



## Wet Maps

### Focus

Bathymetric mapping

### Grade Level

6-8 (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

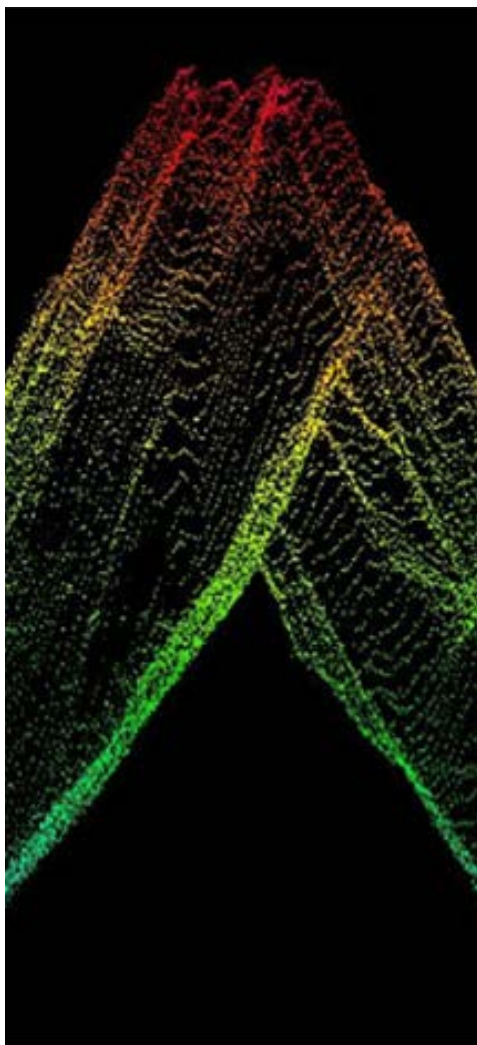
*For each student group:*

- 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 or plastic 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); or pieces of styrofoam
- Masking tape
- Colored pencils, six colors

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Comparison of resolution of satellite-derived bathymetry (top) and multibeam sonar bathymetry collected by the *Okeanos Explorer* (bottom). Example shown is the largest seamount in the Wake Atoll Unit of the Pacific Remote Islands Marine National Monument. Image courtesy of NOAA Office of Ocean Exploration and Research.

<http://oceanexplorer.noaa.gov/okeanos/one-million/media/sat-bathy.html>



Raw multibeam sonar data of an underwater mountain visualized in 3D computer software. Image courtesy NOAA Office of Ocean Exploration and Research, Discovering the Deep: Exploring Remote Pacific MPAs. <http://oceanexplorer.noaa.gov/oceanos/explorations/ex1703/logs/mar11/media/raw-sonar.html>

