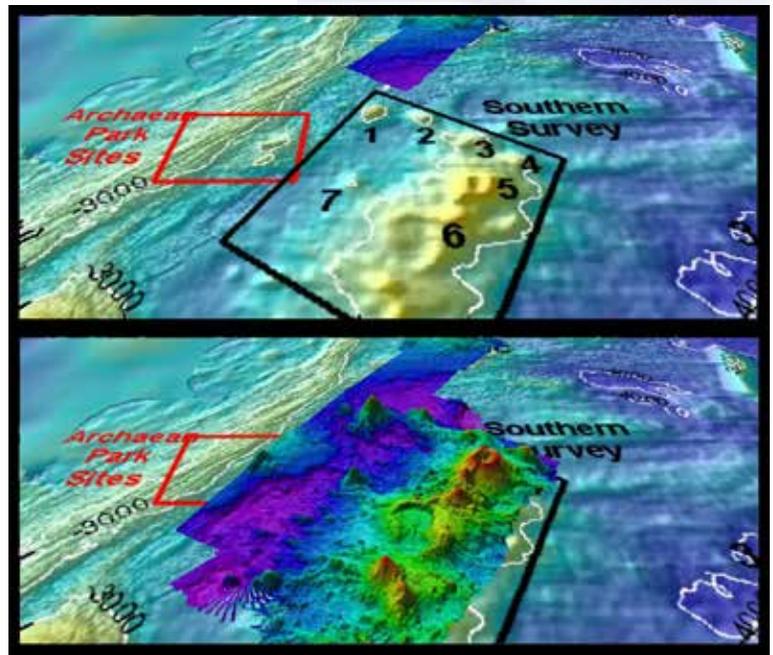
4. Tell students that their assignment is to map an unexplored and invisible landscape using methods that roughly simulate multibeam sonar technology. Divide students into "Beam Teams" of three or four students, and provide each team with a copy of the *Multibeam Mapping Simulation Activity*, and access to necessary materials. Tell students that oceanographers like to graph depth so that the greatest depths are near the bottom of the graph, because this is how we imagine a vertical slice of the ocean would appear. So, the Y-axis on the bar graphs is made so that the largest depth values will be at the bottom of the graphs. You may want to have students color the depth contours on their graphs after they are cut out using the color scheme on the Sounding Rods (or any other scheme that you choose). Coloring the cutouts will make the final model more closely resemble a multibeam sonar image.

When students have completed their 3-D bathymetry models, have each group show their models to the entire class, report their conclusions about the mystery landscape and what they infer about tectonic processes that might have produced this landscape. After each group has reported their conclusions, have them open their box, and compare the actual topography with their predictions.

This "before and after" image provides a glimpse of *Okeanos Explorer*'s EM302 mapping system capabilities in deep water. The top image shows what we previously knew about the seafloor terrain in the southern Mariana region from satellite altimetry data. The bottom image includes an overlay of the information provided by the ship's EM302 multibeam system. Image courtesy of NOAA Office of Ocean Exploration and Research.
http://oceanexplorer.noaa.gov/okeanos/explorations/10index/ background/hires/em302_before_after_hires.jpg

5. When all groups have made their presentations, ask students how their investigations could be improved. Shortening the interval between "soundings" would improve detail in the models; but would also mean a lot more work since an additional graph cutout would have to be made for each row added to the sampling procedure. Having smaller graduations on the sounding rods would help improve the accuracy of "depth" measurements. This accuracy would also be improved by having a way to ensure that the sounding rods are exactly vertical when soundings are made.

Students should realize that a multibeam sonar system would provide an almost continuous record of depth in a swath on either side of the ship. The *Okeanos Explorer*'s EM302 multibeam system can produce swath widths as large as five times the water depth. Students should also realize that rough topography can obscure other topographic features, so better resolution is especially important when there are boulders, reefs, or other irregular objects in a search area.

