5. Seafloor Features

Today we know more about the surface of the moon than about the floor of the ocean. As a result, one of the great adventures of current research is the mapping of this vast unknown domain. Prior to modern times it was believed that the ocean floor was like smooth bowl, devoid of physical features or life. We now know that the ocean floor is not smooth and is the home of many living things. The surface of our world, both above and below the water, is filled with a variety of features.

Today we have **bathymetric maps** that accurately show ocean depths and tell us about elevations and depressions on the ocean floor. By drawing contour lines connecting points of equal depth, oceanographers have found that the floor of the ocean has **physical** or **geological features** similar to the mountains and valleys found on land. We can visualize these features by using contour maps.

Contour Maps

We have examined maps that show us the relative location of landmasses and bodies of water. We can also use **contour maps** that are two dimensional, and use lines, colors, and shades to convey information about elevation and shape of land and sea floor features. These maps show relative depths and elevations. See table 5-1. A contour map can show the depth (below sea level) or the elevation (above sea level) with a series of contour lines that follow a single representative depth or elevation. Sea level is recorded as 0, and represents the average low water level. Features above sea level are recorded with positive numbers, for example, 10 m and 20 m and features below sea level with negative numbers –10 m and –20 m. Convenient contour intervals are multiples of 10 (10 m, 100 m, 1,000 m, and so forth). Contour lines themselves represent a single depth or elevation. The spaces between two contour lines are uncertain but include all elevations or depths greater than the smallest and smaller than the greatest measurement represented by the contour lines.

Three-Dimensional Maps and Models

Raised relief maps are three-dimensional maps that provide a sense of the elevation or depth of geological features. Three-Dimensional Maps can be sculpted into realistic models of these same geological features.

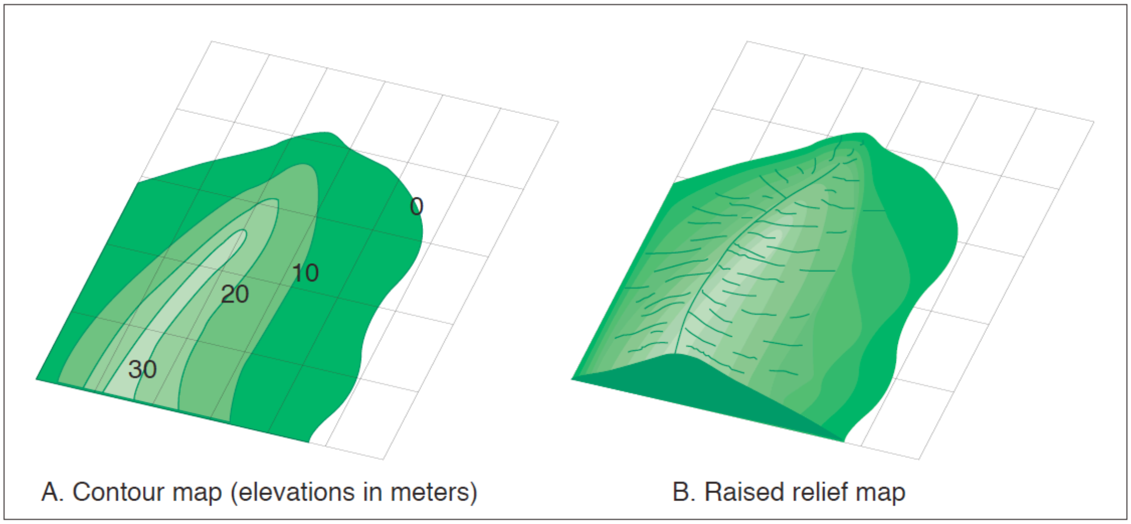


Fig. 5–1. Examples of different types of maps showing the same geological feature

ACTIVITY 1

Interpret contour maps of seafloor and coastal features.

Construct contour and raised relief maps of common underwater features.

MATERIALS

For a contour map

- colored pencils, crayons, tempera paints

For a relief map

- colored construction paper
- carbon paper
- ballpoint pen

- scissors
- scraps of cardboard
- straight pins
- white glue

For a sculptured model (optional)

- eight 8-1/2 X 11-in sheets of cardboard
- 25 X 35-cm sheet of cardboard
- scalpeland and /or Exacto knife
- papiermâché (prepared in class)
- 8-1/2 X 11-in sheet of cotton cloth
- 1,000-mL beaker or 1/2-gal milk carton
- white glue diluted 1:1 with water
- oven or fan (optional)
- wooden skewer
- 1/4-in or 1/2-in brushes
- tempera paints (blue, green, white, brown, and black)
- jars and lids (for paints)
- aprons

PROCEDURE

1. Use the 8-1/2 X 11-in enlargements in the Student Workbook. Refer to Table 5–1 and identify features shown on the contour maps, Figs. 5–2 to 5–10.
    a. Study the shapes of the contour lines, then identify and label features on all of the maps.
    b. Examine each map to find the sea level, the zero (0) elevation contour line. Mark it with a colored pencil.
    c. On the map you have chosen or been assigned, locate the contour lines of dry landform features with elevations above sea level. On the same

map, locate the contour lines of features below sea level that are shown as negative numbers.

d. Construct a color-coded **contour map.** Use shades of blue to show differences in sea level depth. Use other colors to show differences in landform elevations.

2. Construct a color-coded **relief map** from one of the contour maps.

   a. Use the map you have chosen or been assigned. Decide how to color-code the relief map with colors from a package of construction paper. Choose your colors to show increasing depths of water or increasing elevations of land. The color scheme you select should provide meaningful information about the area. Be ready to justify your choices
   b. Place carbon paper inked side down on the construction paper under the enlarged contour map.
   c. Prepare a template out of colored construction paper for each elevation line. Pressing hard with a ballpoint pen, carefully trace the elevation line onto the construction paper. Also trace the elevation line for the next higher contour so that later you will know exactly where to position the higher-contour template. Label the elevations of both contour lines.
   d. Use scissors to cut out the lower elevation line on each of the contour templates. Work slowly and carefully.
   e. Stack the colored contour templates in order of increasing elevation. Use the elevation lines drawn on each template to position the next higher template.

4. Construct the relief map to accurate vertical scale.
   a. Make cardboard risers to put between the contour templates to provide the proper vertical scale for the model. Determine how high

each riser should be. To do this, first decide what elevation interval is to be represented by each thickness of cardboard. See Fig. 5–11 for an example.

b. Assemble the relief map. Glue or pin the risers to the contour templates. Working from the lowest to the highest elevation, carefully position each contour template and its risers.
c. Glue the assembled relief map to a cardboard base.
d. Label the model to identify the features represented. Include a legend showing the elevations. Write your name(s) and the date on the model.

5. (Optional) Construct a papier-mâché **sculptured model** of the geographic feature.
   a. Cut out and assemble a cardboard relief map using scraps of cardboard for the risers. Follow Procedure 3, using corrugated cardboard and a scalpel. Work slowly and carefully. To avoid making slash marks in the table, put a sheet of cardboard under the template you are cutting.
   b. Prepare papier-mâché by carrying out the steps below. Your teacher will give you additional information.
      1) Tear newspaper into strips
      2) Soak newspaper strips in water for a few hours or overnight to soften the paper.
      3) Use a blender to make a slurry of paper and water. Never fill the blender more than half-full. Run the blender on low speed
      4) Filter the water from the slurry through a piece of cloth. Wring out the water. Save the pulp.
      5) Mix pulp with diluted white glue so that it has a smooth, medium-firm, claylike consistency. Use this firm mixture for the first coat on the model.

      6) Make a thinner, moister papier-mâché for the finishing coats. Add a more diluted glue solution to the pulp

   c. Coat the cardboard relief map with firm papier-mâché. Fill in all exposed spaces between the contour templates and the exposed cut ends of the corrugated cardboard. Make a smooth, natural slope between the templates. See Fig. 5–12.
   d. Dry the first coat and the filling. If possible, put the model in a 120°C oven for an hour. Alternatively, use fans or sunlight to hasten drying.
   e. Apply a finishing coat of thinner papier-mâché over the entire model. Using a wooden skewer or the handle of a fine brush, stroke wet papier-mâché in an upward movement to sculpt valleys and erosion effects.
   f. Dry the model thoroughly. To prevent warping, place weights uniformly on the model.
   g. Paint the model. Color-code features on the map using shades of colors to show changes in elevation. Allow the paint to dry.
   h. Label the model. Identify the features. Include a legend showing the elevations. Put your name(s) and the date on the model.