- Ruler, one for each student group
- Graph paper

### Audiovisual 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

### 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

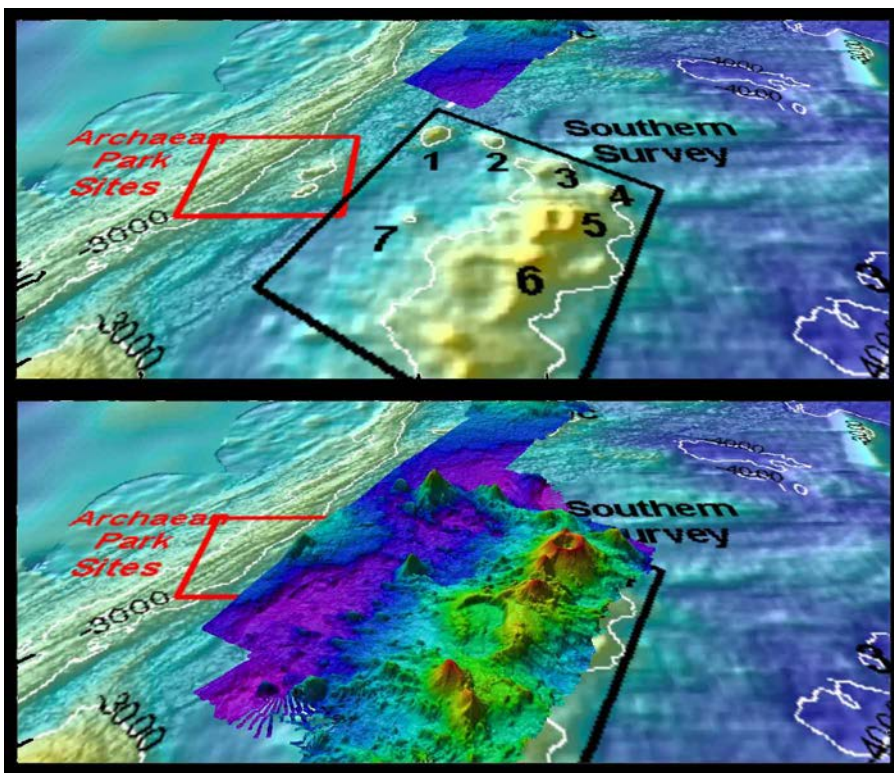
### Background Information

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*, see the *Introduction to Sonar and Multibeam Mapping* <http://oceanexplorer.noaa.gov/oceanos/edu/collection/media/hdwe-MMBkgnd.pdf>. 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:
    - Ocean Mapping: an Essential Part of Ocean Exploration by Derek Sowers, Charles Wilkins, and Jason Meyer <http://oceanexplorer.noaa.gov/oceanos/explorations/ex1703/logs/mar11/welcome.html>;
    - NOAA Ship *Okeanos Explorer*: One Million Square Kilometers of Seafloor Mapped <http://oceanexplorer.noaa.gov/oceanos/one-million/welcome.html>;
    - Seafloor Mapping <https://schmidtocean.org/technology/seafloor-mapping/> and
    - Minding the Multibeam at Midnight by Colleen Peters <http://oceanexplorer.noaa.gov/oceanos/explorations/10index/logs/aug05/aug05.html>



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 NOAA Office of Ocean Exploration and Research.  
[http://oceanexplorer.noaa.gov/oceanos/explorations/10index/background/hires/em302\\_before\\_after\\_hires.jpg](http://oceanexplorer.noaa.gov/oceanos/explorations/10index/background/hires/em302_before_after_hires.jpg)

b) Review the *Introduction to Ships of Exploration and Their Strategy for Ocean Exploration* <http://oceanexplorer.noaa.gov/oceanos/edu/collection/media/hdwe-StrategyBkgnd.pdf>.

c) If desired, download images to accompany discussions in Step 2. You may also want to download these “before and after” images to illustrate the capabilities of multibeam sonar:

[http://oceanexplorer.noaa.gov/oceanos/explorations/10index/background/hires/em302\\_before\\_after\\_hires.jpg](http://oceanexplorer.noaa.gov/oceanos/explorations/10index/background/hires/em302_before_after_hires.jpg)

<http://oceanexplorer.noaa.gov/edu/images/WetMapsImageRev.jpg>

The image below is from a multibeam sonar survey in the Pacific Remote Islands Marine National Monument that shows an approximately 1,700 meter seamount height difference when compared to previous satellite altimetry.

This image, from a multibeam sonar survey in the Pacific Remote Islands Marine National Monument, shows an approximately 1,700 meter seamount height difference when compared to previous satellite altimetry.

<http://oceanexplorer.noaa.gov/edu/images/WetMapsImageRev.jpg>

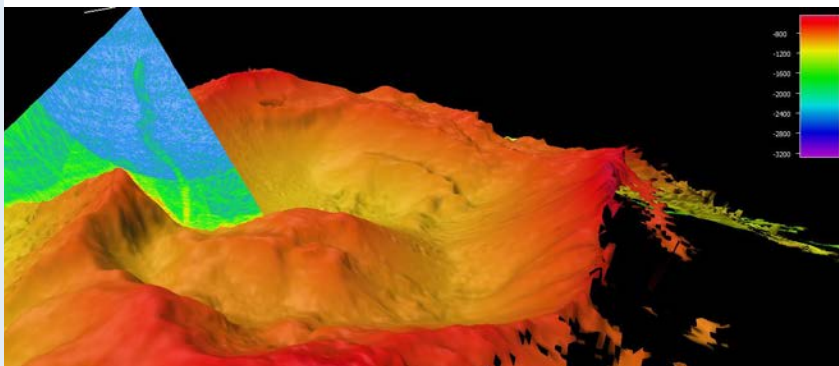


The NOAA Ship *Okeanos Explorer*, America's ship for ocean exploration. Image courtesy NOAA. <http://oceanexplorer.noaa.gov/okeanos/explorations/ex1702/logs/mar1/media/okeanos.html>