Discuss how the ability to accurately map geologic features might help forecast the locations and likelihoods of natural hazards such as volcanic eruptions and earthquakes (see *http://oceanexplorer.noaa.gov/explorations/03trench/welcome.html* for an example).

Discussion of multibeam sonar technology may also include the following components of technological literacy:

- **Scope of technology –** Development of multibeam sonar technology provides detailed images of the ocean floor that were not possible before this technology was developed.
- **Core concepts of technology –** Multibeam sonar is an example of several technological systems connected together; including sonar systems to obtain depth data, global positioning systems for geographic location, sensors to detect ship motion so that data can be corrected for pitch and roll, and computer systems to analyze raw data and convert the data to accurate depth estimates and visual images.
- **Relationships between technologies and other fields of study –** Improvements to each of the technologies listed above improves the overall capability of bathymetric information from multibeam sonar systems; and this information is useful to geologists, biologists, and many other branches of science.
- **Effects of technology on the environment –** Some scientists are concerned that marine mammals may be harmed if they are close to ships using certain types of sonar technology. *Okeanos Explorer*'s EM 302 multibeam system is equipped with a function that reduces transmission power to avoid harming mammals if they are nearby.

The BRIDGE Connection

www.vims.edu/bridge/ – Scroll over "Ocean Science Topics" in the menu on the left side of the page, then "Human Activities," then click on "Technology" for activities and links about satellite communications and other ocean exploration technologies.

The "Me" Connection

Have students write a short essay describing a situation (real or imaginary) in which the accuracy of a map was personally important.

Connections to Other Subjects

English Language Arts, Mathematics, Social Studies

Assessment

Class discussions and students' work with the mapping simulation activity provide opportunities for assessment.

Extensions

See the *Calling All Explorers* lesson for an activity involving maps and GPS technology: *http://oceanexplorer.noaa.gov/okeanos/edu/collection/media/wdwe_callingex.pdf*.

Multimedia Discovery Missions

http://oceanexplorer.noaa.gov/edu/learning/welcome.html – Click on the links to Lessons 5 and 6 for interactive multimedia presentations and Learning Activities on Chemosynthesis and Hydrothermal Vent Life, and Deep-Sea Benthos.

Other Relevant Lesson Plans from NOAA's Ocean Exploration Program

Earth's Ocean is 95% Unexplored: So What?

(from the INDEX-SATAL 2010 Expedition)

http://oceanexplorer.noaa.gov/okeanos/explorations/10index/background/edu/media/so_what.pdf

Focus: Importance of deep-ocean exploration (Grades 5-6; Life Science/Earth Science)

Students describe at least three different deep-ocean ecosystems; explain at least three reasons for exploring Earth's deep ocean; explain at least three ways that deep-ocean ecosystems may benefit humans; and create a wall magazine to communicate scientific ideas.

Sonar Simulation

(from the Cradle of the Earthquake: Exploring the Underwater San Andreas Fault 2010 Expedition)

http://oceanexplorer.noaa.gov/explorations/10sanandreas/background/edu/media/sonarsim78.pdf

Focus: Side scan sonar (Grades 7-8; Earth Science/Physical Science)

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

Mapping the Deep Ocean

(from the INSPIRE: Chile Margin 2010 expedition)

http://oceanexplorer.noaa.gov/explorations/10chile/background/edu/media/mapping.pdf

Focus: Bathymetric Mapping (Grades 7-8; Physical Science/Earth Science)

Students create a two-dimensional topographic map from bathymetric survey data; create a three-dimensional model of seafloor topography from a two-dimensional topographic map; and interpret two- and three-dimensional topographic data.

Sound Pictures

(from the Cradle of the Earthquake: Exploring the Underwater San Andreas Fault 2010 Expedition)

http://oceanexplorer.noaa.gov/explorations/10sanandreas/background/edu/media/soundpics912.pdf

Focus: Sonar (Grades 9-12; Physical Science)

Students explain the concept of sonar, describe the major components of a sonar system; explain how multibeam and side-scan sonar systems are useful

to ocean explorers; and simulate sonar operation using a motion detector and a graphing calculator.