6. Make drawings of the relief map or model. Show all the contours
   a. looking straight down from the top.
   b. from the north looking south.
   c. from south to north.
   d. from east to west.
   e. from west to east.

7. Display each model together with its contour map and your drawings from Procedure 6.

Table 5–1. 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.

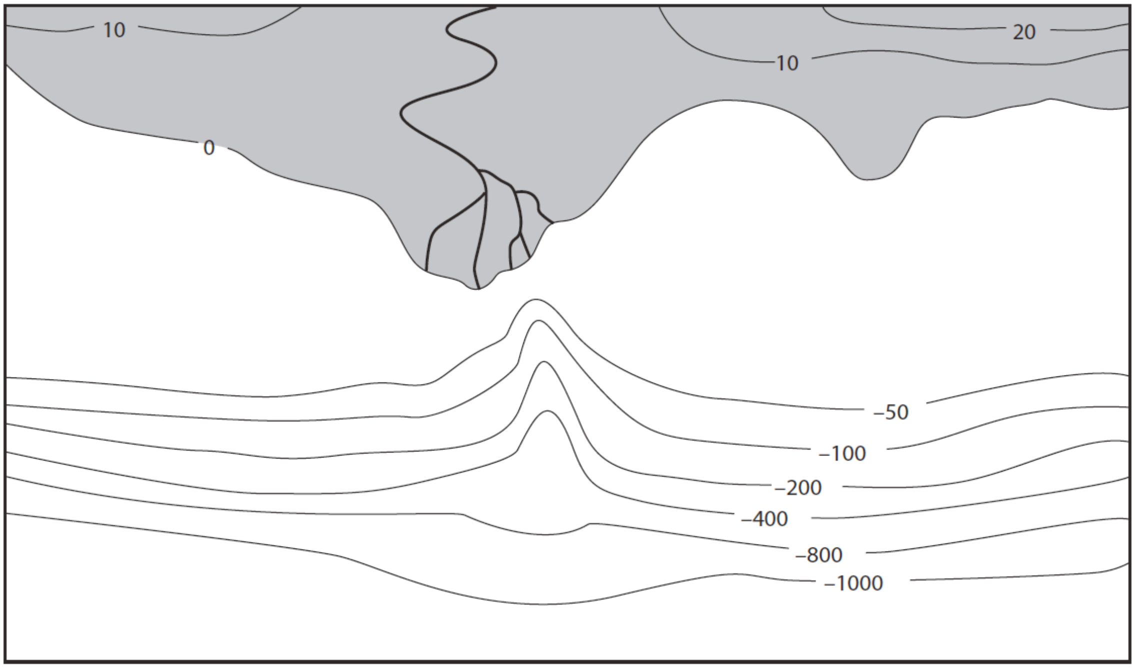


Fig. 5–2. Contour map A (elevation and depth in meters)

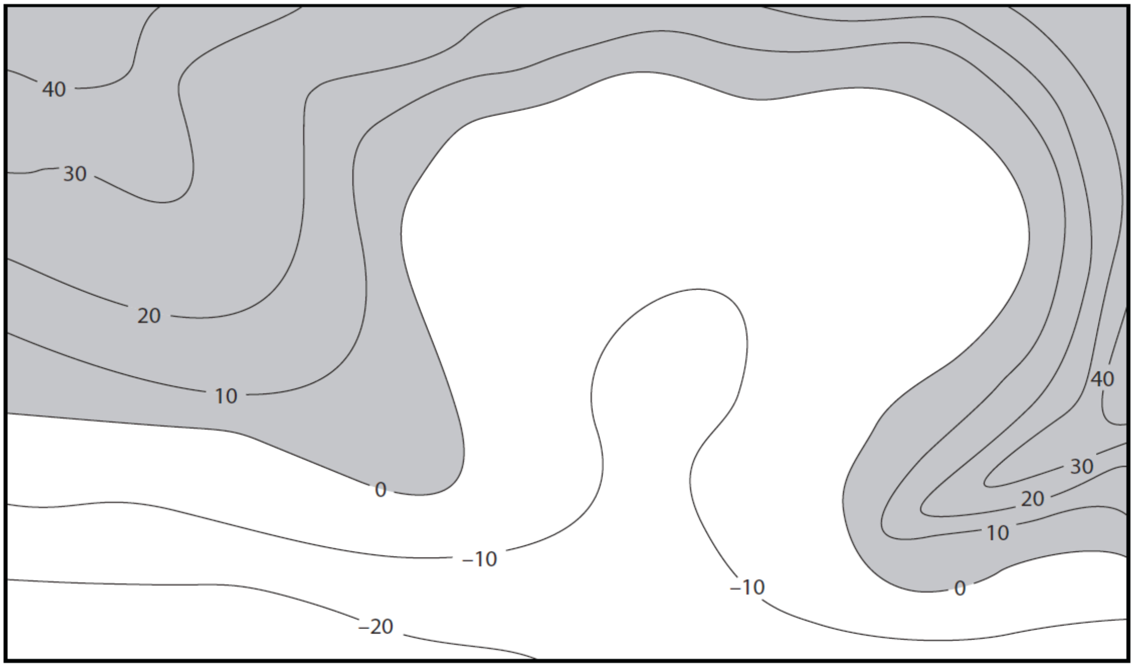


Fig. 5–3. Contour map B (elevation and depth in meters)

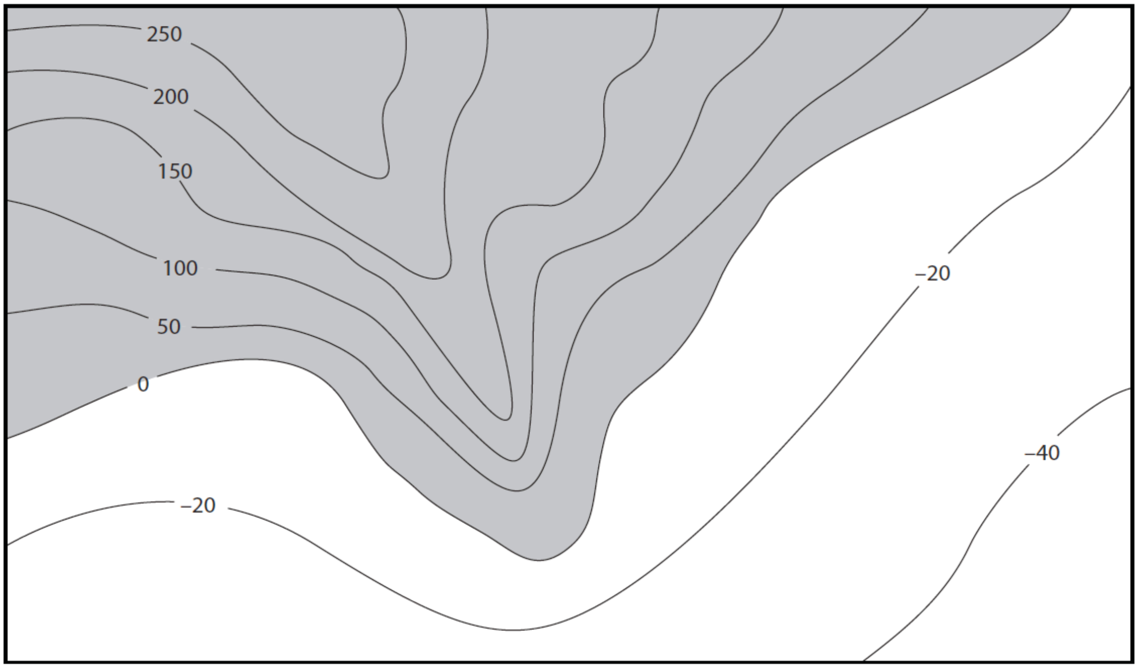


Fig. 5–4. Contour map C (elevation and depth in meters)

Fig. 5–5. Contour map D (elevation and depth in meters)