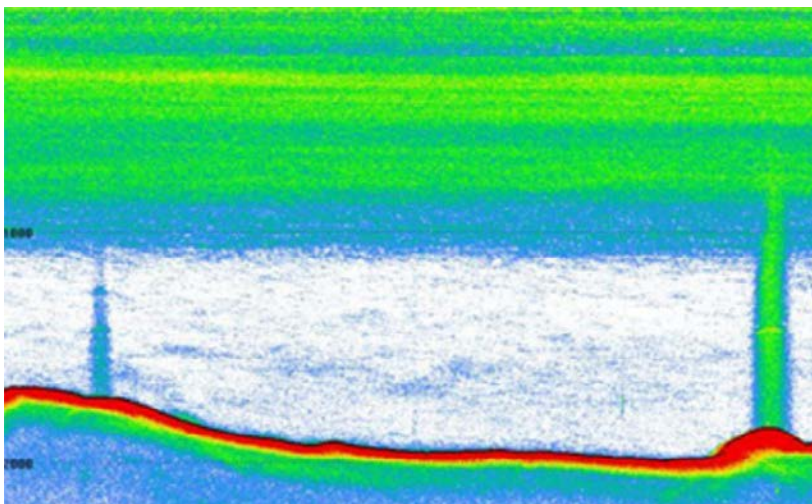
This is a great example of why it is important to map the seafloor using modern, high-resolution sonar systems. This video may be useful to accompany discussions in Step 3: [http://oceanexplorer.noaa.gov/okeanos/media/movies/ex\\_podcast\\_video.html](http://oceanexplorer.noaa.gov/okeanos/media/movies/ex_podcast_video.html)

d) Review the *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.” 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 ships of exploration NOAA Ship *Okeanos Explorer*, E/V *Nautilus*, and R/V *Falkor*; the *Introduction to Ships of Exploration and Their Strategy for Ocean Exploration* <http://oceanexplorer.noaa.gov/okeanos/edu/collection/media/hdwe-StrategyBkgnd.pdf>; and the 2017 Discovering the Deep: Exploring Remote Pacific MPAs Expedition <http://oceanexplorer.noaa.gov/okeanos/explorations/ex1703/background/plan/welcome.html>.



Multibeam sonar imagery shows a plume of bubbles rising from the crater of the Vailulu'u Seamount near American Samoa. Image courtesy of the NOAA 2017 American Samoa Expedition. <http://oceanexplorer.noaa.gov/okeanos/explorations/ex1702/logs/feb22/media/vailulu2.html>



Briefly discuss why this kind of exploration is important (for background information, please see the lesson *To Boldly Go* [http://oceanexplorer.noaa.gov/oceanos/edu/collection/media/wdwe\\_toboldlygo.pdf](http://oceanexplorer.noaa.gov/oceanos/edu/collection/media/wdwe_toboldlygo.pdf)). Highlight the overall exploration strategy used by ships of exploration, including the following points:

- The overall strategy is to develop baseline information about the biological, geological, and water chemistry features of unexplored areas to provide a foundation for future exploration and research.
- This information includes
  - High resolution maps of the area being explored, as well as areas that the ship crosses while underway from one location to the next (underway reconnaissance)
  - Exploration of water column chemistry and other features
  - High definition close-up video of biological and geological features in the exploration area (site characterization)
- This strategy relies on four key technologies:
  - Multibeam sonar mapping system and other types of sonar that can detect specific features in the water column and on the seafloor;
  - Conductivity, Temperature, and Depth profilers (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 6,000 meters; and
  - Telepresence technologies that allow scientists with many different areas of expertise to observe and interact with exploration activities, though they may be thousands of miles from the ship.

Sometimes form wins—*Deep Discoverer* (D2) is an elegant and powerful 9,000 pounds, designed to bring optimal imagery topside, where it is then shipped to shore in real time. Image courtesy of NOAA *Okeanos Explorer* Program, Gulf of Mexico 2014 Expedition. <http://oceanexplorer.noaa.gov/oceanos/explorations/ex1402/logs/apr15/media/drfront.html>

(Left): Example image of echogram from EK60 fisheries sonar. The red feature is the seafloor. Green and blue areas in the water column are features with high backscatter. The lines near the surface show dense layers of biology (zooplankton, fish, gelatinous creatures, etc.), while the vertical lines are bubble plumes emanating from the seafloor. Image courtesy of the NOAA OER, *Discovering the Deep: Exploring Remote Pacific MPAs*.

<http://oceanexplorer.noaa.gov/oceanos/explorations/ex1703/logs/mar11/media/echogram.html>



Scientist Scott France participates in the dives from his home office via telepresence. Image courtesy of NOAA OER, 2016 Deepwater Exploration of the Marianas.

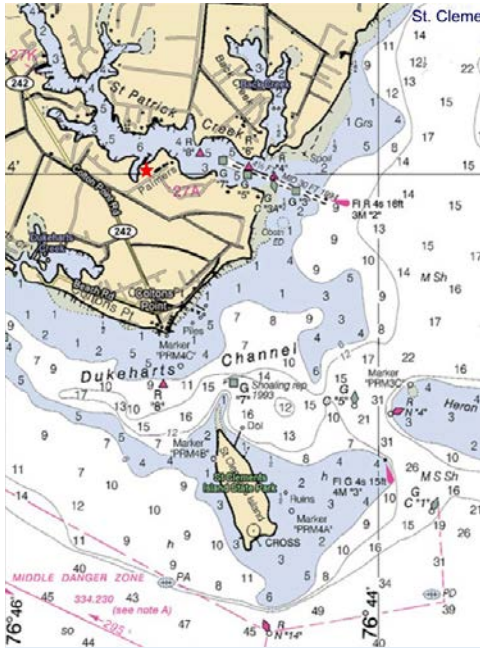
<http://oceanexplorer.noaa.gov/oceanos/explorations/ex1605/logs/jun28/media/1605scott-france.html>



Water samples are collected from the Niskin bottles on a Conductivity, Temperature and Depth profiler (CTD). All 20 Niskin bottles take water samples from various depths, starting near the seafloor and ending close to the surface. Photo courtesy of Caitlin Bailey, GFOE, *The Hidden Ocean 2016: Chukchi Borderlands*. <http://oceanexplorer.noaa.gov/explorations/16arctic/logs/july24/media/shipton.html>



## Exploring the Deep Ocean with NOAA



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. Image courtesy NOAA.

Different types of sonar: Lead line, Single beam and Multibeam. Adapted from the Canadian Hydrographic Service  
<https://noaacoastsurvey.files.wordpress.com/2015/07/surveying.jpg>

3. Ask students what they know about sonar, and provide additional information as necessary. (See the *Introduction to Sonar and Multibeam Mapping* <http://oceanexplorer.noaa.gov/oceanos/edu/collection/media/hdwe-MMBkgnd.pdf>). You may want to show the video clip 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 single beam 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). These images 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](http://oceanexplorer.noaa.gov/okeanos/explorations/10index/background/hires/em302_before_after_hires.jpg).

<http://oceanexplorer.noaa.gov/edu/images/WetMapsImageRev.jpg>

- 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.

- When all groups have made their presentations, ask students how their



Mapping personnel on the Discovering the Deep: Exploring Remote Pacific MPAs expedition (L to R): Mapping Lead Derek Sowers, Watch Lead Jason Meyer, and Survey Technician Charles Wilkins. Image courtesy of the NOAA Office of Ocean Exploration and Research, Discovering the Deep: Exploring Remote Pacific MPAs.

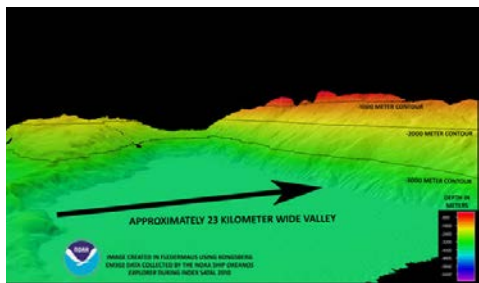
<http://oceanexplorer.noaa.gov/okeanos/explorations/ex1703/logs/mar11/welcome.html>

Typical night time mapping watch in the control room. Back to front: Senior Survey Technician Elaine Stuart monitors incoming data and adjusts settings as necessary; ROV team member, Tom Kok, does double duty by processing mapping data as it is collected; Major Dian Adrianto provides hourly status updates about ship operations to shore via intercom and the Eventlog. Image courtesy NOAA OER, INDEX-SATAL 2010.

[http://oceanexplorer.noaa.gov/okeanos/explorations/10index/logs/aug05/media/night\\_watch.html](http://oceanexplorer.noaa.gov/okeanos/explorations/10index/logs/aug05/media/night_watch.html)



## Exploring the Deep Ocean with NOAA



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. Image courtesy of NOAA *Okeanos Explorer* Program, INDEX-SATAL 2010.

[http://oceanexplorer.noaa.gov/okeanos/explorations/10index/logs/july31/media/seamount\\_channels.html](http://oceanexplorer.noaa.gov/okeanos/explorations/10index/logs/july31/media/seamount_channels.html)



Picture of the EK60 split-beam transducer mounted on the hull of the *Okeanos Explorer*. Image courtesy NOAA Office of Ocean Exploration and Research. <http://oceanexplorer.noaa.gov/okeanos/explorations/ex1503/logs/jun6/media/ek60.html>

### Multibeam Sonar Systems Aboard the *Okeanos Explorer*

*Okeanos Explorer* carries a Kongsberg Maritime EM302 deepwater multibeam sonar system. Transducers for the system are installed on the ship’s hull in a custom-designed housing. The system can transmit up to 288 beams, can collect as many as 864 depth measurements in a single ping, and automatically compensates for movements of the ship. The EM302 operates in depths ranging between 10 m and 7,000 m. The width of the swath is about 5.5 times the depth, to a maximum of about 8 km. Depth resolution of the system is 1 cm. At a depth of 4,000 m, the system can resolve features with a dimension of approximately 50 m.