Tools of Exploration - Multibeam

(from the INDEX SATAL 2010 Expedition)

http://oceanexplorer.noaa.gov/okeanos/explorations/10index/background/edu/media/multibeam.pdf

Focus: Technology for deep ocean exploration: Multibeam Sonar (Grades 9-12; Earth Science/Physical Science)

Students describe multibeam sonar; discuss the advantages of multibeam sonar bathymetry compared to two-dimensional topographic bathymetry; and interpret three-dimensional multibeam bathymetric data.

Next Generation Science Standards

Lesson plans developed for Volume 2 are correlated with *Ocean Literacy Essential Principles and Fundamental Concepts* as indicated in the back of this book. Additionally, a separate online document illustrates individual lesson support for the Performance Expectations and three dimensions of the Next Generation Science Standards and associated Common Core State Standards for Mathematics and for English Language Arts & Literacy. This information is provided to educators as a context or point of departure for addressing particular standards and does not necessarily mean that any lesson fully develops a particular standard, principle or concept. Please see: *http://oceanexplorer.noaa.gov/okeanos/edu/collection/hdwe_ngss.pdf*

Multibeam Mapping Simulation Activity Preparation Guide

Materials

Each student group will need (assuming four students per group):

1 - Cardboard box with lid, approximately 10 x 10 x 6 inches

8 - Pencils, unsharpened; or wood dowels approximately 1/4-inch diameter x 8 inches; two for each student

1 - Copy of Sounding Rod Scale (Figure 2); two for each student

Clear tape

Plaster of Paris, 1 – 2 lb, or plaster wrap cloth (from craft stores)

Masking tape

Colored pencils, six colors

Ruler

Graph paper, at least ten sheets

Awl, icepick or sharp nail

Procedure

1. If cardboard boxes of an appropriate size are not available, they can be constructed from poster board using Figure 1 as a guide. Fold along the dotted lines and tape the corners with masking tape.

2. Mark a grid of 1-inch squares on the top of the box. Make a hole at each junction point large enough so that the pencil or dowel can easily be inserted. TIP: Make a hole in the cardboard with an awl, icepick or nail; then enlarge the hole with a sharpened pencil or dowel. Label each row of holes with a number, and each column of holes with a letter (see Figure 1).

3. Cut out the Sounding Rod Scales, so that each student has two scales. If you are using the uncolored scales, color each interval with a colored pencil using the colored scales as a guide. Tape each scale onto a pencil or dowel to make two Sounding Rods for each student. The bottom of the scale should be even with one end of the pencil or dowel.