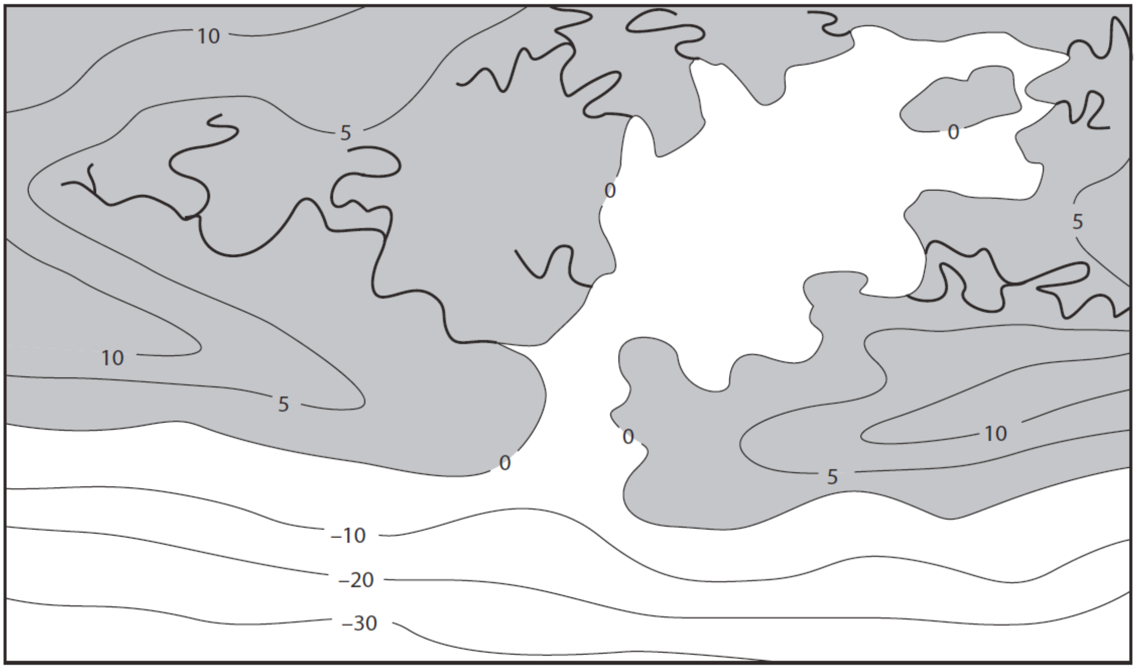


Fig. 5–6. Contour map E (elevation and depth in meters)

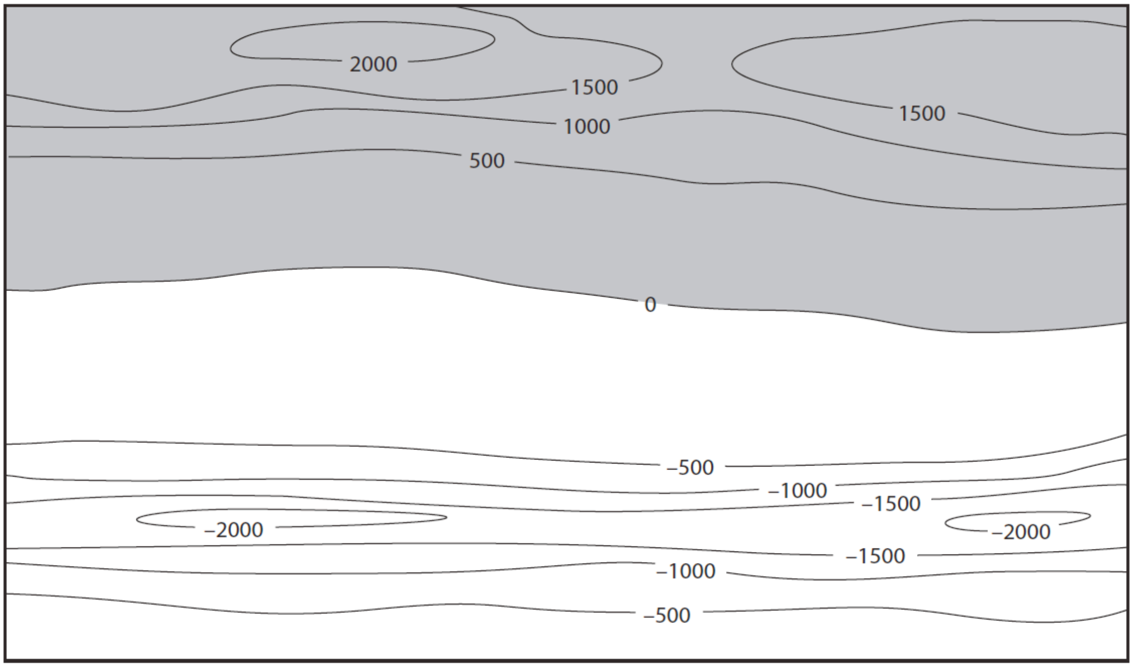


Fig. 5–7. Contour map F (elevation and depth in meters)

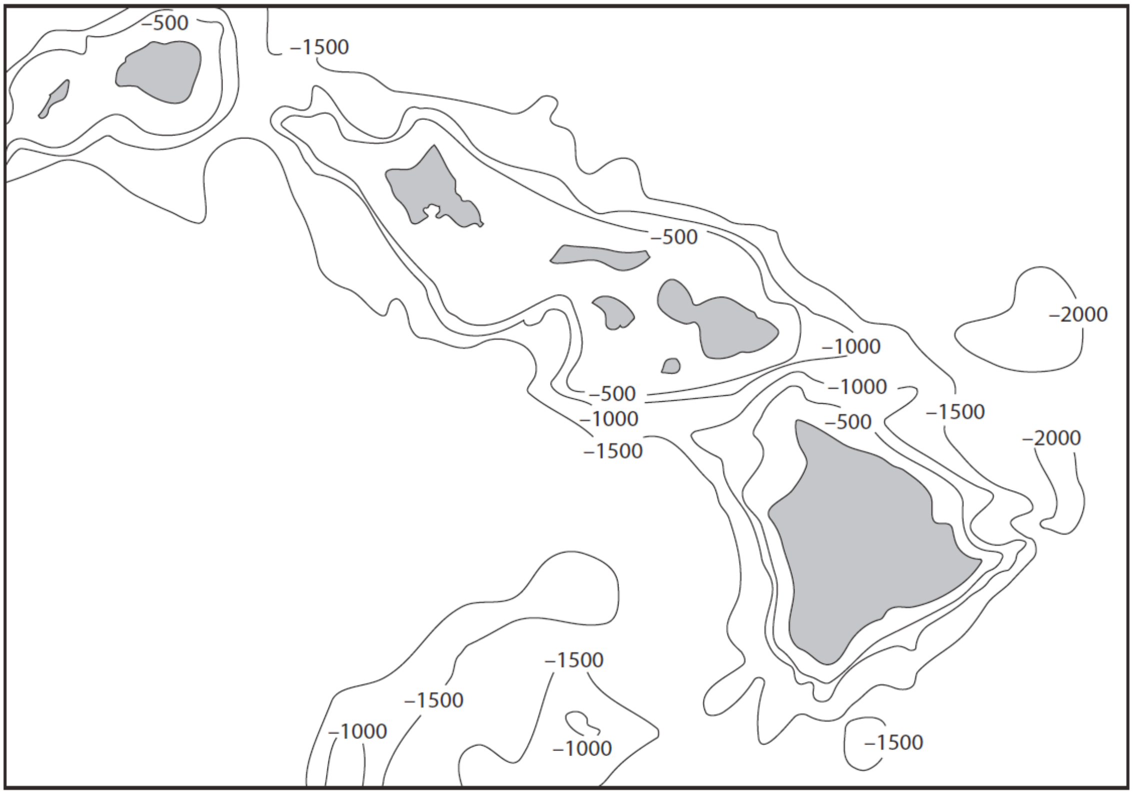


Fig. 5–8. Contour map G (depth in meters)