Software packages used to process data from the EM302 and to integrate these data with GPS information about geographic position and sensor data about ship movements include:

Seafloor Information System  
CARIS  
Fledermaus  
arcGIS  
SonarWiz  
Hypack  
MapInfo

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 multibeam system typically produces swath widths that are three to 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, tsunamis, and earthquakes (see <http://oceanexplorer.noaa.gov/okeanos/explorations/ex1702/logs/feb20/welcome.html> for an example).

### The BRIDGE Connection

[www.vims.edu/bridge/](http://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

### Multimedia Discovery Missions

<http://www.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 Lessons from NOAA OER****Sound Pictures**

<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.

**Next Generation Science Standards and Ocean Literacy Essential Principles and Fundamental Concepts**

This lesson supports the Ocean Literacy Essential Principles and Fundamental Concepts as indicated here <http://oceanexplorer.noaa.gov/oceanos/edu/collection/media/hdwe-Standards.pdf>. Additionally, while this lesson does not target specific Next Generation Science Standards, educators may use multibeam sonar as a topic for other activities that address the following Performance Expectations.

**Specific NGSS Performance Expectation relevant to this lesson is:**

**MS-PS4-2. Develop and use a model to describe that waves are reflected, absorbed, or transmitted through various materials. [Clarification Statement: Emphasis is on both light and mechanical waves. Examples of models could include drawings, simulations, and written descriptions.] [Assessment Boundary: Assessment is limited to qualitative applications pertaining to light and mechanical waves.]**

**HS-PS4-1. Use mathematical representations to support a claim regarding relationships among the frequency, wavelength, and speed of waves traveling in various media. [Clarification Statement: Examples of data could include electromagnetic radiation traveling in a vacuum and glass, sound waves traveling through air and water, and seismic waves traveling through the Earth.] [Assessment Boundary: Assessment is limited to algebraic relationships and describing those relationships qualitatively.]**

**For Information and Feedback**

We value your feedback on this lesson, including how you use it in your formal/informal education settings.

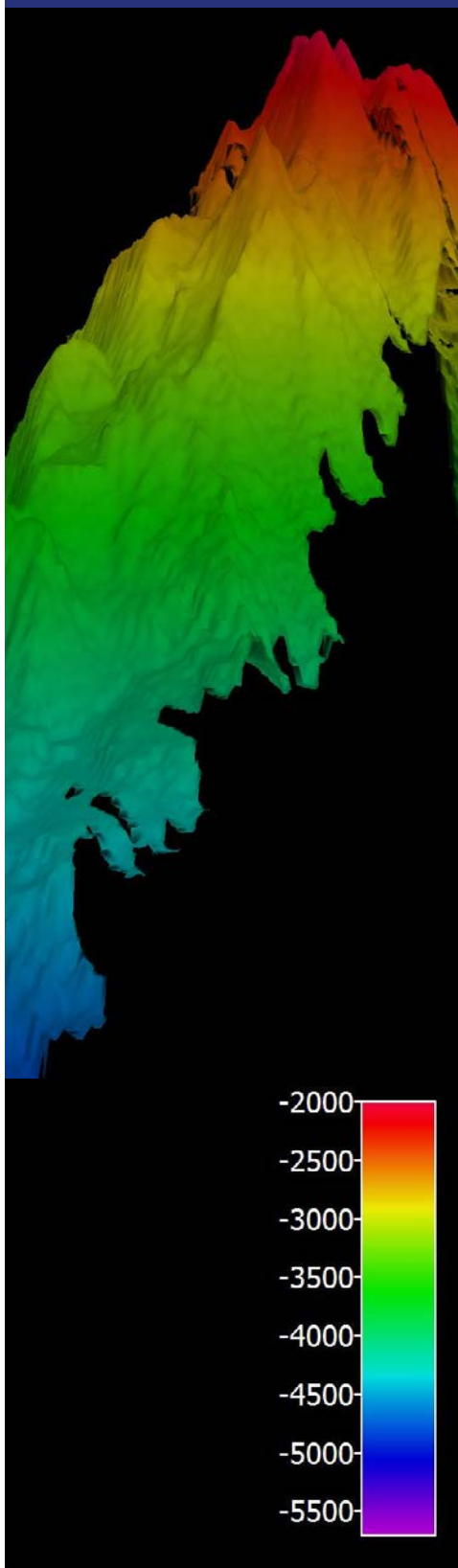
Please send your comments to:  
[oceanexeducation@noaa.gov](mailto:oceanexeducation@noaa.gov)

**Acknowledgments**

Produced by Mel Goodwin, PhD, Marine Biologist and Science Writer, Charleston, SC. Design/layout: Coastal Images Graphic Design, Charleston, SC. If reproducing this lesson, please cite NOAA as the source, and provide the following URL:  
<http://oceanexplorer.noaa.gov>

**The Next Generation Science Standards**

The Next Generation Science Standards integrate three dimensions within each standard: Science and Engineering Practices, Disciplinary Core Ideas, and Crosscutting Concepts. The standards are written as student performance expectations. While specific performance expectations may emphasize only a few of the practice categories, teachers are encouraged to utilize several practices in any instruction. Similarly, only a few crosscutting concepts may be emphasized, but this is not intended to limit instruction.



