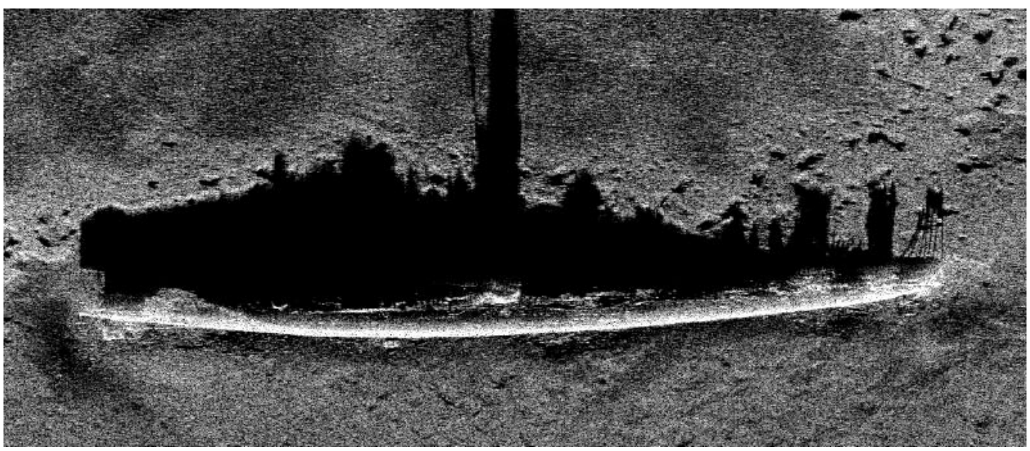
Thinking Inside the Box

Student Activity Sheet (Middle & High School)

Name ___________________ Date ___________________ Class ________

The Mission:
You have been hired by the telecommunications company, Talk To Me, to find an unobstructed relatively level path across the seafloor where they can lay down fiber optic cable. Naval records show that the submarine U.S.S. Bathy sunk somewhere in this area during World War II. The box before you represents an unexplored area of the deep seafloor. You will be using sound to "see" the features of the seafloor. Oceanographers at sea use Sonar equipment which sends out sound waves that are directed straight down towards the seafloor, reflect off, and return to the boat. If you know the round trip time for the sound pulse, you can calculate the one-way time. If you know the one-way time you can calculate the distance the wave traveled using a simple rate equation **(speed = distance/time).** The speed of sound in water varies depending on the temperature, salinity, and pressure. However, for this activity we will assume the average speed of sound in water to be 1500 meters per second. Yikes! That's 3300 miles per hour. Compare that to the speed of sound in air that is 760 miles per hour.



A side scan sonar picture of the U.S. Navy Submarine S5 that sank off the coast of Delaware in 1920
(Courtesy of Klein Associates, Inc.)

Materials:
Copy paper box containing a representative section of the seafloor
Calibrated timing dowel
Data tables

Procedure:
You will use the dowel as an instrument to measure the time it takes for a sound pulse sent from a ship to make a round trip to and from the seafloor. The dowel is marked with numbers that represent the amount of time it will take to hit a surface. Each inch

marked on the dowel represents approximately 0.7 seconds which equals about 1000 meters.
Gently insert the dowel into each grid hole until it hits bottom. Record the "time" from the dowel. The time represents the roundtrip for the sound pulse.

Trial 1

- Tables 1 and 2 below show the grid system on the top of the 15-hole box lid. The first table is to be used for trial 1 where you will collect times at only the specified coordinates. The coordinate system is similar to the game Battleship. Systematically go through the grid filling in the corresponding times in the empty boxes of Table 1 (Time).

Trial 1: Time (s)

	A	C	E	G	I
2					
4					
6					

- Sound travels through water at a speedy 1500 meters per second. Use the equation

speed = distance ÷ time

to solve for distance. Take into account that the times you recorded are the round trip times. The distance calculated is equivalent to the depth of the seafloor at that measured location. Calculate the depth (distances) for all your data points and record the values in the data table below.

Trial 1: Depth (m)

	A	C	E	G	I
2					
4					
6					

Questions:

1. Have you found the submarine? If so list the coordinates where you found it.

2. If you haven't found it, what could you do (besides opening the box) to find it?

Trial 2

- For Trial 2 flip open the 15-hole lid. You will see below it a lid with 60 holes. Follow the same procedure as you did for Trial 1.