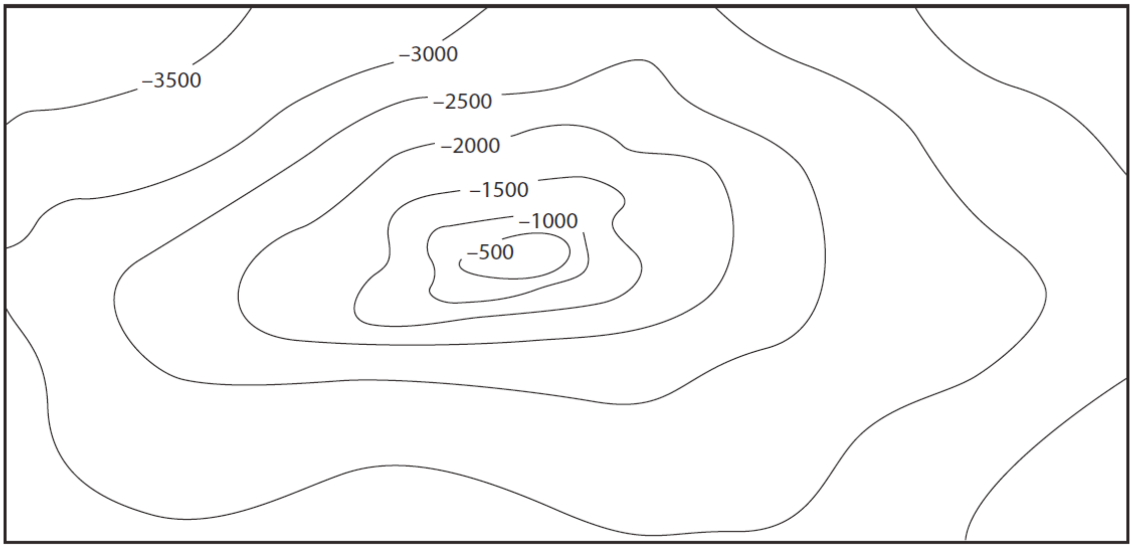


Fig. 5–9. Contour map H (depth in meters)

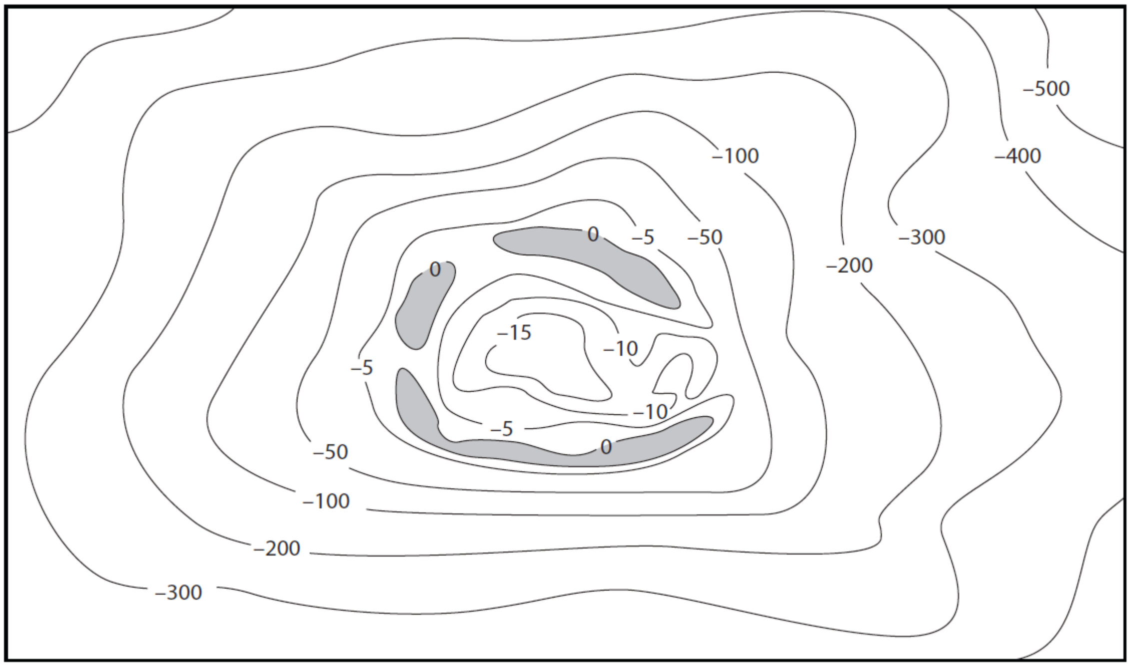


Fig. 5–10. Contour map I (depth in meters)

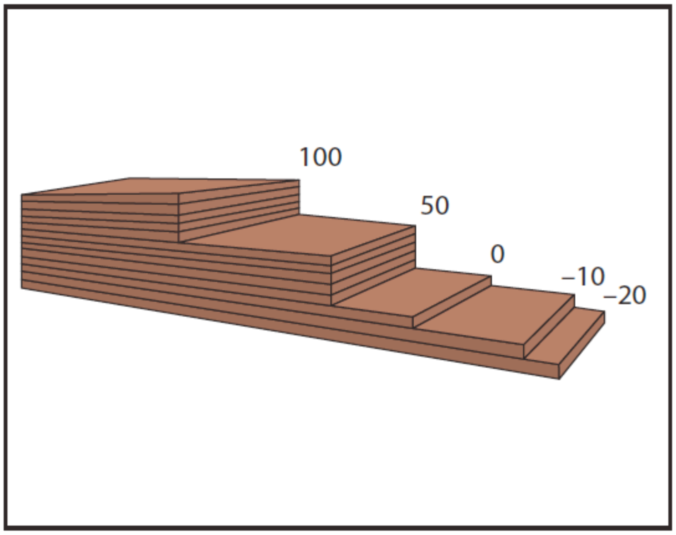


Fig. 5–11. Stacked cardboard contour templates

Fig. 5–12. Coating the cardboard relief map

QUESTIONS

1. Compare a relief map, a contour map, and a shaded contour map. Make a two-column table showing the advantages and disadvantages of each.

2. Discuss the physical feature you have modeled. Suggest relationships to the following:
   a. navigation
   b. economic value
   c. ecological value
   d. aesthetic value

3. Using all your models and contour maps, form hypotheses to explain
   a. how these seafloor features formed.
   b. how the seafloor features might change over time.

4. Check your understanding of the following terms:
   a. contour line
   b. elevation
   c. landform
   d. model
   e. physical feature
   f. sea level

5. Why do we care about what the sea floor is like? Explain why each of the following ocean users might find knowledge of the structure of the sea floor important.
   a. ship navators
   b. marine archeologists
   c. treasure hunters
   d. submariners
   e. geologists
   f. oceanographers

6. Using globes and maps find example of a place that fulfills the definition of more than one of the features in Table 5-1? Explain your reasoning.

7. What is the relationship between
   a. Atolls and lagoons?
   b. Strait and Sound?
   c. Isthmus and Peninsula?
   d. Continental Shelf and Continental Slope?

8. One of the earliest advanced civilizations was Egypt. What kind of physical feature is prominent in Egypt and how might it have contributed to the early rise of the Egyptian civilization?

9. Hawaii has many beautiful islands, but the largest population and center of commerce is on the island of Oahu. Is there a feature on Oahu that might explain why this has happened?

FURTHER INVESTIGATIONS

1. How well do official or popular names of shoreline features agree with the technical terms for geological features? (For example, Diamond Head is both a volcanic feature and a headland.) Examine maps and charts for examples. Look particularly at local shoreline features.

2. Construct a relief map or model of your local shoreline.
   a. Obtain a nautical chart showing your local shoreline.
   b. Label features and lines of latitude and longitude.

3. Construct an enlarged map of your local shoreline. Put a smaller map on an Elmo projector and project it onto a large sheet of paper. Trace the contour lines.

4. Research a specific type of seafloor feature and describe its influence on human activities such as fishing, navigation, and prospecting for resources.

5. Visit a place that sells maps and nautical charts. Find out who buys them and how they use them.

6. Mapping the Seafloor

How do people create maps of the bottom of the ocean? Centuries ago sailors ventured into unknown oceans to discover new lands. They had no accurate charts or maps to guide them to new places or back to homeports. Imagine how relieved they were to see land after enduring the hardships at sea for months. Land meant safety from the dangers of the sea, relief from hard work aboard ship, and fresh food and drinking water.

Seeing land, however, meant new dangers because a ship could run aground in unfamiliar shallow waters. Sea captains had to be cautious. They sent sharp-eyed sailors to the crow’s nest at the top of the mast or to the **bowsprit** at the forward part of the ship to look for dangerous shoals, reefs, and rocky outcroppings. But they all knew that visual sightings do not always detect hazardous underwater features, particularly if the water is choppy or murky. Anxious to avoid running aground, they made **bathymetric** or depth measurements using a process called **sounding.**

Depth Soundings

The earliest soundings were made with a handline of rope weighted at one end. Sticky tallow was often smeared on the weight to pick up sand and other sediments from the seafloor. The weight was then dropped overboard and the rope allowed to run free until the weight reached the bottom. The length of the line let out was an approximate measurement of the water depth. See Fig. 6–1. Simple handline soundings are still used today, but they are reliable only in calm, shallow areas near continental shelves, in inland seas, and near islands.