4. Prepare a "mystery landscape" in the bottom of each box that includes either an ocean ridge or trench. If students are doing this step, they should keep their work out of the sight of other groups. Mix plaster of Paris, and pour a 1 – 2 cm thick layer into the bottom of each box. You may use plaster wrap cloth instead of Plaster of Paris. You can also use crumpled newspaper or other filler to form your landscape before covering with plaster or wrap cloth. This will reduce the amount of plaster or wrap cloth needed. Do not completely cover the bottom of the box, because that will reduce the overall depth range, and we want a lot of variation in these landscapes! Allow plaster to harden. Temporarily fasten the lids to the boxes with masking tape.
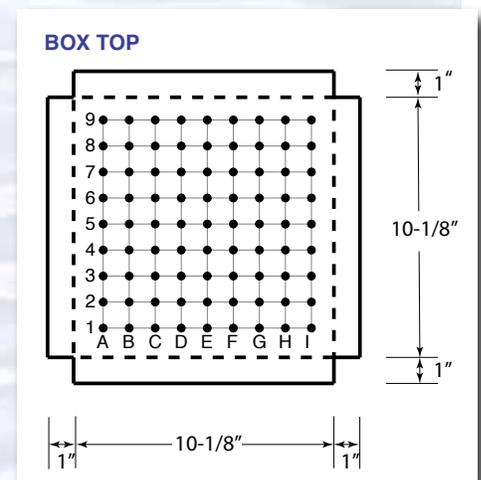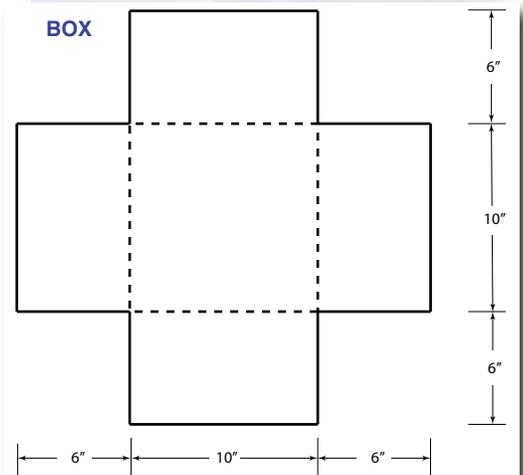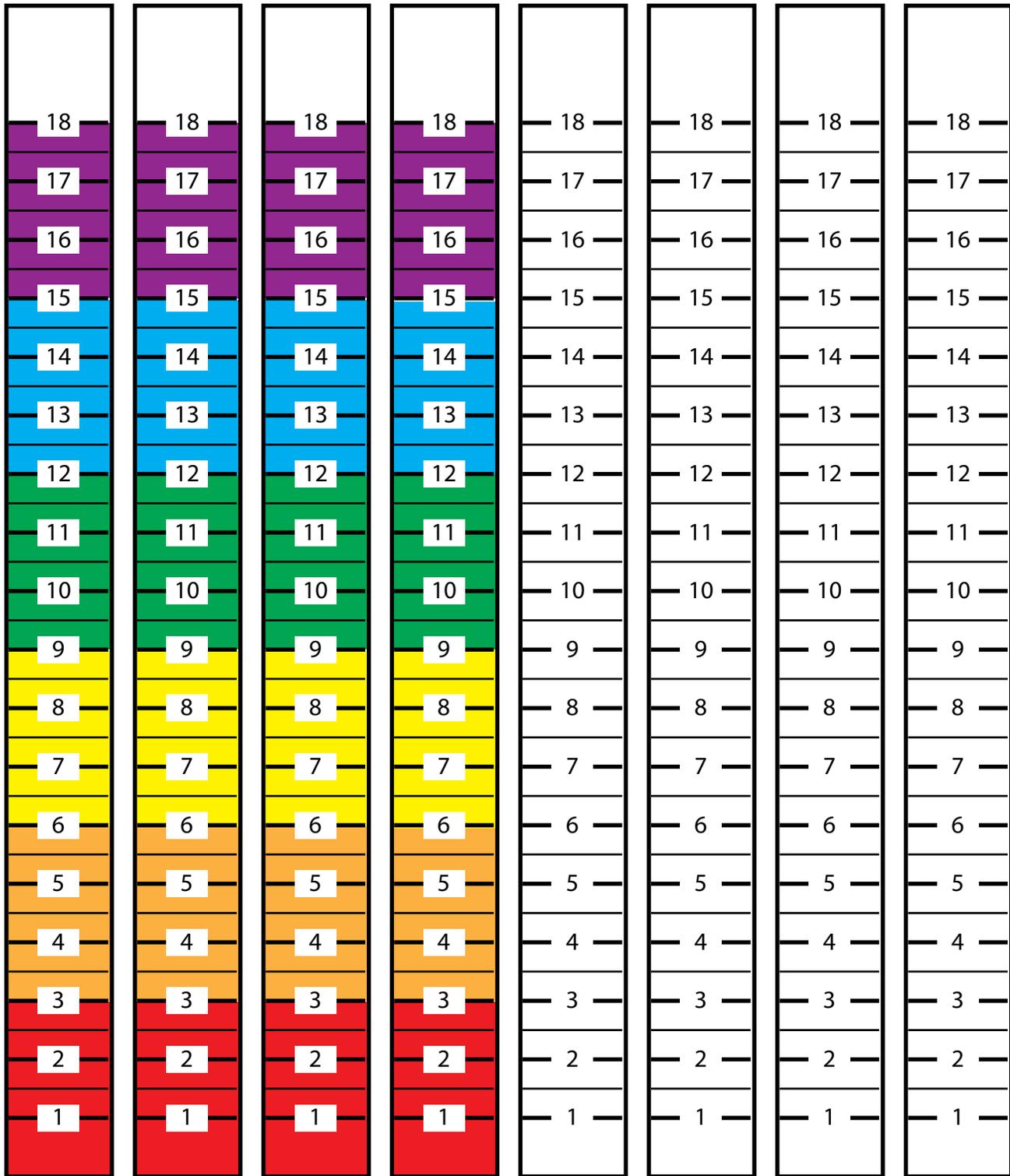
Figure 1. Box Preparation