## Multibeam Mapping Simulation Activity Preparation Guide

### Materials

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

1- Cardboard or plastic 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), or pieces of styrofoam

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

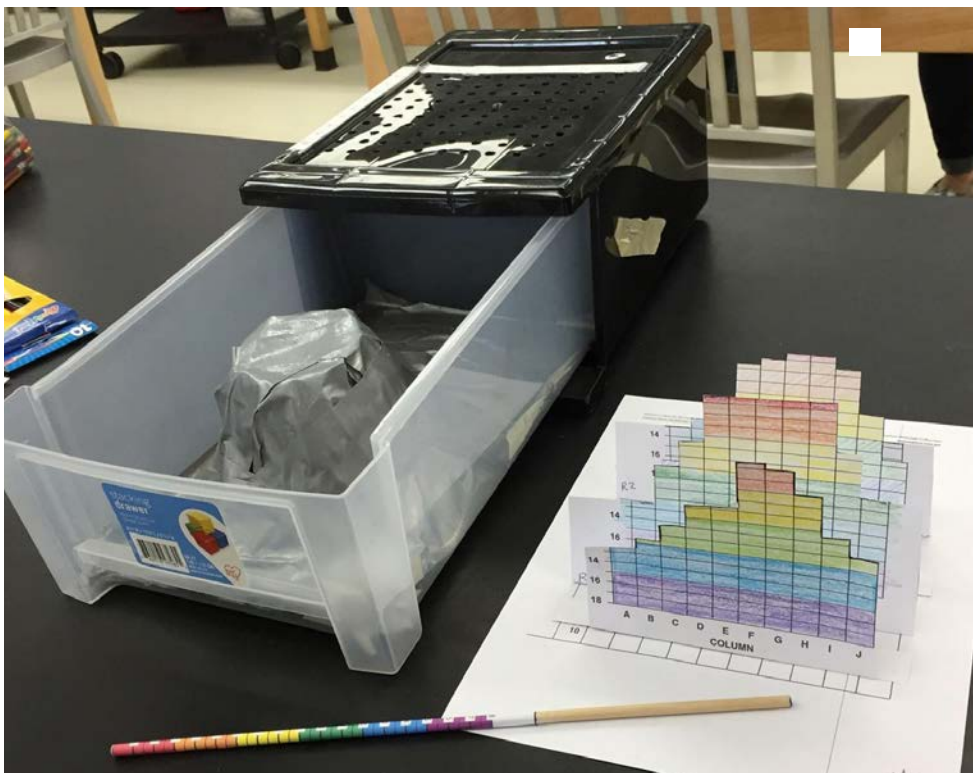
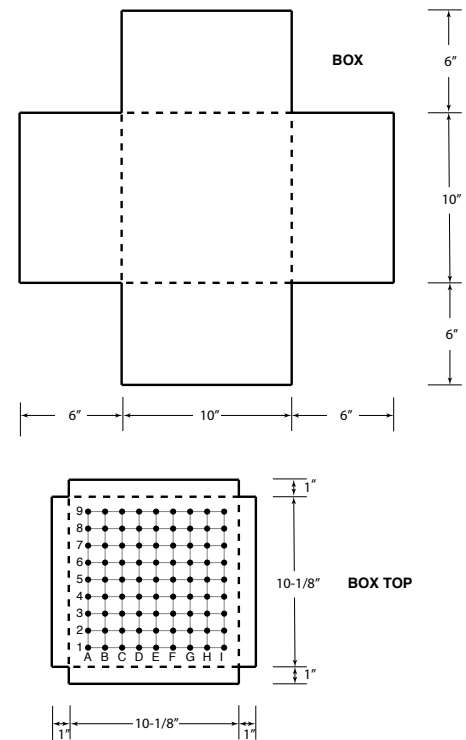
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Seamount mapped on a 2017 return voyage to Honolulu. This “Mountain in the Deep” rose approximately 3,000 meters (9,840 feet) from the seafloor. Image courtesy of the NOAA OER, Mountains in the Deep: Exploring the Central Pacific Basin 2017.

<http://oceanexplorer.noaa.gov/oceanos/explorations/ex1705/dailyupdates/media/may17-1.html>

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. You may also use pieces of styrofoam to form your landscape, with or without a plaster covering. 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.

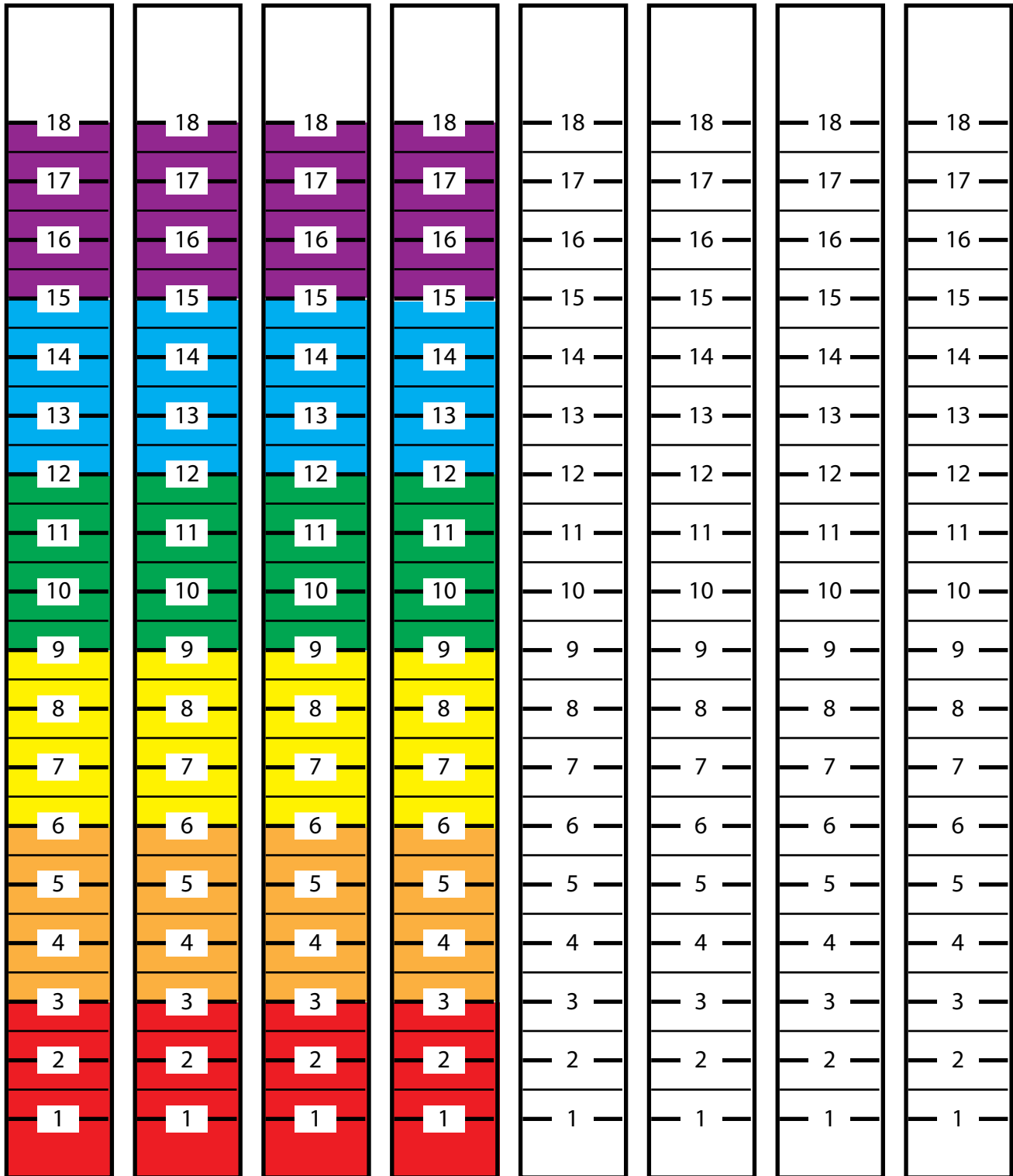
Figure 1. Box Preparation



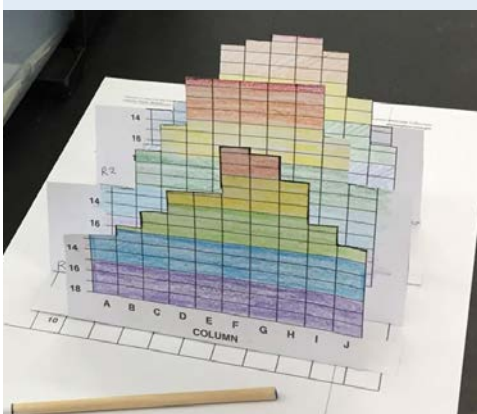
Holes made in plastic box lid; "mystery landscape" in the bottom of the box; dowel taped with colored sounding rod scale; reproduced "landscape" model. Image courtesy NOAA OER.