The first successful deepwater soundings were made with large balls of twine. A heavy weight was attached and tossed overboard, pulling twine from the ball until it hit bottom. Then the ball of twine was cut from the weight and the twine that had run out. The remaining ball of twine was weighed to determine how much had been lost. Because the weight of a length of twine was known, the depth of the ocean at that point could be determined quite easily.

After the twine method came a wire-sounding machine that used a single strand of piano wire running over a measuring pulley. But handlines, twine, and wire pulleys required slowing or stopping the vessel. Because deepwater soundings took a lot of time, they were done only every hundred kilometers or so. Nevertheless, enough sounding data were accumulated to create maps that gave a rough idea of the shape of the seafloor.

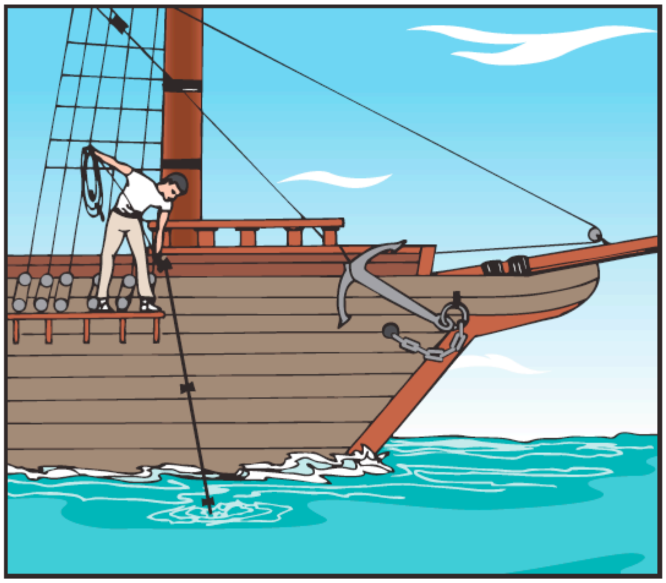


Fig. 6–1. Sounding with a weighted handline

ACTIVITY 1

Construct contour lines and interpret a nautical chart using bathymetric data.

MATERIALS

- Maug Island nautical chart
- colored pencils
- centimeter ruler

PROCEDURE

1. Fig. 6–2 in your workbook is a chart of the Maug Islands. Using the latitude and longitude information given on the chart, locate this island group on a map of the world. Describe its location in your notebook.

2. On the Maug Islands map, locate the deepest sounding on the chart. Draw a box around the number.

3. Use a light color and circle all depths 30 m or less. Choose a new color and circle all depths between 31 and 60 meters and then repeat for deeper depths at 30-meter intervals.

4. Draw the contour line connecting all 30-meter depth readings creating a 30-m **bathymetric contour line**. Draw the contour line so that it goes around and includes all the depths less than 30 m. Remember that contour lines follow a single depth; therefore, all readings that are the same as the labeled line are connected. All shallower soundings will be found above the contour line, deeper sounding below it. Continue drawing contour lines for 60 m, 90 m, and so forth. Your contour lines should never intersect one another and should usually continue completely around the island group. Don’t chart each island separately.

5. Lightly color in the intervals between the contour levels using different colors for each interval. Make a interval color key on the side of the chart.

6. Suppose you were on a sailing ship that **draws** (extends below the waterline) 4 m. You want to sail your ship safely into the protected waters in the center of the Maug Island group and drop anchor.

a. Study the chart to learn about each channel that leads from the open ocean into the protected central water. Describe each channel in terms of depth and hazards to navigation.

b. Decide how you would sail from open ocean into the center of the island group. With the ruler, mark a straight line on the map in your workbook showing the course you would choose.