Trial 2: Time (s)

	A	B	C	D	E	F	G	H	I	J
1										
2										
3										
4										
5										
6										

- Again use the equation, **speed = distance ÷ time** to solve for depths (distance) considering that sound travels at 1500 meters per second. Take into account that the times you recorded are the round trip times. Calculate the depth (distances) for all your data points and record the values in the data table below.

Trial 2: Depth (m)

	A	B	C	D	E	F	G	H	I	J
1										
2										
3										
4										
5										
6										

Mapping

To get an idea of the underwater terrain draw in bathymetric lines (depth contour lines) that connects points of equal depth.

The following two methods are suggestions for how you can convert your Table 5 data into a map that will help you visualize the features of your ocean floor. Method 1 is a low-tech method using crayons or color pencils while Method 2 requires computers with the program Excel.

Method 1

Materials:

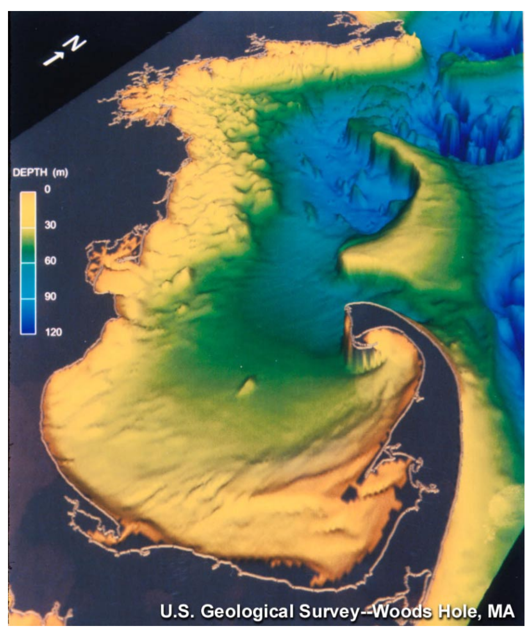
Crayons or color pencils, 1 each of black, dark blue, light blue, green, yellow, orange, red, and pink.
Seafloor Mapping Sheet

Procedure:

Systematically move across each row of your Trial 2 depth data and for each depth look on the depth color table below to find the corresponding color. Color the appropriate square that color on the Seafloor Mapping Sheet. For example, if square A2 is 2500 meters deep then color section A2 green on the Seafloor Mapping Sheet.

Depth Color Table

Depth (meters)	Color Code
4500	Black
4000	Purple
3500	Dark Blue
3000	Light Blue
2500	Green
2000	Yellow
1500	Orange
1000	Red
500	Pink



Once it is completed you should have a simplified view of the your ocean floor similar but less detailed than the map of Cape Cod Bay & Stellwagen Bank above.

<u>Method 2</u>

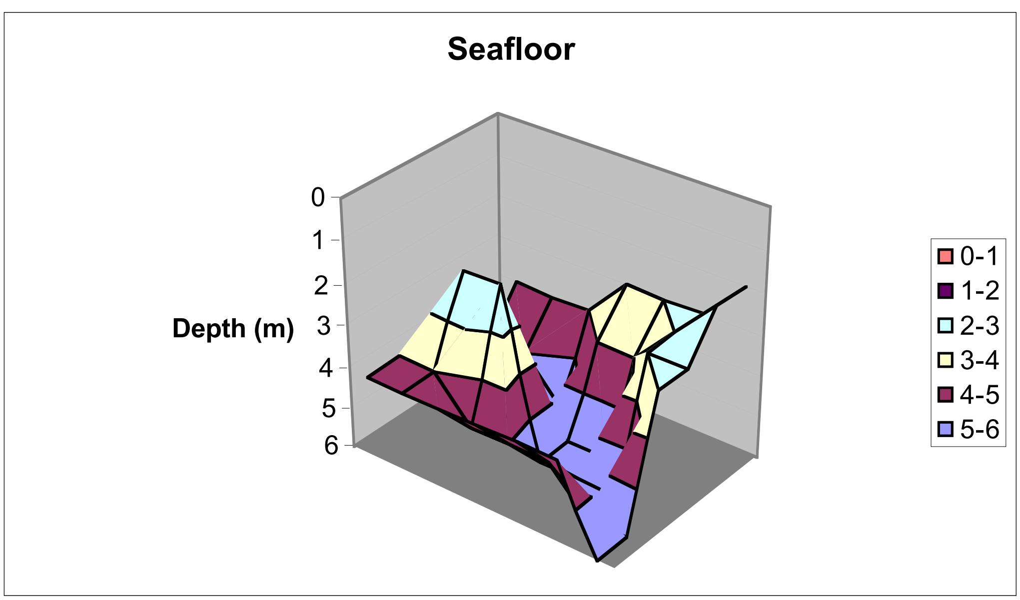
Materials:

Completed Trial 2 Depth data
Computer with the program Excel

Procedure:

The computer program Excel has the capability to make a 3- dimensional surface map from data such as the data collected in Trail 2.

- Click on Excel to open the program.
- Enter all the depth data into the corresponding boxes on the Excel table.
- Once you have entered all the data, highlight all your data by clicking in box A1 and dragging to J6 so that all of your data is highlighted.
- Go up to the tool bar and click on "chart".
- Scroll down to "surface" and click on the view you prefer.
- Fill in a chart title and label the x, y and z-axes. The z-axis is the depth.
- To rotate the graph to get a better view of it, go up to the tool bar and click on "chart".
- Scroll down to "3-D view" and play with the elevation and perspective until your seafloor is easy to see.
- To be consistent with standard oceanographic graphs you will need to reverse the order of numbering on the depth axis. Generally the top of the graph is sea level and depth increases as you go down. To change that on the depth axis move the cursor over to the depth axis and right click. Scroll down to "format axis". Click on the "scale" tab. Check the box that reads, "values in reverse order".
- To get more definition in your depth scale, change the major unit to 300 (or whatever works for you). These changes are made in the same "format axis", "scale" section as above.
- Once you are satisfied with your graph, you can print it out. (See an example of a 3-D plot below.)



Questions:

3. Now have you found the submarine? If so list the coordinates where you found it.

4. Think about how this area might have formed geologically. Do you see evidence for converging or diverging plate boundaries? Explain.

5. What differences did you have between your 15-hole "picture" and your 60-hole "picture"?

6. Below is an area of seafloor that you want to map. You are the captain of the ship. What will be the best way to cover every square without passing over any square twice? Draw arrows to mark your path.

7. What is your recommendation to Talk To Me in terms of placement of their pipeline for fiber optic cable? Explain your reasoning.

8. Look at your bathymetric lines map. Which face of the mountain is the steepest and how do you know just by looking at the bathymetric lines?

9. Why does sound travel faster in water than in air?

Teacher Strategy

Grade Level: 8-12

Time Required: 3, 45-minute class periods

Standards Addressed:

<u>New Standards Middle School</u>

Applied Learning
Information Tools and Techniques - A3a, A3b

Mathematics
Geometry and Measurement Concepts - M2a, M2b, M2c, M2g, M2I, M2k
Function and Algebra Concepts - M3b, M3c,
Statistics and Probability Concepts - M4a, M4b, M4c

Science
Physical Science Concepts - S1b
Earth and Space Science Concepts - S3a
Scientific Connections and Applications - S4
Scientific tools and Technologies - S6a, S6b, S6c
Scientific Communication - S7a

<u>New Standards High School</u>

Science
Physical Science Concepts - S1b
Earth and Space Science Concepts - S3a
Scientific Connections and Applications - S4a
Scientific tools and Technologies - S6a, S6b, S6c
Scientific Communication - S7a

Science Literacy for ALL Students
<u>Rhode Island Science Framework</u>

Processes That Shape the Earth Grade 9-12
(Benchmark 4 of 5)
(Benchmark 5 of 5)

Motion Grade 6-8
(Benchmark 4 of 5)

Objectives:

1. Students will develop an understanding of how Sonar is used and how it works.
2. Students will develop an understanding that sound travels faster through water compared to air.
3. Students will develop an understanding that it takes a longer time for sound to come back to you the farther away the object is you are bouncing the sound off.
4. Students will demonstrate that you can use sound to show what you can not see.
5. Students will demonstrate the collection of data in an organized fashion using grids and data tables correctly.
6. Students will use the data collected to create and build 2 and 3 dimensional topographical maps and graphs by hand with grid paper and by computer with Excel.
7. Students will gain an understanding that the more sound pulses used, the more data collected, the more detailed and clearer the finished product will be.
8. Students will demonstrate the use of the equation, speed = distance ÷ time or the correct use of a conversion table.

Background Information:

The ocean is relatively opaque to light and radio waves, but transparent to sound. Sound is the only energy that will travel a large distance at sea. The speed of sound in water varies depending on the temperature, salinity, and pressure of the water. The speed of sound increases with increased salinity, increased temperature, and increased pressure. The speed of sound ranges from 1440 m/s in cold fresh water to 1540 m/s for tropical waters. The average speed is1500 meters per second.

