Module 1 Unit 6: Ocean Floor

Sonar Soundings and Seafloor Profiles

Modern oceanographers use sophisticated **remote-sensing** techniques to gather data about the sea floor. The data are then plotted on charts and maps and used to create models that help us understand what seafloor features are like. A major advance in the ability to measure ocean depths was made in the 1930s when **echo-sounding sonar** devices (also called fathometers) replaced sounding lines (lengths of rope with a weight at one end) for determining the depth of the ocean (See Fig. 1.1). The word **sonar** is formed from the term **so**und **na**vigational **r**anging. Sonar works by sending out pulses of sound waves. Instruments record the time it takes for the sound waves to travel to the bottom, reflect, and return to the instrument. Because the speed of sound in seawater is known to be about 1,460 meters per second, depth can be calculated based on the time it takes for the sound wave to leave the instrument, reflect off the bottom, and return to the instrment. The speed of sound in seawater varies with the temperature and salinity in different regions of the ocean, and these variations must be taken into account when depth determinations are being made. Sonar devices are now so inexpensive and easy to operate that they are commonly used even on small outboard motorboats.

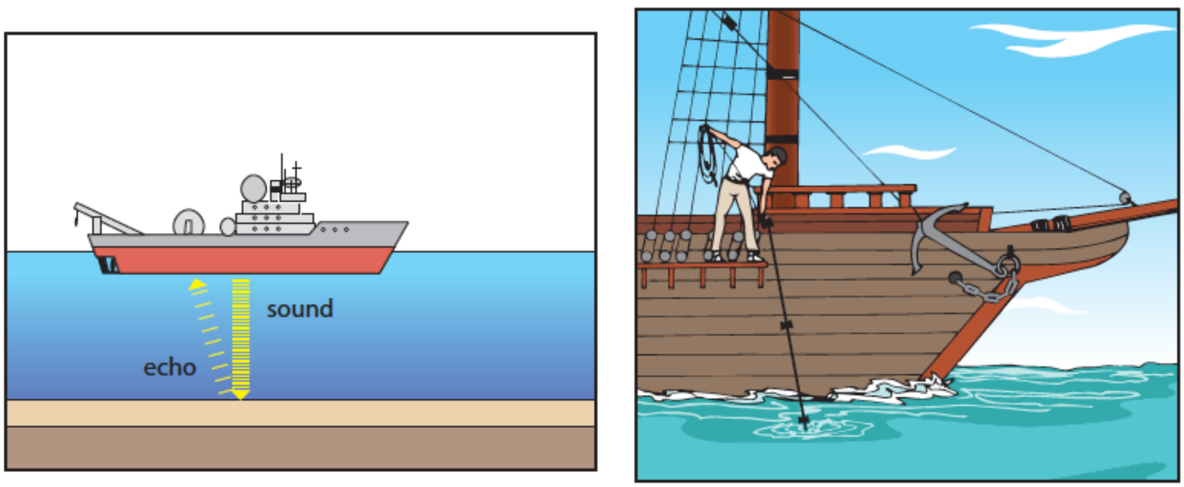

Figure 1.1. (**A**) Echo soundings can be made while a ship is under way. (**B**) Echo soundings replaced sounding lines.

The great advantage of using sonar is that a vessel can keep moving at normal speed while soundings are made. Recording a series of soundings on a strip of paper, or making a computer printout, produces a two-dimensional visual **profile** of the seafloor, called an **echogram** or **sonograph** (Fig. 1.2). To map the seafloor, research vessels cross the ocean making sonar profiles along carefully navigated, parallel courses. After many profiles are made, they can be cut out of cardboard or wood and assembled in order. A three-dimensional model of the seafloor can be constructed by filling the spaces between the profiles with modeling material (Fig. 1.3).