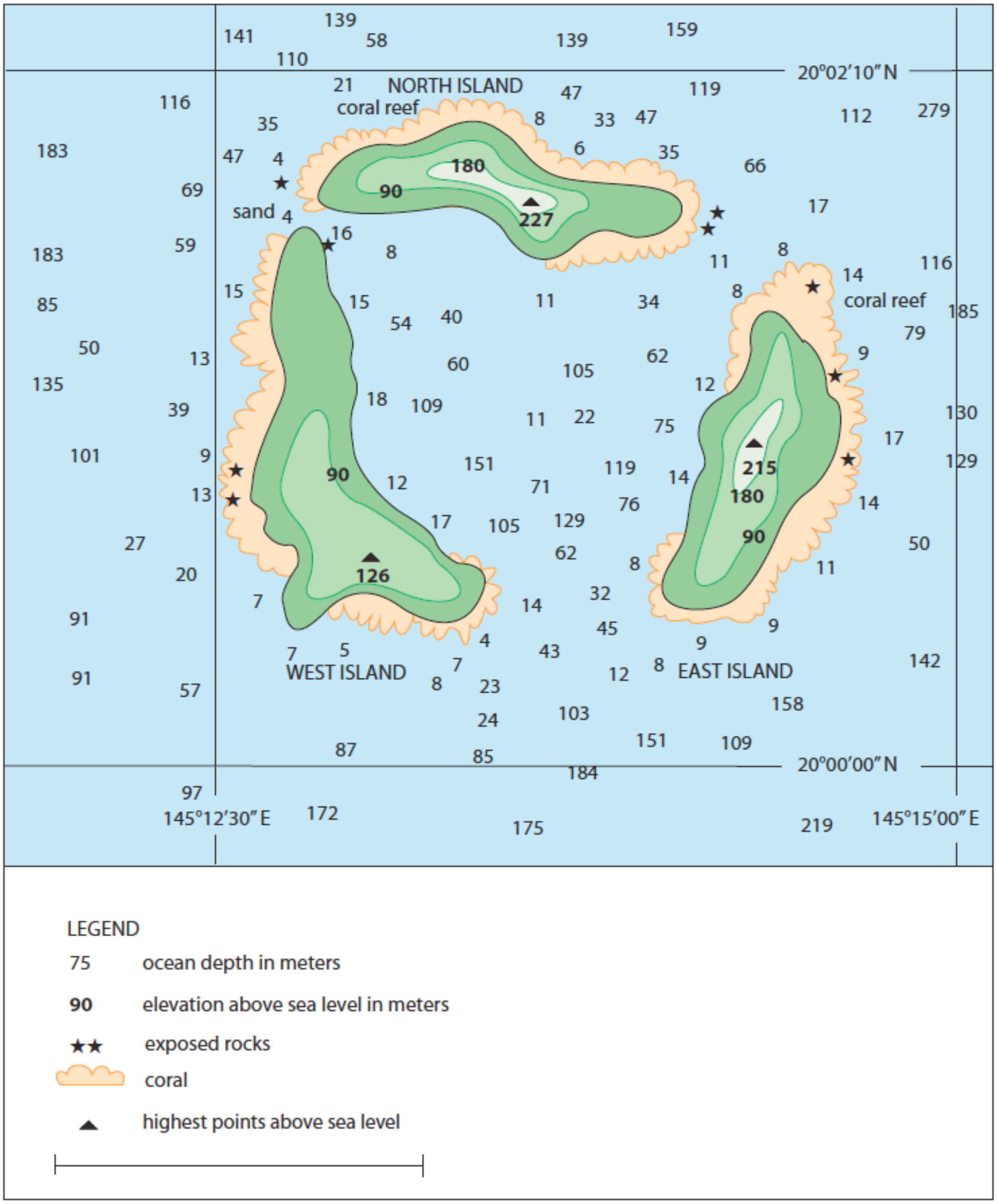


Fig. 6–2. Nautical navigation chart of the Maug Islands

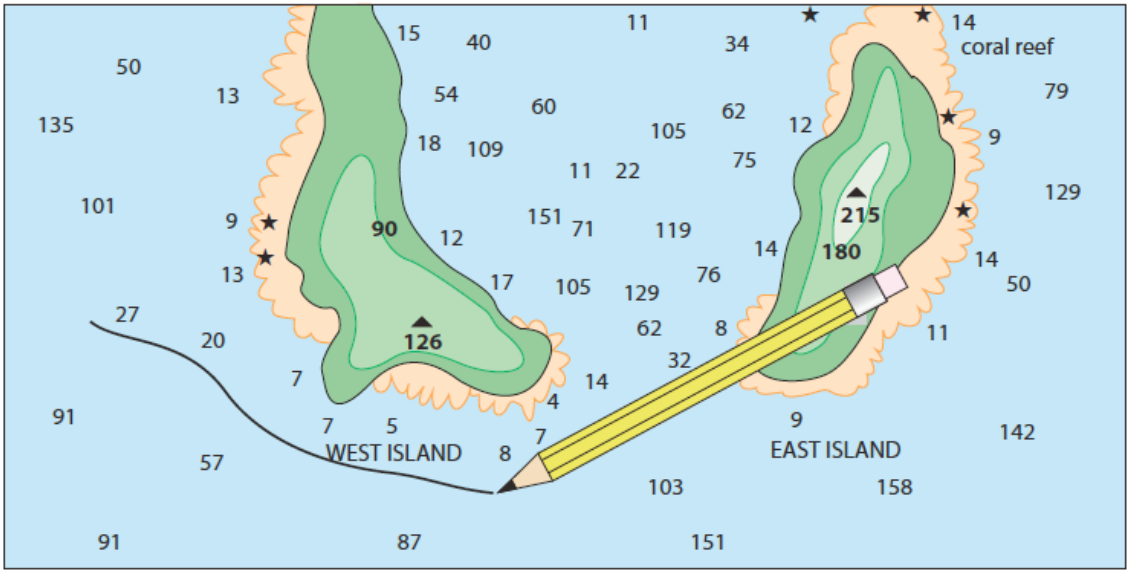


Fig. 6–3. Drawing the 30-m contour line

QUESTIONS

1. What seafloor features did you find on your chart?

2. Why shouldn’t the contour lines on a contour map cross one another?

3. Why was the middle portion of the map challenging to chart?

4. If you heard that centuries ago a pirate ship loaded with gold had run aground and sunk trying to reach protected waters within the Maug Islands, where would you look? What is your reasoning?

5. Would the Maug Islands be considered an atoll or a mountainous island group? What is your reasoning?

Sonar Soundings and Seafloor Profiles

Modern oceanographers use sophisticated remote-sensing techniques to gather data. 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. The word **sonar** was formed from the term **so**und **na**vigational **r**anging. Sonar works by sending out pulses of sound waves from a ship. Instruments record the time it takes for the sound waves to travel to the bottom, reflect, and return to the ship. See Fig. 6–4. Because the velocity of sound in seawater is known to be about 1,460 m/sec, the depth can be calculated. The velocity 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 so inexpensive and easy to operate that they are commonly used even on small outboard motorboats.

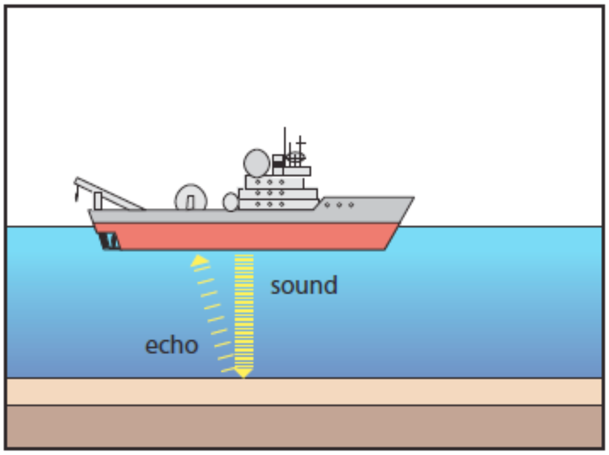


Fig. 6–4. Echo soundings can be made while a ship is under way.

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**. See Fig. 6–5.

To map the seafloor, research vessels cross the ocean making sonar profiles along carefully navigated parallel courses called transect lines. 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. See Fig. 6–6.

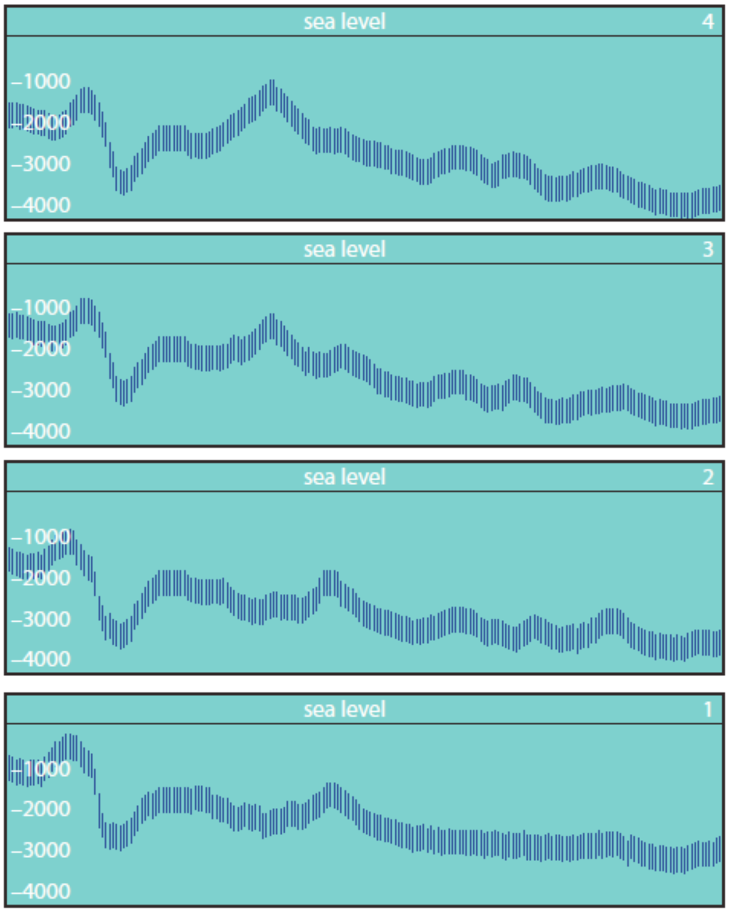


Fig. 6–5. Echograms are two-dimensional images of seafloor features along a transect line. The profile series shown here illustrates data obtained from parallel transects made several kilometers apart.

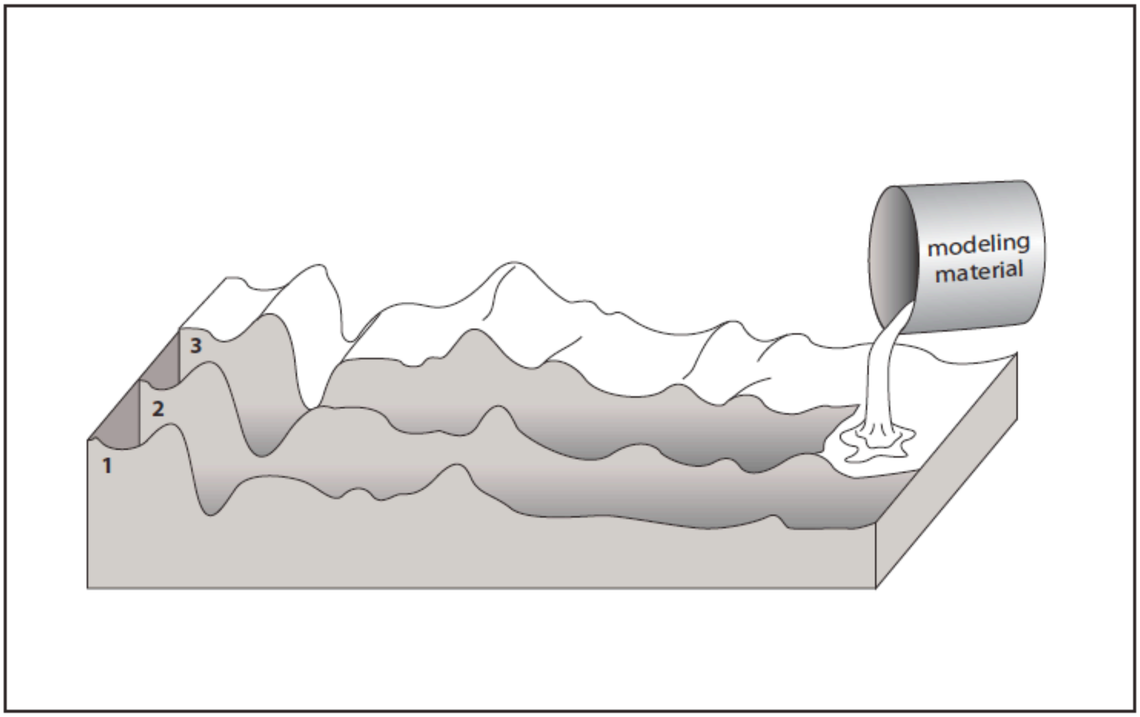


Fig. 6–6. Making a three dimensional model of the ocean floor constructed by assembling a series of parallel profiles

Your contour map from Activity 1 shows a “bird’s eye view” of the Maug islands. Let us now make a bathymetric profile to get a “fish’s eye view” of the island’s harbor.

ACTIVITY 2

Construct a bathymetric profile drawing from data along a transect line.

MATERIALS

- ¾ in x8-in paper strip
- centimeter rule
- grid paper

* Maug Island navigation chart from Activity 1

PROCEDURE

1. Use the Maug Island navigation chart from Activity 1. Extend the line you drew to mark your course into the center of the island group so that it cuts across the entire chart, including a portion of any of the islands. This your **transect line**, the line along which you will collect data. See Fig. 6–7 (A).

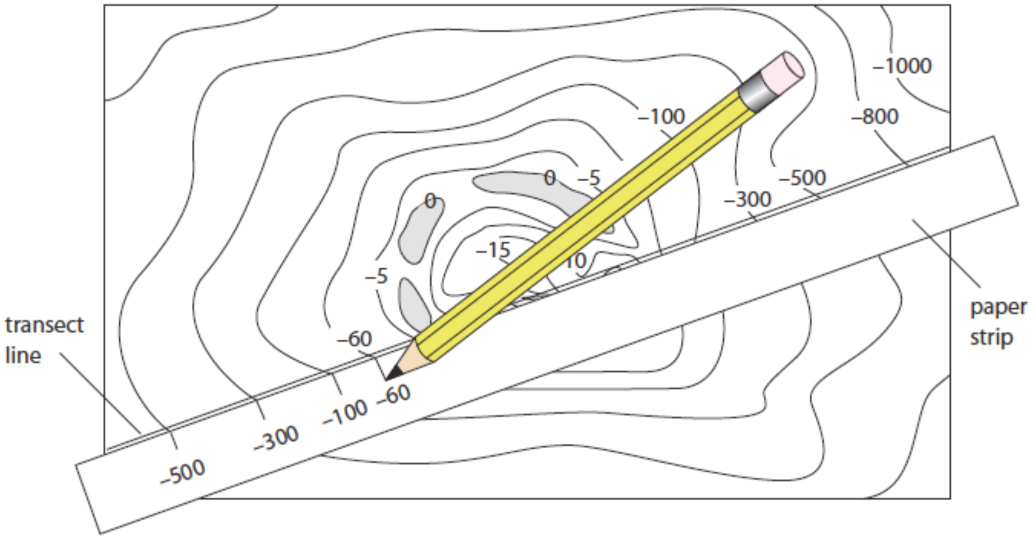
2. Lay the edge of a piece of paper along side your transect line. See Fig. 6–7 (A).

3. Mark the strip at each point where the edge of the paper strip touches a contour line and record the depth or elevation alongside the mark. See Fig. 6–7 (B).

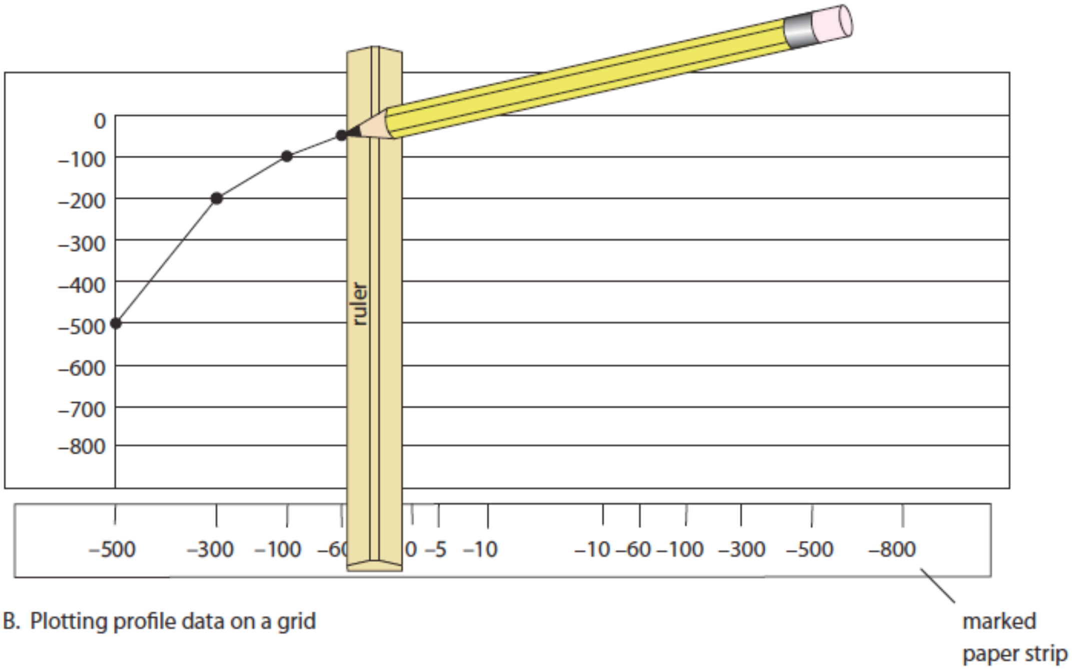
4. Use the grid provided in workbook Fig. 6-8 and label each axis. The horizontal axis represents the distance across the transect line. Note that the chart in Fig. 6–2 gives a scale for distance. The vertical axis represents the depths below sea level and the elevations above sea level in meters. Don't forget that sea level is 0, so some of your points will be above and some will be below 0.

5. Place the paper "transect" along the bottom of the grid in Fig 6-7 (B) and transcribe the depth information along the base of the graph. Plot each depth and elevation marked on the paper strip. Hold the strip along the horizontal axis of the grid and make a dot corresponding to each contour line marked. Read the depth or elevation marked on the strip, beginning with the first mark on the left. Move your pencil straight up from the mark on the bottom to the appropriate level on the grid and make another mark at the corresponding depth or elevation. Use a ruler to help you stay directly above the mark on the horizontal axis.

6. Draw the profile by connecting all the depth and elevation marks. This will show the side view of the islands.



A. Marking points where contour lines touch a paper strip



B. Plotting profile data on a grid

Fig. 6-7. Constructing a profile drawing from a transect line drawn on a contour map

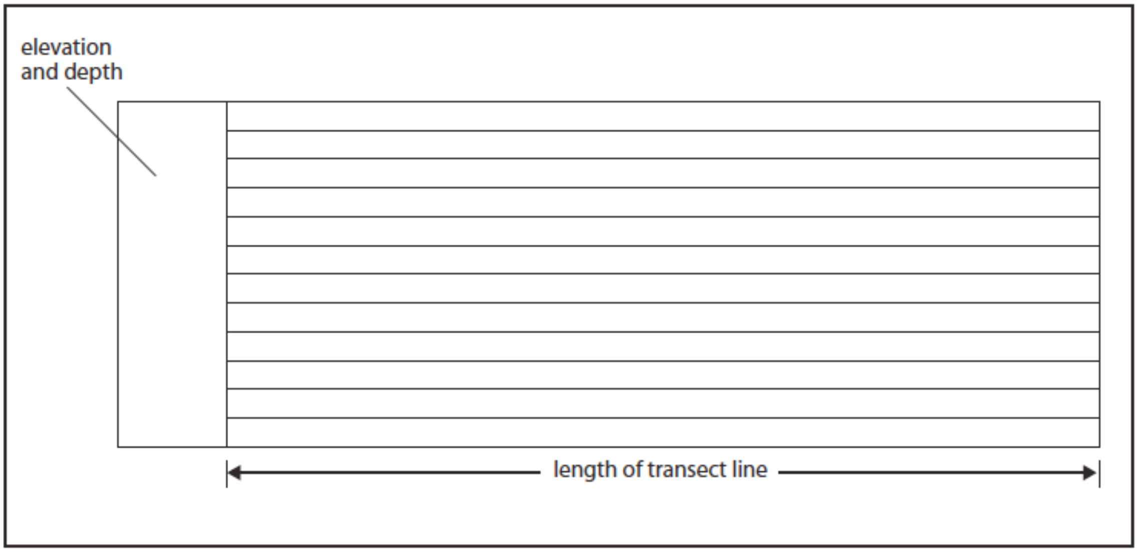


Fig.6–8. Grid for plotting profile data

Activity 3

Simulate using sonar or make ocean soundings.

Construct a seafloor profile from the simulation.