Sonar (Sound navigation and ranging) was developed in the early 20th century and used to detect submarines in World War I. Sonar systems can be active or passive. Passive systems only receive sound. A submarine uses passive sonar to hear without being heard. Active sonar systems send and receive sound. They send out a sound pulse, which hits a surface, and bounces back creating a picture in sound of the surfaces it hits. Refer to Discovery of Sound in the Sea, "What is sonar?" (http://omp.gso.uri.edu/dosits/science/whatis/4a.htm)

Side scan sonar is used to look at the detail of the ocean floor. Side scan sonar instruments are towed behind ships and often called towfish or tow vehicles. The instrument sends out a sonar signal in pulses at right angles to the direction the ship is moving (so it is "looking" sideways and down). The sonar signal is concentrated in a narrow band on both sides of the tow vehicle. Today's side scan sonar systems generate sound pulses at a frequency around 100kHz. Typical uses of side scan sonar include: looking for objects on the seafloor (sunken ships, pipelines, downed aircraft, lost cargo), detailed mapping of the seafloor, investigation of seafloor properties (grain size, etc) and looking at special features on the seafloor like underwater volcanoes. Refer to Discovery of Sound in the Sea, "How do we find objects on the bottom of the ocean?" (http://omp.gso.uri.edu/dosits/people/navigatn/3.htm)

Instructional Strategies:

Optional Introductory Activity: *The following activity is optional and can be done to introduce the students to some important concepts.*

Have students lay on the floor in a long hallway with one ear to the floor. Have a teacher or student with clicking heals or shoes walk down the hallway toward the group of students on the floor. (Be sure to have the students on the floor face away from the person walking down the hall.) Ask the students to raise their hands as soon as they hear the person coming. Have one or more students mark down the time. (A stop watch or counting 1 one thousand 2 one thousand could be used.)

Next have students stand in the hallway in the same place with their backs to the person walking down the hall toward them. Ask the students to raise their hand as soon as they hear the person coming. Have one or more students mark down the time.

1. Which way did you hear the person coming down the hall sooner, with your ear to the floor, or standing with your back to the person?
2. Does sound travel faster through air or the solid floor?
3. Does sound travel faster through air or water?
4. (Refer to http://omp/gso.uri.edu/dosits/science/sndmoves/1.htm) Sound is a pressure wave that travels through different media differently. In general, the denser the medium, the faster the wave travels. Sound travels at about 340 meter per second in air and about 1500 meters per second in seawater.

Optional Opening Demonstration: *The following demonstration is optional and can be done to introduce the students to some important concepts.*

Throw a ball against a wall and catch it from a close distance. Tell the students that you are always throwing the ball at the same speed. Now back up and throw the ball from farther away.

1. What do you note about what happens with the ball as I step back away from the wall?

Continue to bounce the ball off the wall from different distances until the students get the idea that it takes a longer time for the ball to return to you the farther you are from the wall. Explain that sonar works in a similar fashion.
(Refer to http://omp.gso.uri.edu/dosits/science/whatis/4a.htm)

Preparation:

1. Assemble enough Seafloor Boxes for your class. Download Seafloor Box Instructions from the Sounds in the Sea web site, (http://omp.gso.uri.edu/dosits/teacher/activity/activity.htm#inside)
2. Be sure to include the Seafloor mapping- student worksheet with the Student Activity packet.

Assessing Prior Knowledge:

Begin the class with a group discussion or short writing activity. Ask/Give the students the following questions:

1. How do scientists find out what the bottom of the seafloor looks like or find sunken ships or planes?
2. Here in front of you we have a model of the seafloor but it is inside this covered copy paper box. Why is the box covered? How is this like the seafloor?
3. What other sense could we use to find out what the seafloor or any thing else looks like if we could not see it?
4. How do some animals tell what is in front of them if they can not see it? (Refer to Discover of Sound in the Sea, "How do marine animals use sound to navigate?", http://omp.gso.uri.edu/dosits/animals/use/3.htm)
5. List tools that researchers and scientists use to see the seafloor. (Refer to Discovery of Sound in the Sea, People and Sound in the Sea, http://omp.gso.uri.edu/dosits/people/intro.htm)
6. How could we use this wooden dowel to see or find out what is in the bottom of our copy paper box without opening the box.
7. What research tool would the wooden dowel represent?

Procedural Tips:

- Note that the times marked on the dowel are based on the time it takes for the sound signal to reach the seafloor and then return to the surface (round-trip). The depths calculated represent the distance from the surface to the seafloor.
- The following is sample data that may be helpful when the students are conducting this activity. It also may be useful for when you are constructing the Seafloor Box.

Sample Data:

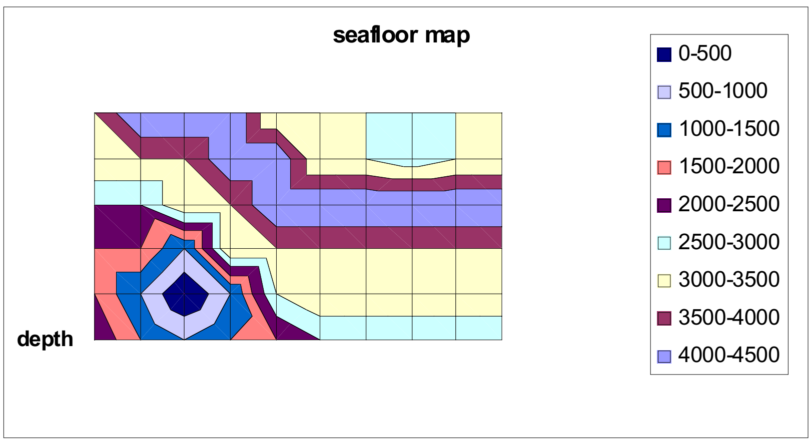
Trial 2, Time (s)

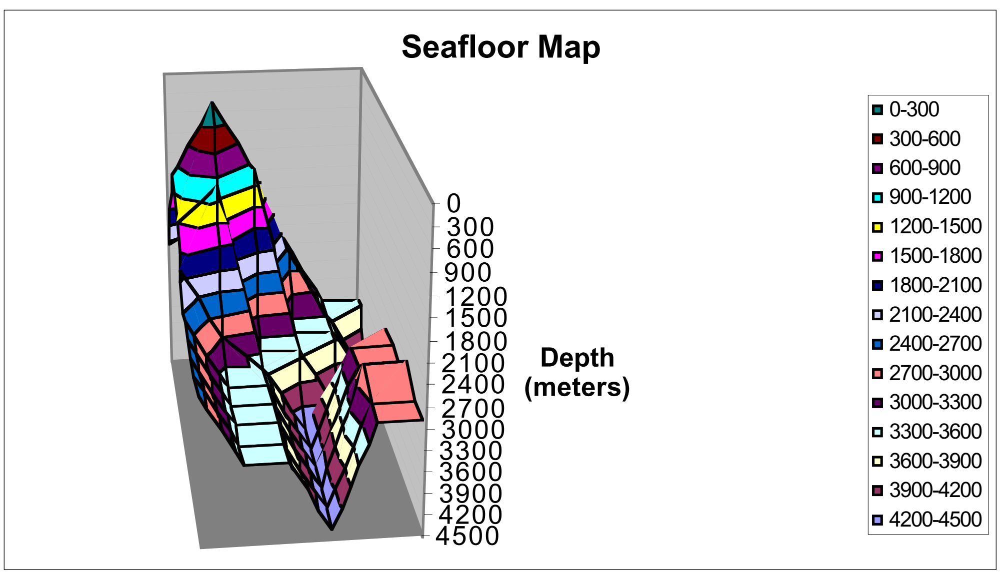
	A	B	C	D	E	F	G	H	I	J
1	3.3	2.0	1.3	2.0	2.7	3.3	3.3	3.3	3.3	3.3
2	2.7	1.3	0.7	1.3	4.0	4.7	4.7	4.7	4.7	4.7
3	2.7	2.7	1.3	4.7	4.7	4.7	4.7	4.7	4.7	4.7
4	3.3	3.3	4.7	4.7	6.0	6.0	6.0	6.0	6.0	6.0
5	4.7	4.7	4.7	6.0	6.0	4.0	4.0	3.6	4.0	4.0
6	4.7	6.0	6.0	6.0	4.0	4.0	4.0	3.6	4.0	4.0

Trial 2, Depth (m)

	A	B	C	D	E	F	G	H	I	J
1	2500	1500	1000	1500	2000	2500	2500	2500	2500	2500
2	2000	1000	500	1000	3000	3500	3500	3500	3500	3500
3	2000	2000	1000	3500	3500	3500	3500	3500	3500	3500
4	2500	2500	3500	3500	4500	4500	4500	4500	4500	4500
5	3500	3500	3500	4500	4500	3000	3000	2700	3000	3000
6	3500	4500	4500	4500	3000	3000	3000	2700	3000	3000

Samples of Surface Maps Using the Data from the Activity and Graphing With Excel





Answers to Questions:

Example of Bathymetric Lines For Map Data

	A	B	C	D	E	F	G	H	I	J
1	2500	1500	1000	1500	2000	2500	2500	2500	2500	2500
2	2000	1000	500	1000	3000	3500	3500	3500	3500	3500
3	2000	2000	1000	3500	3500	3500	3500	3500	3500	3500
4	2500	2500	3500	3500	4500	4500	4500	4500	4500	4500
5	3500	3500	3500	4500	4500	3000	3000	2700	3000	3000
6	3500	4500	4500	4500	3000	3000	3000	2700	3000	3000

1. Students should not see evidence of the submarine at this point.

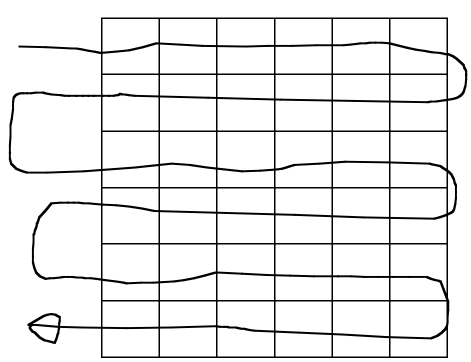
2. Collecting data at more locations (more holes in the box) would give a more complete picture of the seafloor.

3. The seafloor is similar to the classroom floor in that they are both at the bottom. They are different in that the seafloor is not flat and the classroom floor is.

4. The trench and mountain is evidence of a subduction zone at a converging boundary.

5. The 60-hole lid provides more sounding data and a more complete picture of the seafloor.

6.



7. There is a relatively flat area that runs from A5 and A6 to J2 and J3 at a depth of 3000 meters.

8. The face at C4/C5 and D2/D3 is the steepest because the bathymetric lines are closest together there.

9. Sound travels faster in water than air because water is more dense that air.

Post Activity Assessment:

- Have students present their findings to a group. In their presentation they should
    1. discuss the process they used (sonar) to collect their data
    2. present their data so that it is easy for the group to read and understand
    3. present their findings as a result of the data they collected

- Have students try the whole process in reverse. Start by giving them a section of a nautical map that has depths on it. What would be the time data that they would get if they were in a boat traversing that quadrant?

Extensions:

- If you have the time students can make their own boxes/seafloor.

- If your students have knowledge of trigonometry you could mimic a multibeam sonar system which sends sound pulses out at angles and depending on the angle translates it into a vertical depth. To mimic the multibeam system, use a box top with one row of holes running the length of the box on the centerline.

Vocabulary

Bathymetric Lines:
    Lines of seafloor topography that denote the depth in an area.

Converging Plate
    A boundary where two tectonic plates come together

Diverging Plate
    A boundary where two tectonic plates are separating

Salinity
    The amount of salt dissolved in seawater

Sonar
    A method or devise that uses sound waves to see beneath the surface of the ocean

Resources/References:

Fish, John P. and Carr, H. Arnold; Sound Underwater Images; American Underwater Search and Survey Ltd.; Cataumet, Massachusetts; 1990.

Web Sites:

Discovery of Sound in the Sea
http://omp.gso.uri.edu/dosits.htm

Side scan and Multibeam Sonar Information- NOAA
http://chartmaker.ncd.noaa.gov/hsd/wrecks.htm

Mapping the Seafloor and Biological Habitats of the Stellwagen Bank
http://pubs.usgs.gov/factsheet/fs78-98

Pacific Seafloor Mapping Project (check out the fly-by movie section)
http://walrus.wr.usgs.gov/pacmaps

Images of the Seafloor off the U.S. Coast
http://www.ldeo.columbia.edu/us_margins/

Stellwagen Bank National Marine Sanctuary
http://stellwagen.nos.noaa.gov

Sonar Images
http://www.kleinsonar.com/imgal.html

Institute for Marine Acoustics- Acoustics & Sonar Primer
http://www.instituteformarineacoustics.org/SonarPrimer/SideScanSonar.htm

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This activity was developed by Rhode Island school teachers Diane Mayers and Sarah Quan during the Discovery of Sound in the Sea Teacher Institute. University of Rhode Island, Office of Marine Programs, 2002.