Figure 2. Sounding Rod Scale



## Multibeam Mapping Simulation Activity Guide



Images of the Wet Maps activity from a Professional Development Workshop. Images courtesy NOAA.

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 Multibeam Mapping Simulation Data Sheet (Figure 3). 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 copy of the blank data sheet (Figure 5). Use one copy of the data sheet for each row. Figure 4 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 4. 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 (see photo at left). Wait for further instructions from your teacher.



Figure 3. Multibeam Mapping Simulation Data Sheet

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

Figure 4. Example of graph of data from Row 1.

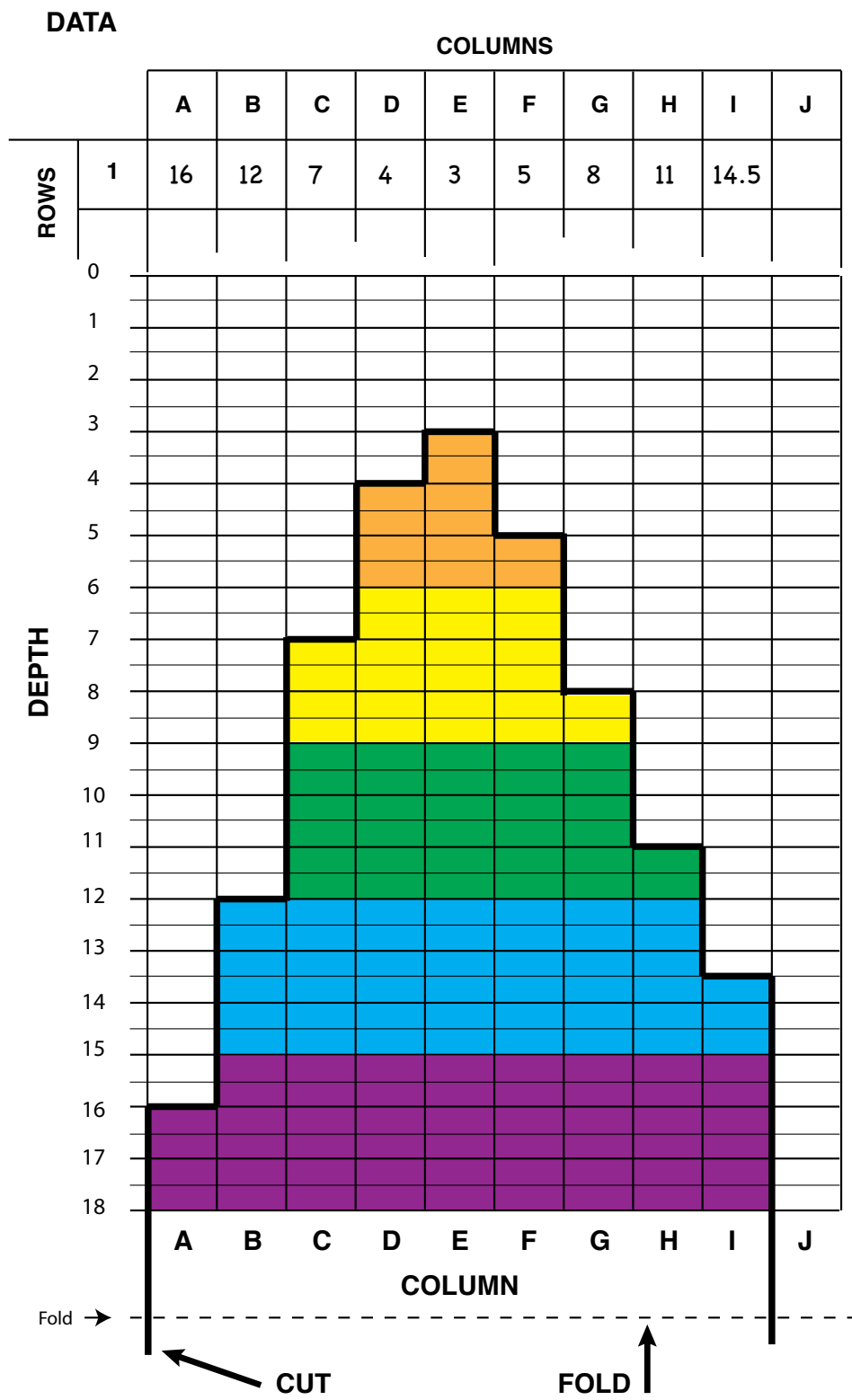


Figure 5. Blank data sheet. Use one data sheet for each row in the box.

		DATA COLUMNS									
		A	B	C	D	E	F	G	H	I	J
ROW											
	DEPTH	0									
1											
2											
3											
4											
5											
6											
7											
8											
9											
10											
11											
12											
13											
14											
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17											
18											

Fold → -----