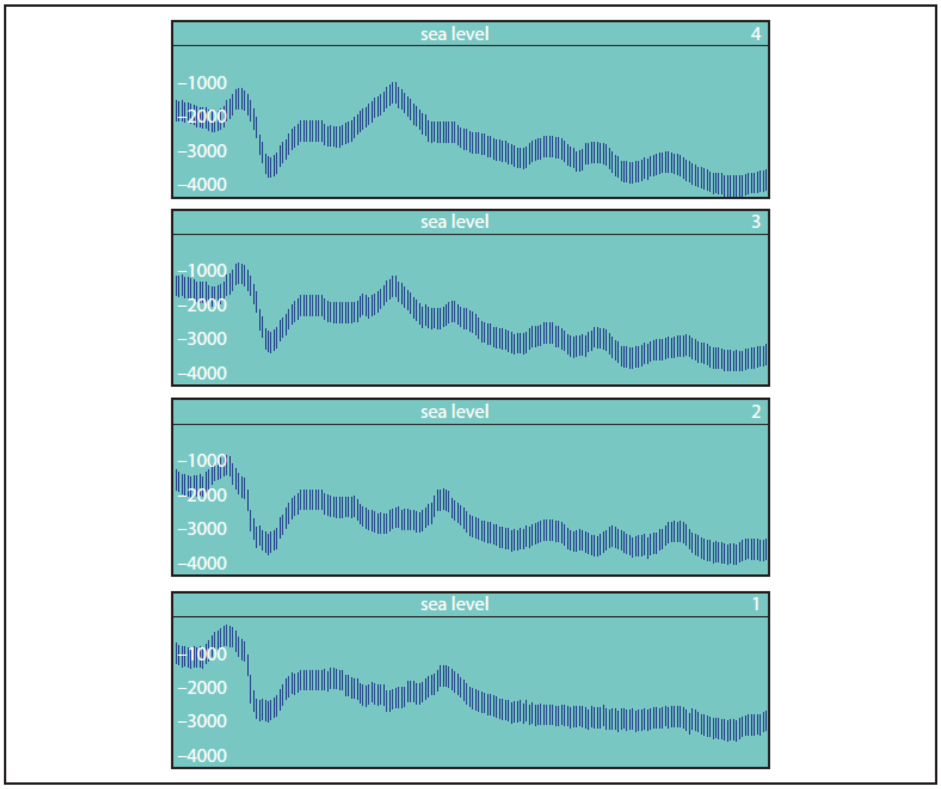

Figure 1.2. Echograms are two-dimensional images of seafloor features along a transect line. The profile series shown here illustrates data obtained from parallel transects made several kilmeters apart.

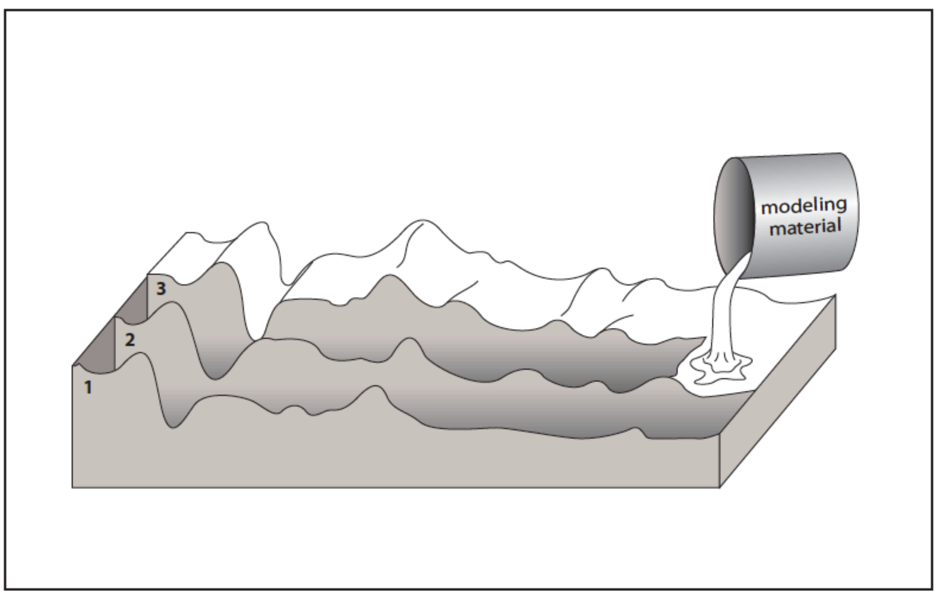

Figure 1.3. A three-dimensional model of the ocean floor constructed by assembling a series of parallel profiles.

Ocean Floor Activity 1: Simulating Sonar Mapping of The Ocean Floor
Simulate the collection and use of sonar data to make hypotheses about the ocean floor.

MATERIALS
• centimeter ruler
• three-dimensional seafloor model
• cardboard box
• paper
• colored pencils
• masking tape
• paper with 1 cm grid (Fig. 1.4)
• wooden skewers

PROCEDURE
Part A
Date: 1940
Imagine that it is 1940 and you have landed your dream job as an oceanographer on a research ship using single-beam sonar technology to explore a never-before mapped section of the ocean floor. You wish to conduct a large survey of your study area, but your granting agency is first requesting general sea floor topography. Your job is to investigate your seafloor effectively, reporting back to the funding agency on prominent sea floor topography, so that you can request additional funds.

1. Obtain a 3-dimensional seafloor model in a box covered with paper from your teacher. The paper represents the water surface. If your teacher has not already done so, tape the paper with a 1 cm grid on top of the paper cover.

3. Mark a straight line across the grid paper to represent a transect line. The line should extend from one edge of the grid to the opposite edge, but does not have to be perpendicular to the edges. This is the line your boat is traveling over this area of the ocean.

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Figure 1.4. One centimeter grid paper

4. A funding agency has given you money for 20 depth soundings (wooden skewer probes) along your transect. You do not have to use all 20 soundings, but you should use enough to adequately sample the seafloor.
    a. Make marks along your transect where you will make your depth soundings. Your depth soundings should be made at regular intervals along your transect. The intervals should be no closer than 0.5 cm apart.
    b. Measure the interval between each skewer probe (e.g. probes are 0.5 cm apart, 1 cm apart, etc.)
    c. Insert the sharp skewer probe. Keep the probe vertical, being careful not to let it slide down a slope on the model.
    d. For each location, measure the distance in centimeters that the probe is inserted. This is equivalent to the seafloor depth. Use one of the following methods for mesuring the depth of your seafloor (or come up with your own way) *(note: corresponding figures for these methods being developed)*:
        I. Pinch the skewer after it touches the seafloor bottom where the skewer meets the water (paper). Carefully pull out the skewer and measure to your pinched fingers.
        II. Mark the location where the skewer meets water (paper) with pencil or tape. Carefully pull out the skewer and measure to your pencil mark or tape. Remove the tape or erase the pencil mark before continuing.
        III. Make your skewer into a centimeter ruler. Make clear ruler marks on your skewer (starting from the point) with a pen or fine-tipped marker. When your skewer touches the bottom, read the ruler mark where it meets the water (paper).

6. Record each depth at its proper location on the grid. You can mark this data directly on the grid covering your seafloor box or have a second grid printed out where you record your data. Note that depth measurements (below the paper, or water line) are negative because they represent elevations below sea level.

7. Use the data to make a profile of the seafloor feature(s) along the transect line in Fig. 1.5.

8. Examine, identify, and label the seafloor features on the profile (use Table 1.1).

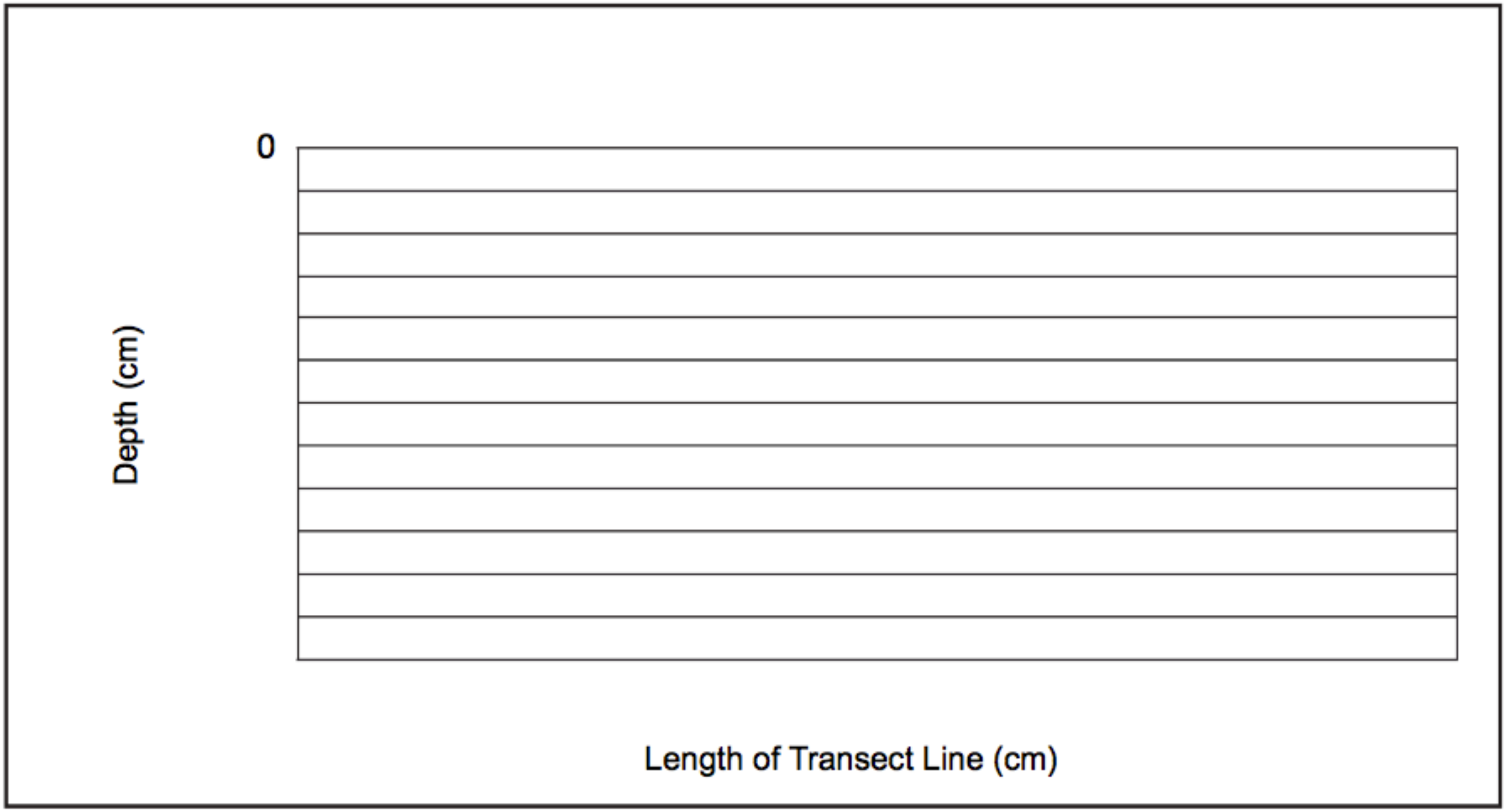


Figure 1.5. Figure for plotting seafloor profile data. Record the interval between each skewer on the X-axis. The top line on this grid represents the water line. Record the depth from the water line (paper on your seafloor model) to the seafloor on the Y-axis.

Part B

Date: 1943

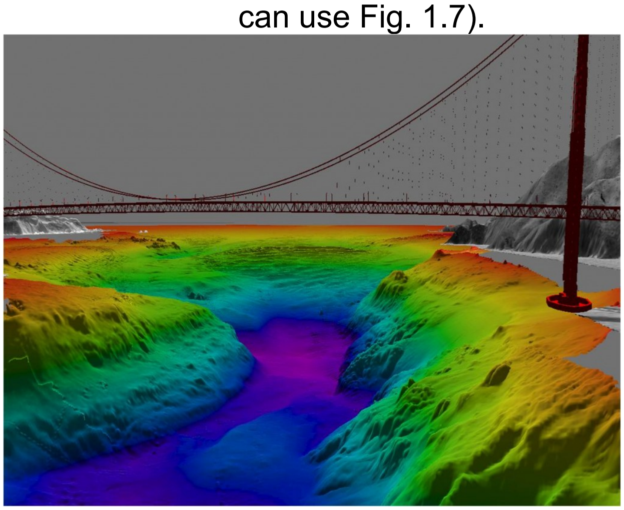
Based on your preliminary transect, your funding agency has granted you additional research money to prepare a more complete map of your sea floor area using single-beam sonar. You can take an unlimited under of depth soundings, but have only 10 minutes for further exploration.

1. Use your initial transect to develop a mapping procedure for the remaining area. Will you continue to do transects or will you look more in depth at a particular area of your sea floor? Write down your intended procedure.

2. Follow your procedure for 10 minutes.

3. If you wrote your measurements directly on the grid taped to the seafloor box, carefully remove the grid from the paper covering the seafloor box without uncovering the seafloor (**you should not look into your seafloor box**).

4. In the next part of the procedure, you will be color-coding and drawing contour lines on your seafloor grid. Have a discussion with your class to standardize your colors and contour lines so different seafloor grids can be compared.
    a. Color-coding (refer to Fig. 1.6 for an example)
        i. Your class's color scheme should be (from shallowest to deepest): red – orange - yellow – green – blue – purple.
        ii. Determine a depth scale to correspond to these colors, For example, zero to -1 cm could be colored red, -1 to -2 cm could be colored orange, etc. Develop a legend for your color-coded depth scale (you can use Fig. 1.7).



http://www.opc.ca.gov/webmaster/_media_library/2010/03/SFBAyBAthyColor1-1024x767.jpg

Figure 1.6. United States Geological Service (USGS) exaggerated seafloor relief looking west under the golden gate bridge. Red indicates the shallowest areas, purple indicates the deepest area of the bay.

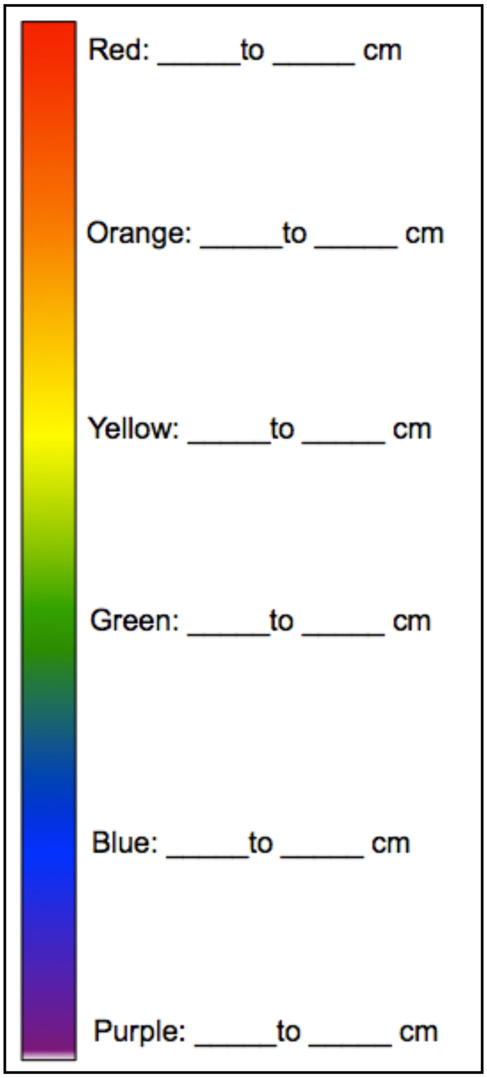


Figure 1.7. Color ledged for seafloor grid corresponding to depth. Red indicates shallow seafloor and purple indicates deep seafloor.

   a. Contour lines
      iii. Determine with your class at what regular depth intervals to draw contour lines on your grid (e.g. every 0.5 cm or every 1 cm).
      iv. Note this interval on your grid.

5. Color-code the known sonar points of your seafloor grid.
   a. If you did not investigate a section of your seafloor, do not make assumptions about the features (you may leave uncharted areas blank).

6. Draw contour lines on your seafloor grid.
   a. If you did not investigate a section of your seafloor, do not make assumptions about the features (you may leave uncharted areas blank).

7. Write down in your notebook how additional research, coloring the depth of your sonar points, and drawing contour lines has added to your knowledge and interpretation of your seafloor feature(s). Identify any additional features discovered in your exploration (use Table 1.1).

Part C

Date: 2005

You have been given the opportunity as a preeminent oceanographer to descend to ocean floor in a submersible on your 90th birthday. Because you are so famous, you get to choose the location of the submersible dive. You choose to revisit the section of seafloor you originally studied at the start of your career and compare your original single-bean sonar mapping to the actual seafloor.

1. Remove the cover on the box and examine the actual sea floor.

2. Describe similarities and differences between your profile map, your subsequent research and the actual sea floor.

Table 1.1. Common features of the seafloor and coastline

Abyssal plain. A flat region of deep ocean basins.

Alluvial fan. A broad, sloping deposit of sediments at the mouth of a river or at the foot of a submarine canyon or a river canyon.

Atoll. A ring-shaped coral reef surrounding a lagoon. It may have low sand islands. Atolls rest on submerged volcanic islands.

Bank. A navigable shallow area of the ocean caused either by elevation of the seafloor or by submergence of a landmass.

Bay. An inlet of the sea; an indentation in the shoreline, often between headlands or capes.

Cape. A large point or extension of land jutting into a body of water. A cape may be a peninsula or a hook of land.

Channel. A deeper part of a river or harbor that is navigable. The word is sometimes used to name a broad strait, for example, the English Channel.

Cliff. A very steep or overhanging land feature.

Coast. A strip of land bordering the sea. A coast is affected by marine waves and wind.

Continental shelf. The land forming the shallow seafloor extending outward from the edge of a continent; submerged part of a continent extending outward 15 km to 50 km to the continental slope.

Continental slope. The sloping front of a continental shelf; the place where the continent ends. These are long slopes, often 20 km to 40 km wide or more. The bottom of the continental slope is the continental rise.

Continental rise. The area of the continental shelf between the continental slope and the deep seafloor where sediments from the continent accumulate.

Delta. An alluvial deposit at the mouth of a river.

Estuary. A river mouth or channel, or the drowned seaward end of a valley where fresh water from land mixes with seawater. River flow in some estuaries continues across the continental shelf, carving out a submarine canyon.

Guyot. A seamount with a flat top. Guyot tops are always below the ocean surface.

Also called a tablemount.

Headland. A cape or other landform jutting into the ocean. It is usually high above water and prominent when viewed from the sea. It gets its name from the practice of sailors using such features to take their bearings or "headings."

Island. A landmass smaller than a continent and surrounded by water.

Island chain. A group of islands formed by the same geological process (also called an archipelago).

Isthmus. A narrow strip of land connecting two larger landmasses.

Lagoon. A shallow body of relatively quiet water almost completely cut off from the open ocean by coral reefs, barrier islands, or barrier beaches.

Ocean basin. A large depression in the earth's crust that holds the water of an ocean.

Ocean ridge. A long, continuous mountain range on the seafloor. Ocean ridges are often of volcanic origin at a point or line of separation in the earth's crust.

Ocean trench. A deep cut or trench in the seafloor, usually close to where continental shelves and seafloors meet.

Peninsula. A piece of land almost completely surrounded by water. It is usually connected to a larger land body by a narrow land strip called a neck or an isthmus.

Point. The tip-end of a cape, headland, peninsula, or other land feature jutting into a body of water.

Reef. A shallow rock or coral formation, often exposed at low tide. A **fringing reef** forms along the shore; a **barrier reef** is an offshore coral ridge.

Seamount. An isolated undersea hill or mountain. It is usually in the form of a cone.

Shoal. An area of the ocean, such as a sandbar, that is too shallow to navigate.

Sound. A wide waterway connecting two larger bodies of water. It may be a body of water between the mainland and an offshore island.

Strait. A long, narrow water passage connecting two larger bodies of water.

Submarine canyon. A deep canyon cut into the continental shelf and slope, often at the mouth of a large river.

ACTIVITY QUESTIONS

1. How did your initial transect map of the seafloor compare with the additional data collected on your second exploration?

2. How were you able to take advantage of what you learned during the preliminary transect to develop your procedure in Part B?

3. What sources of error in the procedure may have contributed to discrepancies on your map?

4. How did the map created with additional data (Part B) compare to the actual seafloor?

5. How realistic was it to expose the seafloor in Part C?

6. How do you think your seafloor feature(s) formed?

Swath Mapping

Maps and models produced from single-beam sonar profiles lack the precision and detail needed for modern oceanography. Most are made from profile lines spaced from 1 to 10 km apart. Without more data, mapmakers can only guess what features lie between the sample lines. In the 1970s, a whole new seafloor-mapping technology was developed called **swath mapping** (see Fig. 1.8). Instead of sampling depth along a line like a single-beam sonar sounding, swath mapping makes many measures of depth within a two-dimensional area of the seafloor. On a single transect, swath mapping can sound an area 10 to 60 km wide and as long as the distance traveled by the ship. Swath bathymetric maps and images are produced by placing the strips of data together. Features as small as 10 m across can be detected. In fact, details in swath maps are so clear that small-scale features such as faults, craters, landslides, and the paths of sediments flowing through submarine canyons can be clearly identified (for an examples, see Fig. 1.9).

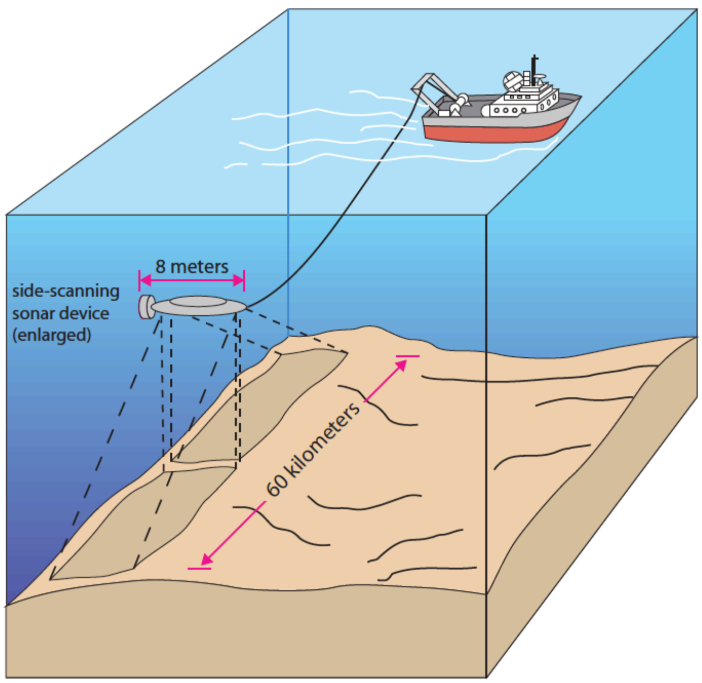
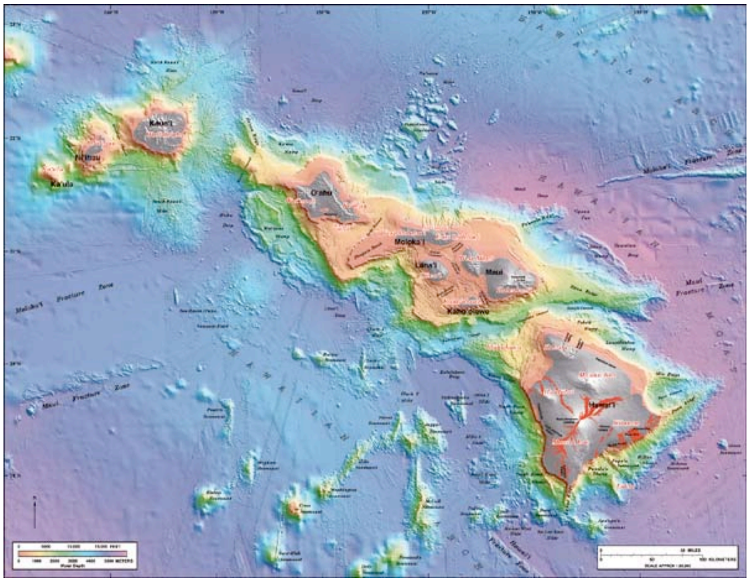


Figure 1.8. Swath mapping enables scientists to collect data over a large area of the seafloor.



http://soundwaves.usgs.gov/2004/01/hawaii-sea-floor.jpg

Figure 1.9. This is a sea floor map made of the Southernmost Hawaiian Island chain by University of Hawai‘i researchers using sonar. It depicts the underwater volcanoes and other features of the sea floor.

One swath-mapping device called **multibeam sonar** sends out and tracks up to 16 closely-spaced sonar beams at a time. Computers translate the multiple echoes, assemble data from parallel transects, and then draw a detailed bathymetric contour map of that section of the seafloor. Another swath-mapping device called **side-scanning sonar** uses computers to translate the multiple echoes into detailed, three-dimensional images of seafloor features. The images look like photographs taken from an airplane. The difference is that sound waves, not light waves, are used to produce the images.

Light Detection And Ranging Systems (LiDAR)
LiDAR uses lasers (light waves) and Global Positioning Systems (GPS) to determine the position of topographic features. LiDAR can be used to obtain very accurate measurements of the sea floor, often within a few centimeters. LiDAR is very powerful for research because people can use LiDAR from moving planes. However, because lasers use light waves, LiDAR can not penetrate as deep as sound waves in water. Typically, LiDAR can be used to measure the depth of water, and map the sea floor, to about 50 m. However, the exact depth depends on water turbidity; the less turbid (more clear) the water, the deeper LiDAR can penetrate.

Satellite Oceanography
Satellites are essential to mapping and measuring the oceans (Fig. 1.10). Satellites equipped with communication devices and power sources make global communication

possible by telephone and television. Now ships and airplanes can be linked to land stations and to each other. Navigation is more advanced because satellite communication systems help to determine exact latitude and longitude. Computers record seafloor measurements and locations, and then people can use the computers to plot the data onto maps.

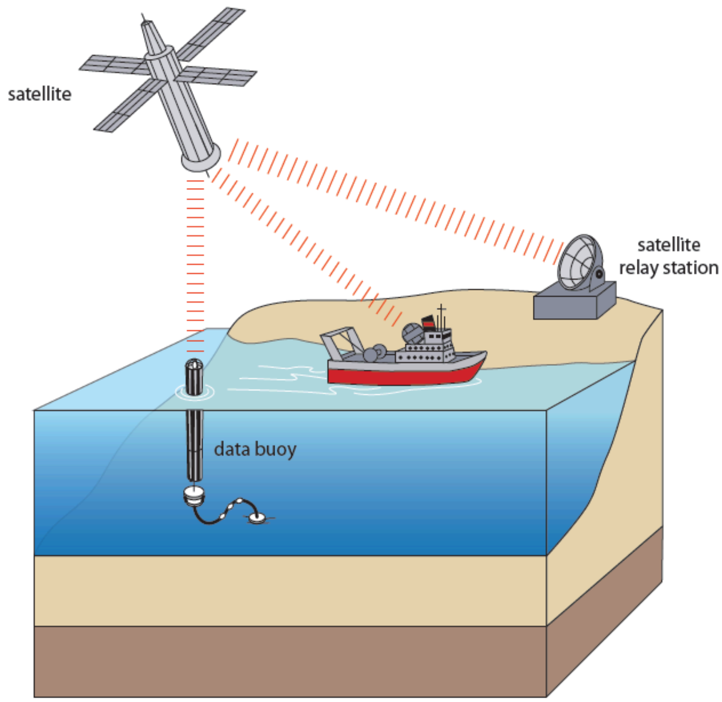


Figure 1.10. Satillite oceanography

Some satellites are equipped with cameras that continuously make photographs of the earth's surface and relay them to receiving stations. The satellite weather maps in newspapers are a familiar example. For oceanographers and others who work or travel on the ocean, satellites provide up-to-date information about storms and other weather conditions at sea.

Seasat, the first satellite dedicated to oceanography, was launched in 1978. It allowed researchers to detect and map seafloor features around areas rarely visited by ships, like Antarctica. Seasat mapped seafloor features indirectly by measuring sea height. It sent out pulses of **electromagnetic radiation** that reflected off the ocean surface, giving precise measurements of the distances between the satellite and the ocean at different points. These measurements showed that the surface of the ocean is uneven. **Depressions** in the surface suggest the presence of massive seafloor features, such as midocean ridges and seamounts that increase gravitational pull. **Bulges** in the surface are evidence of deep seafloor trenches and fracture zones, which decrease the gravitational pull.

Although satellites cannot yet give us precise information about small areas of the seafloor, they provide oceanographers with information about global phenomena such as cloud and ice formation, wind patterns, and surface temperatures. Interpreting all the data collected by modern oceanographic research ships and satellites occupies many researchers and complex computer systems full-time.

QUESTIONS

1. Explain how mapping with single-beam sonar differs from swath mapping.

2. Why do you think our seafloor box simulation used sonar rather than another sea floor mapping technique such as LiDAR or satellite mapping?

3. Why is it important to map the ocean floor?