MATERIALS

- centimeter ruler
- three-dimensional seafloor model
- cardboard box
- paper
- masking tape
- paper with 1/2-in grid
- wooden skewers

PROCEDURE

1. Place a 3-dimensional seafloor model in a cardboard box.

2. Tape paper with 1/2-in grid on top of the box. This paper represents the ocean’s surface. Trade boxes with another group

3. Mark a straight line across the grid paper to represent a transect line.

4. At regular intervals along the transect line, insert a sharp probe such as a skewer. Keep the probe vertical, being careful not to let it slide down a slope on the model.

5. For each location, measure the distance in centimeters that the probe is inserted. This is equivalent to the seafloor depth.

6. Record each depth at its proper location on a grid like Fig. 6–9. Here 0 depth will be the top line of the grid.

7. Use the data to make a profile of the seafloor features along the transect line.

8. Examine, identify, and label the seafloor features on the profile.

9. Test the accuracy of your seafloor profile by opening the box to examine the model inside.

QUESTIONS

6. Was your profile of the seafloor features contained in your box accurate? What were the challenges to developing a clear model of the seafloor?
7. Who might find the information that you collected about this portion of the seafloor valuable? Why would this information be helpful to them?

	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P	Q	R	S
1																			
2																			
3																			
4																			
5																			
6																			
7																			
8																			
9																			
10																			
11																			
12																			
13																			

Fig. 6-9. Grid for plotting depth data on a sea floor profile

Swath Mapping

Maps and models produced from single-beam sonar profiles lack the precision and detail needed for modern oceanography. Most are made from relatively sparse data based on 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. Instead of sampling depth along a line, as does single-beam sonar sounding, swath mapping makes many measures of depth within a two-dimensional area of the seafloor. On a single transect, the area sounded may be 10 to 60 km wide and as long as the distance traveled by the ship. One swath-mapping device called **multibeam sonar** sends out and tracks up to 16 closely spaced sonar beams at a time. See Fig. 6–10. Computers translate the multiple echoes, assemble data from parallel transects, and then draw a detailed bathymetric contour map of the selected 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.

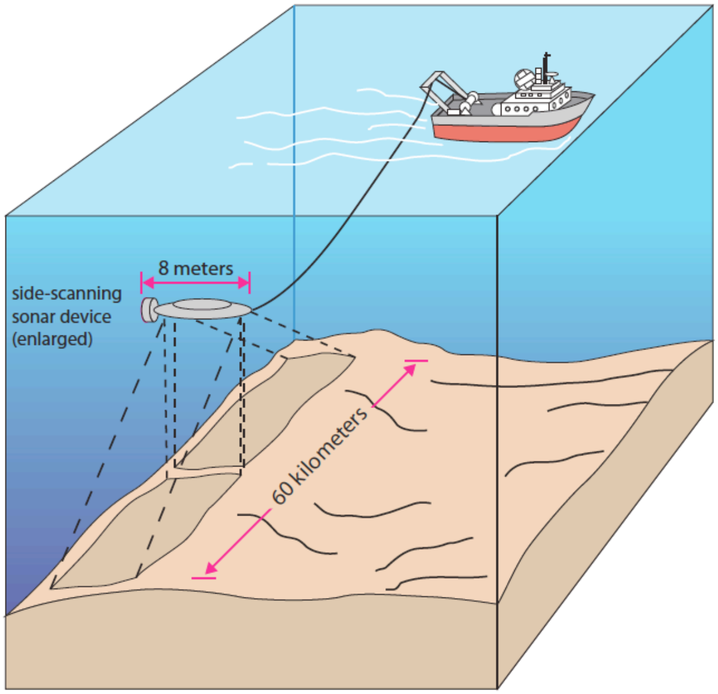


Fig. 6-10. Swath mapping enables scientists to collect data over a large area of the seafloor.

Swath bathymetric maps and images are produced by placing the strips of data together. 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. Features as small as 10 m across can be detected. To get an idea of the significance of this, imagine that your town is submerged under several thousand meters of water. Using swath technology, scientists in a ship at the surface could not only produce a bathymetric map of your town that accurately represents the locations of all its natural and manmade features, but also make photograph-like images of structures as small as single-car garages and outdoor swimming pools.

Scientists are using the detailed swath mapping techniques and image-mapping tools to learn more about the processes that form such seafloor features as underwater volcanoes and island chains and cause sediment erosion and deposition. Furthermore, swath-mapping technology has made it possible to locate potentially valuable mineral resources on the seafloor. We will investigate the mining of seafloor minerals in Unit 4, Chemical Oceanography.

Satellite Oceanography

Satellites are essential to mapping and measuring the oceans. 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, then plot the data onto maps.

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.

Satellites continue to improve; although they do not 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.

See Fig.6-11.

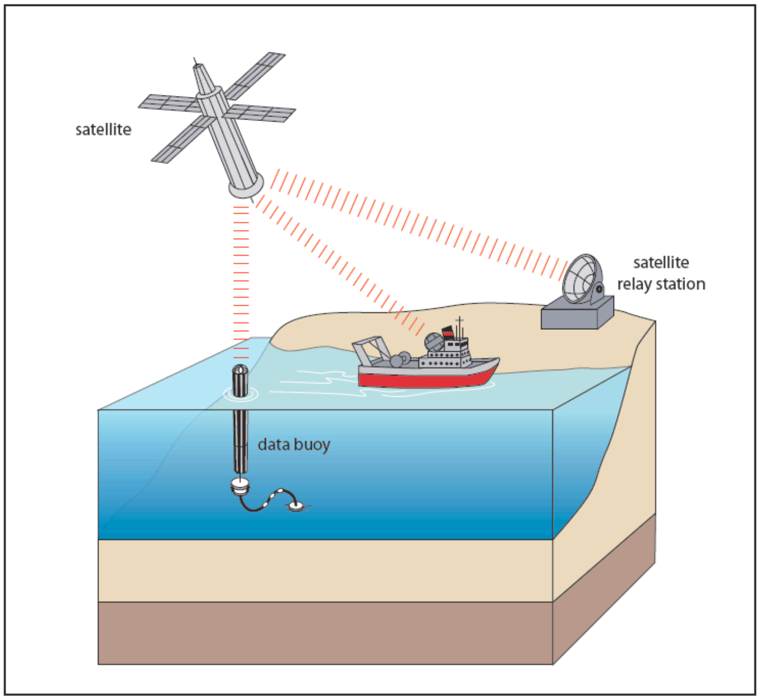


Fig. 6–11 Satellites collect data directly from the ocean and link oceanographic ships with data-collecting buoys. .

QUESTIONS

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

9. What are some other uses for sonar technology aside from mapping the seafloor?

10. What are some sources of error that might exist for soundings and sonar readings?

11. Modern technology has made tools like swath and satalite mapping available to researchers and others and direct observation tools like submarines. Why is sonar still in wide use despite the prevalence of these tools?

FURTHER INVESTIGATIONS

1. Construct a three-dimensional model of a section of a coastal area from topographic maps and nautical charts of the region.

2. In the profile drawing you made in Activity 2, note that the horizontal measurement is in nautical miles, but the vertical measurement (height and depth) is in meters. This way of measuring magnifies the vertical distance and is called vertical exaggeration. Draw two new profiles using a verti**cal scale**
   a. in hundreds of meters.
   b. in kilometers.

   Which of the drawings is most accurate or realistic? Why do we use vertical exaggeration in profile drawings?

3. Advances in seafloor mapping have made it possible to locate sunken ships. Using library references, read and report to the class on
   a. the search for the Titanic, including how it was discovered and how it was explored with research submersibles and remotely operated vehicles.
   b. modern efforts to locate sunken treasure.
   c. searches for the recording devices from airplanes downed at sea and efforts to retrieve these devices.

4. An interesting biological discovery was made by marine technicians from careful examinations of unusual sonar data. In some regions of the ocean, it appeared that the level of the ocean bottom changed at different times of the day. Groups of small marine organisms were identified whose bodies scatter sonar sound waves. They are collectively called the **DSL** for deep-scattering

layer. These animals spend the day in deep water and migrate nearer to the surface at night, causing the sonar readings to change. Commercial fishermen use fathometers to locate large schools of fish. Read and report to the class on the uses of fathometers and sonar in fishing.

5. Some areas are famous for shipwrecks. Cape Hatteras, off the Atlantic coast of North America, for example, is known as the “Graveyard of the Atlantic.” Find an area that has had many shipwrecks and examine a topographic map of the seafloor nearby. Can you determine some reasons why there may be so many shipwrecks in that location?