Figure 2. Sounding Rod Scale

Multibeam Mapping Simulation Activity Guide

1. Your Beam Team should include three or four students, and each student should have two Sounding Rods. You will use these Rods to measure the depth under each of the holes in the lid of your box, then you will plot these depths to create a three-dimensional model of the landscape hidden inside the box. Each student will be responsible for measuring the depth of two or three of the holes in each row. Do one row at a time, simulating a swath. If you stand in a circle (or part of a circle) around the box, you should all be able to make your measurements at the same time.

2. When your teacher tells you to begin, each member of your team should measure the depth in their assigned holes in the first row using a Sounding Rod. Leave the Rods in place until you have recorded your measurements on the Data Sheet. It will probably be easiest if one team member does the recording while the other members call out the depth measurements.

3. When you have finished measuring the depths in the first row, use the same procedure to measure depths of the remaining holes, recording the data from your measurements one row at a time.

4. When you have measured all of the depths, and entered all the values, plot the results for each row on a bar graph as directed by your teacher. Figure 3 shows an example of the graph that resulted from plotting one row of depth data. It will probably be quickest if each team member is responsible for plotting specific rows of data.

5. When your graphs are completed, cut them out as shown in Figure 3. Be sure to leave the border at the bottom of each graph! Fold as shown, and tape each graph onto the top of the box so that the folded edge of each graph lies on its corresponding row on the box top. Stand the graphs up so that they are perpendicular to the top of the box (additional tape may be needed to keep the graphs upright).
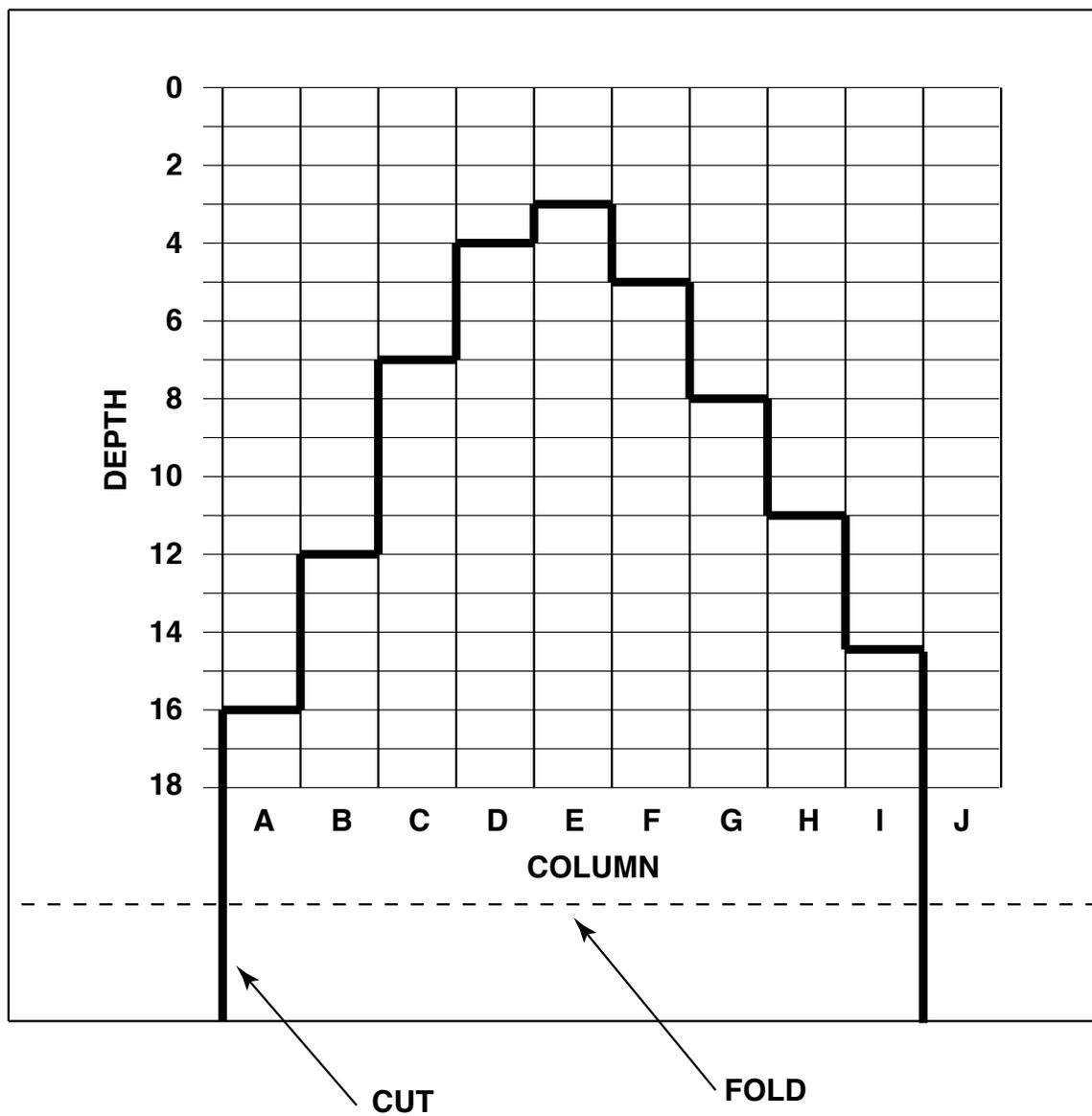
   Now you should have a three-dimensional model of the mystery landscape inside the box. Wait for further instructions from your teacher.

Multibeam Mapping Simulation Data Sheet

COLUMNS	A	B	C	D	E	F	G	H	I	J
1										
2										
3										
4										
5										
6										
7										
8										
9										
10										

ROWS

The NOAA Ship *Okeanos Explorer* Education Materials Collection
oceanexplorer.noaa.gov

Volume 2: How Do We Explore?
Multibeam Sonar – Wet Maps (5-6)

Figure 3. Example of graph of data from Row 1.

DATA

ROWS		A	B	C	D	E	F	G	H	I	J
	COLUMNS										
	1	16	12	7	4	3	5	8	11	14.5	

DATA

COLUMNS

	A	B	C	D	E	F	G	H	I	J
ROWS										

DEPTH

```
        A   B   C   D   E   F   G   H   I   J
   0
   1
   2
   3
   4
   5
   6
   7
   8
   9
  10
  11
  12
  13
  14
  15
  16
  17
  18
        A   B   C   D   E   F   G   H   I   J
```

COLUMN

Fold → –

63

Notes: