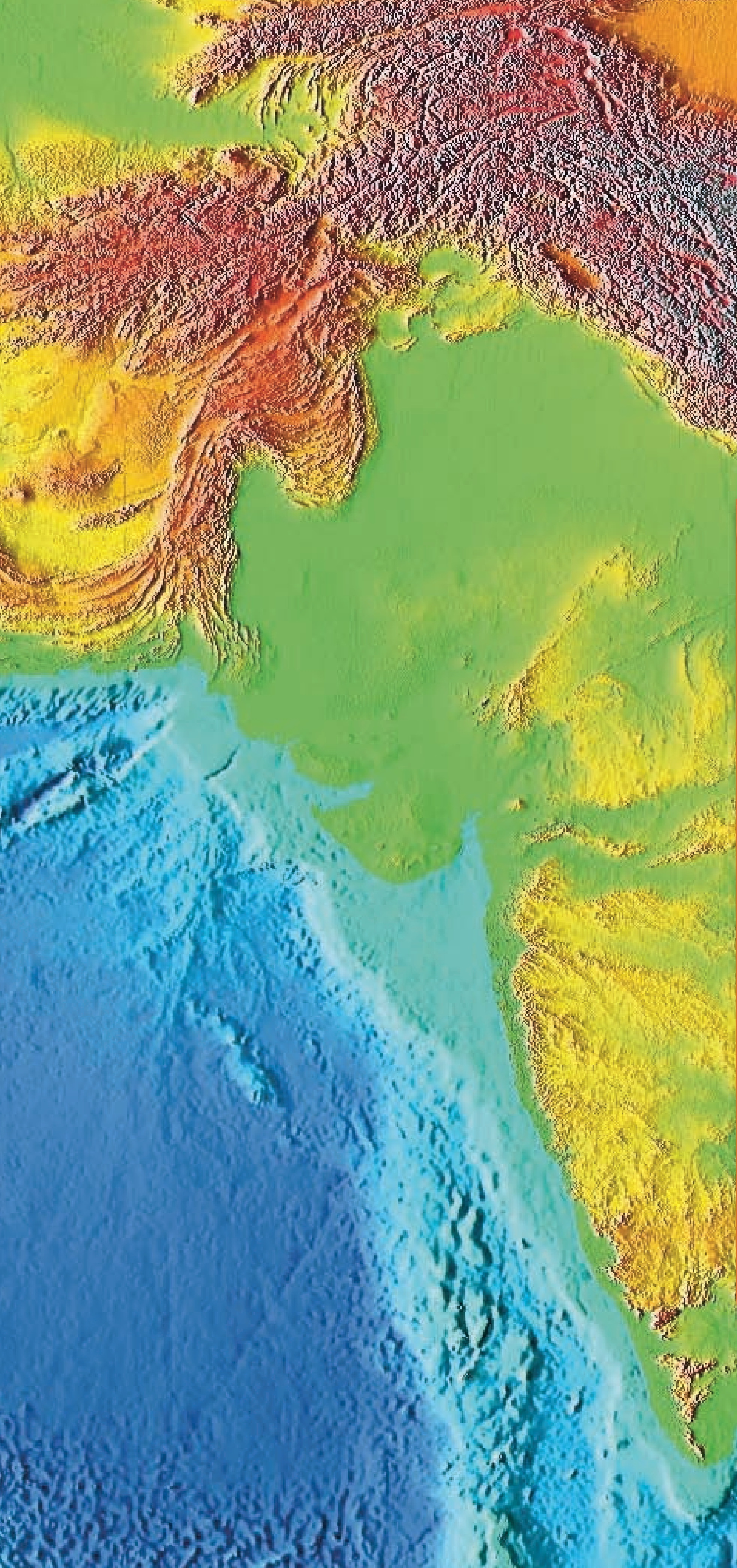
Chapter 3

Models of the Earth

Chapter Outline

Why It Matters

Using past and present technologies, scientists can create extremely accurate models of Earth's surface. These models, commonly called maps, help people navigate and find locations. Scientists use maps to study changes in Earth's four "spheres."

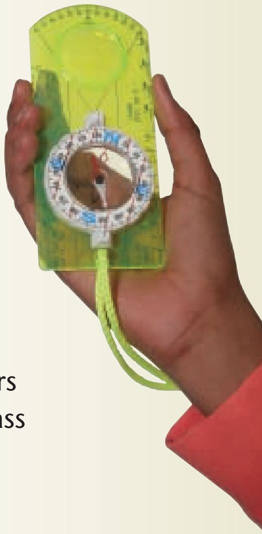


Inquiry Lab

30 min

Using a Compass

Working as a team, choose an object in your classroom. Use a **directional compass** to determine and record directions that another team could follow to arrive at the object you chose. Use cardinal directions (north, south, east, and west) and ordinal directions (northeast, northwest, southeast, and southwest). For example, you could write directions like these: "Stand with your back to the classroom door. Turn east, and walk five steps. Then walk three steps northeast." Trade directions with other teams.



Questions to Get You Started

1. In what direction does a compass needle always point?
2. How do you use the letters and numbers on a compass housing to adjust the compass?

READING TOOLBOX

These reading tools will help you learn the material in this chapter.

Science Terms

Everyday Words Used in Science All the key terms in this textbook are words that scientists use. Many words that are used in science are also used in everyday speech. You should pay attention to the definitions of these words so that you can use them correctly in scientific contexts.

Your Turn As you read Chapter 3, make a table like the one below for the terms *relief* and *projection* (from the key term *map projection*). Add other everyday words that are used by scientists as you find them in the chapter.

Term	Scientific context	Everyday meaning
relief	the difference between the highest and lowest elevations in a given area	a lessening or easing of a burden or anxiety, pain, or stress

Frequency

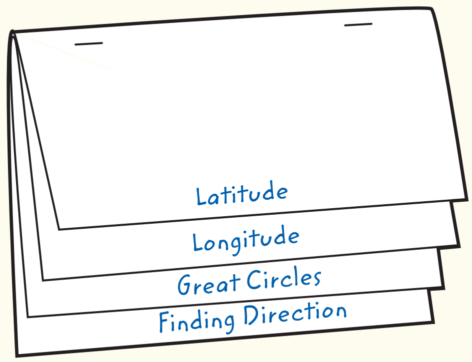
Always, Sometimes, or Never? Many statements include a word that tells you how often they are true. Examples include words such as *always, often, sometimes,* and *never*. Words such as *all, some, many,* and *most* tell you about frequency in number.

Your Turn As you read this chapter, make a list of statements that contain frequency words. For each statement in your list, underline the word or phrase that tells how frequently the statement is true. Here is an example: Air and sea routes often travel along great circles.

FoldNotes

Layered Book FoldNotes are a fun way to help you learn and remember ideas that you encounter as you read. You can use the four flaps of the layered book to divide the ideas into four categories.

Your Turn As you read Section 1, make a layered book, as described in **Appendix A.** Label the tabs of the layered book with "Latitude," "Longitude," "Great Circles," and "Finding Direction." Write notes on the appropriate layer as you read the section.



For more information on how to use these and other tools, see **Appendix A.**

SECTION 1

Finding Locations on Earth

Key Ideas

- Distinguish between latitude and longitude.
- Explain how latitude and longitude can be used to locate places on Earth's surface.
- Explain how a magnetic compass can be used to find directions on Earth's surface.

Key Terms

parallel
latitude
meridian
longitude

Why It Matters

Latitude and longitude form a frame of reference that is based on Earth's axis of rotation, making it possible to identify and locate any point on Earth.

The points at which Earth's axis of rotation intersects Earth's surface are used as reference points for defining direction. These reference points are the geographic North and South Poles. Halfway between the poles, a circle called the *equator* divides Earth into the Northern and Southern Hemispheres. A reference grid of additional circles is used to locate places on Earth's surface.

Latitude

One set of circles describes positions north and south of the equator. These circles are called **parallels** because they run east and west around the world, parallel to the equator. The angular distance north or south of the equator is called **latitude.**

parallel any circle that runs east and west around Earth and that is parallel to the equator; a line of latitude

latitude the angular distance north or south from the equator; expressed in degrees

Degrees of Latitude

Latitude is measured in degrees, and the equator is designated as 0° latitude. Because the distance from the equator to either of the poles is one-fourth of a circle, and a circle has 360°, the latitude of both the North Pole and the South Pole is one-quarter of 360°, or 90°, as shown in **Figure 1.** In actual distance, 1° of latitude equals 1/360 of Earth's circumference, or about 111 km. Parallels north of the equator are labeled N; those south of the equator are labeled S.

Minutes and Seconds

Each degree of latitude consists of 60 equal parts, called *minutes*. One minute (symbol: ') of latitude equals 1.85 km. In turn, each minute is divided into 60 equal parts, called *seconds* (symbol: "). So, the latitude of the center of Washington, D.C., could be expressed as 38°53'23"N.

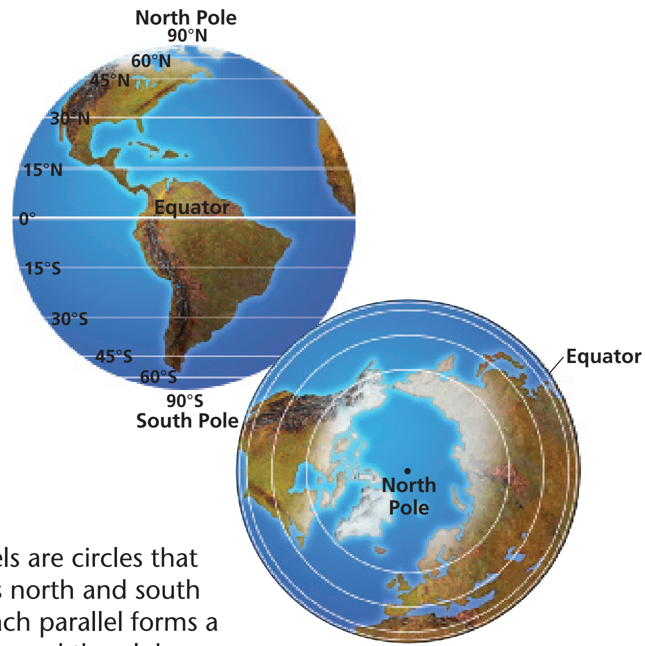


Figure 1 Parallels are circles that describe positions north and south of the equator. Each parallel forms a complete circle around the globe.

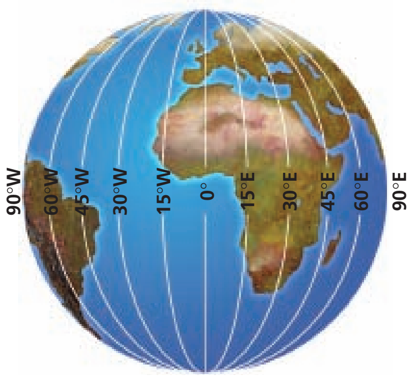


Figure 2 Meridians are semicircles reaching around Earth from pole to pole.

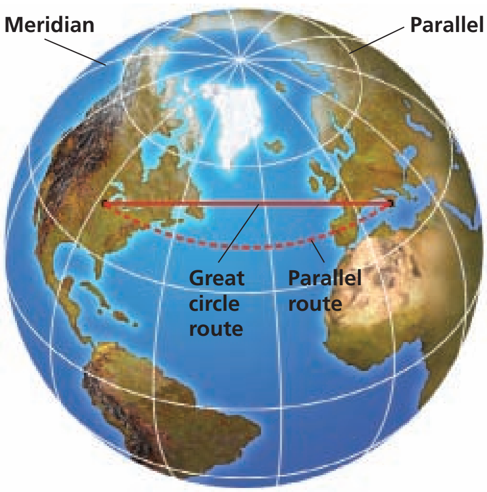
meridian any semicircle that runs north and south around Earth from the geographic North Pole to the geographic South Pole; a line of longitude

longitude the angular distance east or west from the prime meridian; expressed in degrees

Academic Vocabulary

location (loh KAY shuhn) place or position

Figure 3 A great-circle route from Chicago to Rome is much shorter than a route following a parallel is.



Longitude

The latitude of a particular place indicates only its position north or south of the equator. To determine the specific location of a place, you also need to know how far east or west that place is along its circle of latitude. East-west locations are established by using meridians. As **Figure 2** shows, a **meridian** is a semicircle (half of a circle) that runs from pole to pole.

By international agreement, one meridian was selected to be 0°. This meridian, called the *prime meridian,* passes through Greenwich, England. **Longitude** is the angular distance, measured in degrees, east or west of the prime meridian.

Degrees of Longitude

Because a circle is 360°, the meridian opposite the prime meridian, halfway around the world, is labeled 180°. All locations east of the prime meridian have longitudes between 0° and 180°E. All locations west of the prime meridian have longitudes between 0° and 180°W. Washington, D.C., which lies west of the prime meridian, has a longitude of 77°W. Like latitude, longitude can be expressed in degrees, minutes, and seconds. So, a more precise location for Washington, D.C., is 38°53'23"N, 77°00'33"W.

Distance Between Meridians

The distance covered by a degree of longitude depends on where the degree is measured. At the equator, or 0° latitude, a degree of longitude equals approximately 111 km. However, all meridians meet at the poles. Because meridians meet, the distance measured by a degree of longitude decreases as you move from the equator toward the poles. At a latitude of 60°N, for example, 1° of longitude equals about 55 km. At 80°N, 1° of longitude equals only about 20 km.

Great Circles

A great circle is often used in navigation, especially by long-distance aircraft. A *great circle* is any circle that divides the globe into halves, or marks the circumference of the globe. Any circle formed by two meridians of longitude that are directly across the globe from each other is a great circle. The equator is the only line of latitude that is a great circle. Great circles can run in any direction around the globe. Just as a straight line is the shortest distance between two points on a flat surface or plane, the route along a great circle is the shortest distance between two points on a sphere, as shown in **Figure 3.** As a result, air and sea routes often travel along great circles.

Reading Check **Why is the equator the only parallel that is a great circle?** (See Appendix G for answers to Reading Checks.)

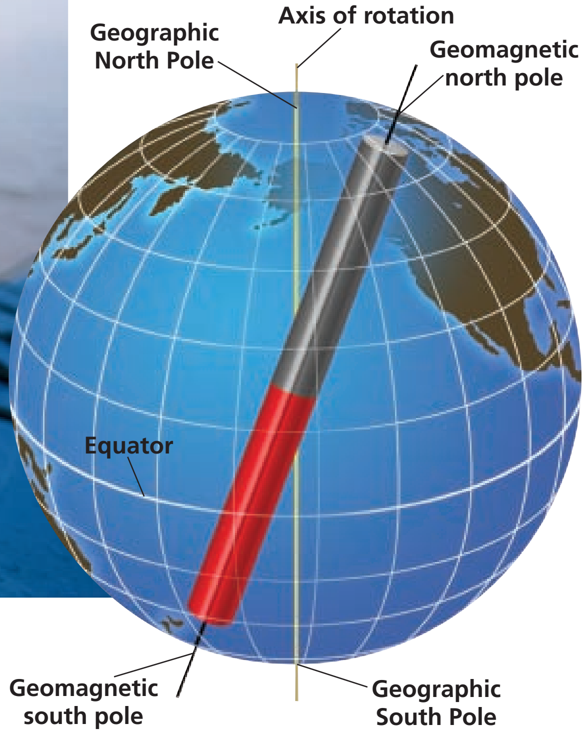


Figure 4 Earth's magnetic poles are at an angle to Earth's axis of rotation.

Finding Direction

One way to find direction on Earth is to use a magnetic compass. A magnetic compass can indicate direction because Earth has magnetic properties as if a powerful bar-shaped magnet were buried at Earth's center at an angle to Earth's axis of rotation, as shown in **Figure 4.**

The areas on Earth's surface where the poles of the imaginary magnet would be are called the *geomagnetic poles*. The geomagnetic poles and the geographic poles are different and are located in different places. The north end of a compass needle points in the direction of the geomagnetic north pole.

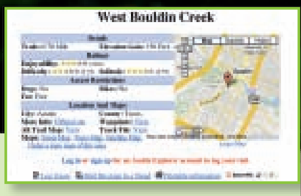
Why It Matters

SCIENCE & SOCIETY

Geocaching

Finding direction is not only for when you're lost. In geocaching, people hide a cache of "treasure" and post the coordinates (latitude and longitude) online. Other people then use GPS (Global Positioning System) receivers to find the cache.

People hide a cache of items, including a logbook, in a safe place.



The cache's coordinates are posted on a geocaching Web site.

People can trade items that they find and write an entry in the logbook.

YOUR TURN

ONLINE RESEARCH
Research how a GPS receiver uses satellite signals to pinpoint its location.

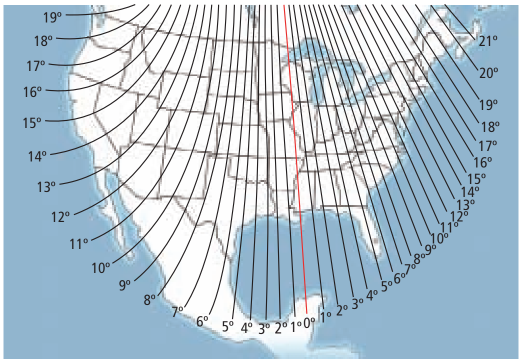


Figure 5 This map shows the pattern of magnetic declinations over North America. The lines connect points that have the same magnetic declination.

Magnetic Declination

The angle between the direction of the geographic pole and the direction in which the compass needle points is called *magnetic declination*. In the Northern Hemisphere, magnetic declination is measured in degrees east or west of the geographic North Pole. A compass needle will align with both the geographic North Pole and the geomagnetic north pole for all locations along the line of 0° magnetic declination, which is shown as the red line in **Figure 5.**

Magnetic declination has been determined for points all over Earth. However, because Earth's magnetic field is constantly changing, the magnetic declinations of locations around the globe also change constantly. **Figure 5** shows recent magnetic declinations for most of the United States. By using magnetic declination, a person can use a compass to determine geographic north for any place on Earth. Current declination at any location can be obtained from the Internet. Locating geographic north is important in navigation and in mapmaking.

SCILINKS.
www.scilinks.org
Topic: Global Positioning System
Code: **HQX0680**

READING TOOLBOX

Everyday Words Used in Science
Use a dictionary to help you compare the scientific and everyday meanings of the term *declination*.

The Global Positioning System

Another way people can find their location on Earth is by using the *global positioning system*, or *GPS*. GPS is a satellite navigation system that is based on a global network of satellites that transmit radio signals to Earth's surface. The first GPS satellite, known as NAVSTAR, was launched in 1978.

A GPS receiver held by a person on the ground receives signals from at least three satellites, which it uses to calculate the latitude, longitude, and altitude of the receiver on Earth. Personal GPS receivers are accurate to within 10 to 15 m of their position, but high-tech receivers designed for military or commercial use can be accurate to within several centimeters of their location.

Section 1 Review

Key Ideas

1. **Describe** the difference between lines of latitude and lines of longitude.
2. **Explain** how latitude and longitude are used to find specific locations on Earth.
3. **Summarize** why great-circle routes are commonly used in navigation.
4. **Explain** how a magnetic compass can be used to find directions on Earth.

Critical Thinking

5. **Applying Concepts** How might GPS technology be beneficial when used in airplanes or on ships?
6. **Making Comparisons** How do parallels differ from latitude?
7. **Identifying Patterns** Explain why the distance between parallels is constant but the distance between meridians decreases as the meridians approach the poles.

Concept Mapping

8. Use the following terms to create a concept map: *equator, second, parallel, degree, Earth, minute, longitude, meridian, prime meridian,* and *latitude.*

SECTION 2

Mapping Earth's Surface

Key Ideas	Key Terms	Why It Matters
❯ Explain two ways that scientists get data to make maps. ❯ Describe the characteristics and uses of three types of map projections. ❯ Summarize how to use keys, legends, and scales to read maps.	**remote sensing** **map projection** **legend** **scale** **isogram**	Maps are models of Earth's surface that can be made or chosen to display characteristics for a specific purpose, such as plotting the best route for your next road trip.

A globe is a familiar model of Earth. Because a globe is spherical like Earth, a globe can accurately represent the locations, relative areas, and relative shapes of Earth's surface features. A globe is especially useful for studying large surface features, such as continents and oceans. But most globes are too small to show details of Earth's surface, such as streams and highways. For that reason, a great variety of maps have been developed for studying and displaying detailed information about Earth.

How Scientists Make Maps

The science of making maps, called *cartography*, is a subfield of Earth science and geography. Scientists who make maps are called *cartographers*.

Cartographers use data from a variety of sources to create maps. They may collect data by conducting a field survey, shown in **Figure 1.** During a field survey, cartographers walk or drive through an area to be mapped and make measurements of that area. The information they collect is then plotted on a map. Because surveyors cannot take measurements at every site in an area, they often use their measurements to make estimated measurements for sites between surveyed points.

remote sensing the process of gathering and analyzing information about an object without physically being in touch with the object

By using remote sensing, cartographers can collect information about a site without being at that site. In **remote sensing,** equipment on satellites or airplanes obtains images of Earth's surface. Maps are often made by combining information from images gathered remotely with information from field surveys.

Figure 1 Cartographers in the field use technology to enhance the precision of their measurements. Electronic devices can be used to measure the distance between an observer and a distant point with a high degree of accuracy.

Quick **Lab** 20 min

Making Projections

Procedure

1. Use a **fine-tip marker** to draw a variety of shapes on a **small glass ivy bowl** or **clear plastic hemisphere.**
2. Shine a **flashlight** through the bottom of the bowl.
3. Shape a **piece of white paper** into a cylinder around the bowl.
4. Trace the shapes projected from the bowl onto the paper.
5. Using a cone of paper, repeat steps 3 and 4.

Analysis

1. What type of projection did you create in steps 3 and 4? in step 5?
2. Compare the sizes of the shapes on the bowl with those on your papers. What areas did each projection distort?

map projection a flat map that represents a spherical surface

Map Projections

A map is a flat representation of Earth's curved surface. However, transferring a curved surface to a flat map results in a distorted image of the curved surface. An area shown on a map may be distorted in size, shape, distance, or direction. The larger the area being shown is, the greater the distortion tends to be. A map of the entire Earth would show the greatest distortion. A map of a small area, such as a city, would show only slight distortion.

Over the years, cartographers have developed several ways to transfer the curved surface of Earth onto flat maps. A flat map that represents the three-dimensional curved surface of a globe is called a **map projection.** No projection is an entirely accurate representation of Earth's surface. However, each kind of projection has certain advantages and disadvantages that must be considered when choosing a map.

Cylindrical Projections

Imagine Earth as a transparent sphere that has a light inside. If you wrapped a cylinder of paper around this lighted globe and traced the outlines of continents, oceans, parallels, and meridians, a *cylindrical projection,* shown in **Figure 2,** would result. Meridians on a cylindrical projection appear as straight, parallel lines that have an equal amount of space between them. On a globe, however, the meridians come together at the poles. A cylindrical projection is accurate near the equator but distorts distances and sizes near the poles.

Though distorted, cylindrical projections have some advantages. One advantage is that parallels and meridians form a grid, which makes locating positions easier. Also, the shapes of small areas are usually well preserved. When a cylindrical projection is used to map small areas, distortion is minimal.

Reading Check **Why do meridians and parallels appear as a grid when shown on a cylindrical projection?**

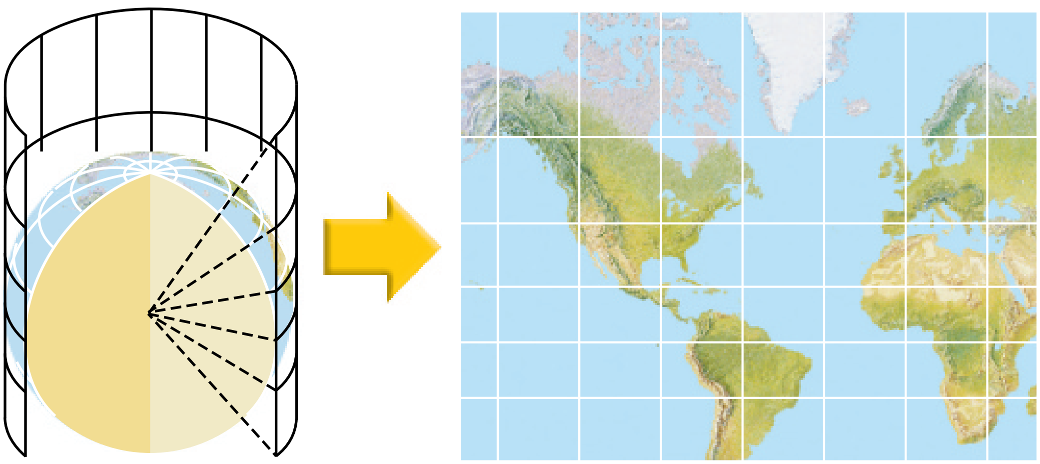


Figure 2 A light at the center of a transparent globe would project lines on a cylinder of paper (left) that would produce a cylindrical projection (right).

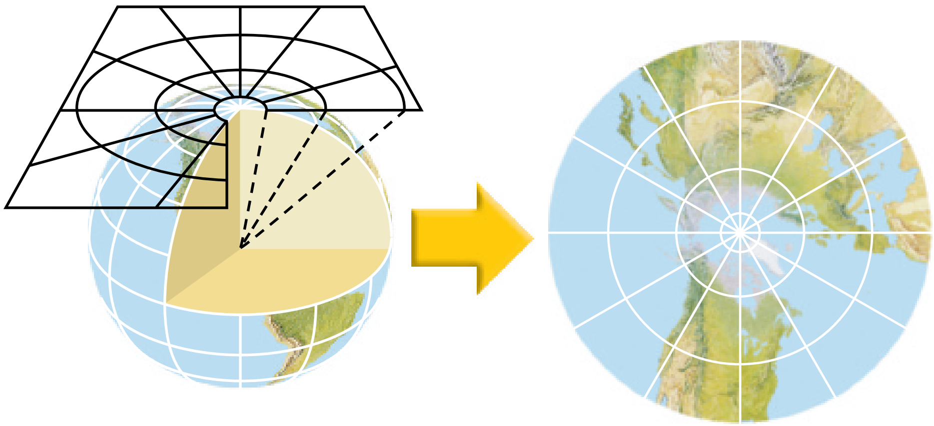


Figure 3 When a sheet of paper is placed so that it touches a lighted globe at only one point (left), the lines projected on the paper form an azimuthal projection (right).

Azimuthal Projections

A projection made by placing a sheet of paper against a transparent, lighted globe such that the paper touches the globe at only one point is called an *azimuthal* (AZ uh MYOOTH uhl) *projection*, as shown in **Figure 3.** On an azimuthal projection, little distortion occurs at the point of contact, which is commonly one of the poles. However, an azimuthal projection shows unequal spacing between parallels that causes a distortion in both direction and distance. This distortion increases as distance from the point of contact increases.

Despite distortion, an azimuthal projection is a great help to navigators in plotting routes used in air travel. As you know, a great circle is the shortest distance between any two points on the globe. When projected onto an azimuthal projection, a great circle appears as a straight line. Therefore, by drawing a straight line between any two points on an azimuthal projection, navigators can readily find a great-circle route.

Conic Projections

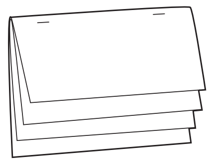
A projection made by placing a paper cone over a lighted globe so that the axis of the cone aligns with the axis of the globe is known as a *conic projection*. The cone touches the globe along one parallel of latitude. As shown in **Figure 4,** areas near the parallel where the cone and globe are in contact are distorted the least.

A series of conic projections may be used to increase accuracy by mapping a number of neighboring areas. Each cone touches the globe at a slightly different latitude. Fitting the adjoining areas together then produces a continuous map. Maps made in this way are called *polyconic projections*. The relative size and shape of small areas on the map are nearly the same as those on the globe.

READING TOOLBOX

Layered Book

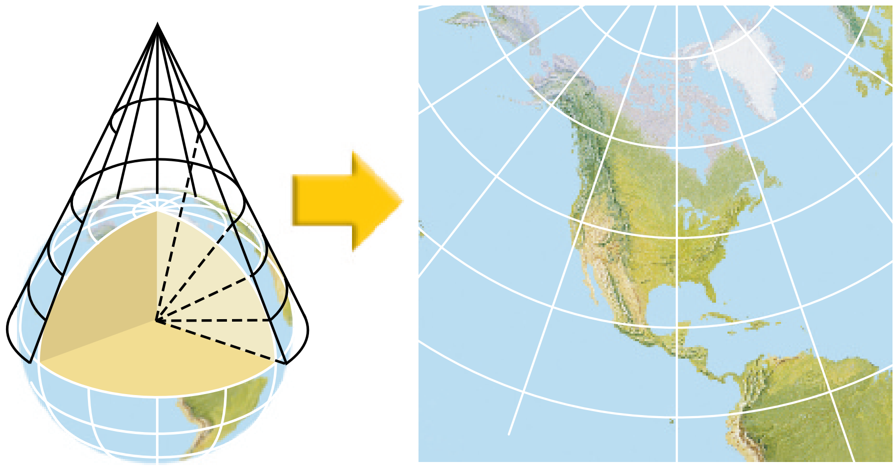
Make a layered book FoldNote. Label the tabs with the three types of map projections. Write notes on the appropriate tab to list the advantages and disadvantages of each type of map projection.



Academic Vocabulary

contact (KON takt) state of touching; coming together of objects or surfaces

Figure 4 A light at the center of a transparent globe would project lines on a paper cone (left) that would produce a conic projection (right).



Reading a Map

Maps provide information through the use of symbols. To read a map, you must understand the symbols on the map and be able to find directions and calculate distances.

SCILINKS.
www.scilinks.org
Topic: Cartography
Code: **HQX0229**

Direction on a Map

To correctly interpret a map, you must first determine how the compass directions are displayed on the map. Maps are commonly drawn with north at the top, east at the right, west at the left, and south at the bottom. Parallels run from side to side, and meridians run from top to bottom. Direction should always be determined in relation to the parallels and meridians.

On maps published by the United States Geological Survey (USGS), such as the one shown in **Figure 5,** north is located at the top of the map and is marked by a parallel. The southern boundary, at the bottom of a map, is also marked by a parallel. At least two additional parallels are usually drawn in or indicated by cross hairs at 2.5' intervals. Meridians of longitude indicate the eastern and western boundaries of USGS maps. Additional meridians may also be shown. All parallels and meridians shown on these maps are labeled in degrees, minutes, and seconds.

Many maps also include a compass rose, as shown in **Figure 5.** A *compass rose* is a symbol that indicates the cardinal directions. The *cardinal directions* are north, east, south, and west. Some maps replace the compass rose with a single arrow that points to geographic north. This arrow is generally labeled and may not always point to the top of the map.

Figure 5 Maps may show locations by marking parallels and meridians. Direction is commonly shown with a compass rose (inset).

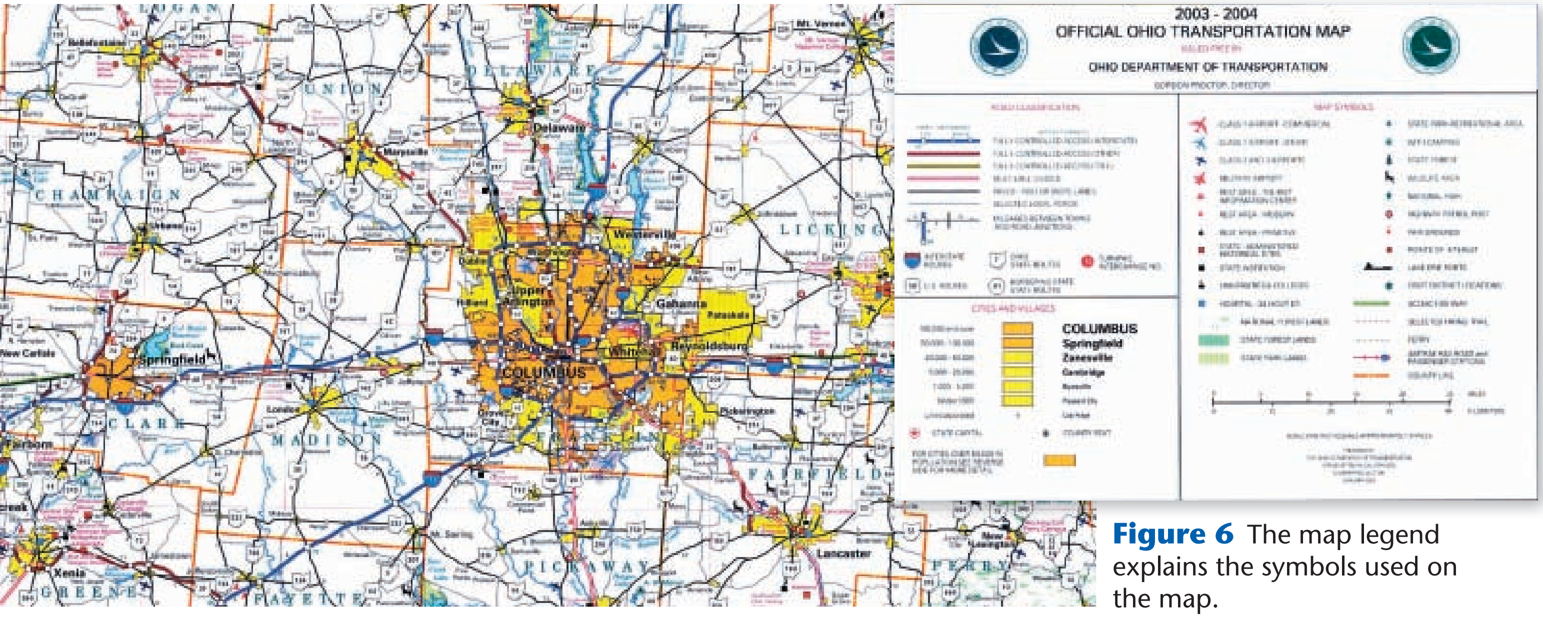


Figure 6 The map legend explains the symbols used on the map.

Symbols

Maps often have symbols for features such as cities and rivers. The symbols are explained in the map **legend,** a list of the symbols and their meanings, such as the one shown in **Figure 6.** Some symbols resemble the features that they represent. Others, such as those for towns and urban areas, are more abstract.

legend a list of map symbols and their meanings

scale the relationship between the distance shown on a map and the actual distance

Map Scales

To be accurate, a map must be drawn to **scale.** The scale of a map indicates the relationship between distance shown on the map and actual distance. A map scale can be expressed as a graphic scale, a fractional scale, or a verbal scale.

A *graphic scale* is a printed line that has markings on it that are similar to those on a ruler. The line represents a unit of measure, such as the kilometer or the mile. Each part of the scale represents a specific distance on Earth. To find the actual distance between two points on Earth, you first measure the distance between the points as shown on the map. Then, you compare that measurement with the map scale.

A second way of expressing scale is by using a ratio, or a *fractional scale.* For example, a fractional scale such as 1:25,000 indicates that 1 unit of distance on the map represents 25,000 of the same unit on Earth. A fractional scale remains the same with any system of measurement. In other words, the scale 1:100 could be read as 1 in. equals 100 in. or as 1 cm equals 100 cm.

A *verbal scale* expresses scale in sentence form. An example of a verbal scale is "One centimeter is equal to one kilometer." In this scale, 1 cm on the map represents 1 km on Earth.

Reading Check **Name three ways to express scale on a map.**

Math Skills

Determining Distance You notice that the scale on a map of the United States says, "One centimeter equals 120 kilometers." By measuring the straight-line distance between Brooklyn, New York, and Miami, Florida, you determine that the cities are about 14.5 cm apart on the map. What is the approximate distance in kilometers between the two cities?

Figure 7 Areas connected by the isobars on the map share equal atmospheric pressure.

Isograms

A line on a map that represents a constant or equal value of a given quantity is an **isogram.** The prefix *iso-* is Greek for "equal." The second part of the word, *-gram,* means "drawing." This part of the word can be changed to describe the measurement being graphed. For example, when a line connects points of equal temperature, the line is called an *isotherm* because *iso-* means "equal" and *therm* means "heat." All locations along an isogram share the value that is being measured.

Isograms can be used to plot many types of data. Meteorologists use these lines to show changes in atmospheric pressure on weather maps. Isograms used for this purpose on a weather map are called *isobars*, as shown in **Figure 7.** All points along an isobar share the same pressure value. Because one location cannot have two air pressures, isobars never cross one another.

isogram a line on a map that represents a constant or equal value of a given quantity

Scientists can use isograms on a map to plot data that represent almost any type of measurement. Isograms are commonly used to show areas that have similar measurements of precipitation, temperature, gravity, magnetism, density, elevation, or chemical composition.

Section 2 Review

Key Ideas

1. **Identify** two methods that scientists use to get the data needed to make maps.
2. **Describe** three types of map projections in terms of their different characteristics and uses.
3. **Explain** why all maps are in some way inaccurate representations.
4. **Summarize** how to use legends and scales to read maps.
5. **Describe** what isograms show.
6. **Explain** why maps are more useful than globes are for studying small areas on the surface of Earth.
7. **Summarize** how to find directions on a map.

Critical Thinking

8. **Applying Concepts** If a cartographer is making a map for three countries that do not use a common unit of measurement, what type of scale should the cartographer use on the map? Explain your answer.
9. **Making Inferences** Why would a conic projection produce a better map for exploring polar regions than a cylindrical projection would?

Concept Mapping

10. Use the following terms to create a concept map: *cartography, map projection, cylindrical projection, azimuthal projection, conic projection, map, legend, scale,* and *symbol.*

SECTION 3

Types of Maps

Key Ideas	Key Terms	Why It Matters
❯ Explain how elevation and topography are shown on a map. ❯ Describe three types of information shown in geologic maps. ❯ Identify two uses of soil maps.	**topography** **elevation** **contour line** **relief**	Different types of maps enable scientists to display detailed three-dimensional information about the surface and below-surface features of Earth.

Earth scientists use a wide variety of maps that show many distinct characteristics of an area. Some of these characteristics include types of rocks, differences in air pressure, and varying depths of groundwater in a region. Scientists also use maps that show locations, elevations, and surface features of Earth.

Topographic Maps

One of the most widely used maps is called a *topographic map*. Topographic maps show the surface features, or **topography,** of Earth. Most topographic maps show both natural features, such as rivers and hills, and constructed features, such as buildings and roads. Topographic maps are made by using both aerial photographs and survey points collected in the field. A topographic map shows the **elevation,** or height above sea level, of the land. Elevation is measured from *mean sea level*, the point midway between the highest and lowest tide levels of the ocean. The elevation at mean sea level is 0.

topography the size and shape of the land surface features of a region, including its relief

elevation the height of an object above sea level

Advantages of Topographic Maps

An aerial view of an island is shown in **Figure 1.** Although the drawing shows the shape of the island, it does not indicate the island's size or elevation. A typical map projection would show the island's size and shape but would not show the island's topography. A topographic map provides more detailed information about the surface of the island than either the drawing or a projection map does. The advantage of a topographic map is that it shows the island's size, shape, and elevation.

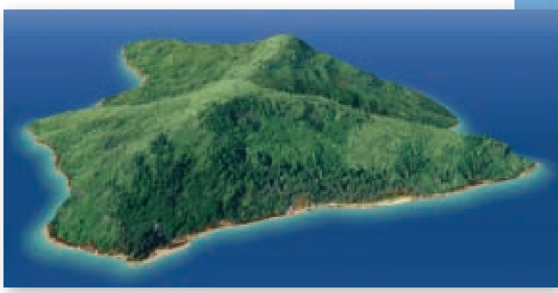


Figure 1 A drawing gives little information about the elevation of the island (left). In the topographic map (right), contour lines have been drawn to show elevation. An × marks the highest point on this map.

Figure 2 On a topographic map, the contour interval for this mountain would be very large because of the mountain's steep slope.

Elevation on Topographic Maps

On topographic maps, **contour lines** are used to show elevation. Each contour line is an isogram that connects points that have the same elevation. Because points at a given elevation are connected, the shape of the contour lines reflects the shape of the land.

The difference in elevation between one contour line and the next is called the *contour interval*. A cartographer chooses a contour interval suited to the scale of the map and the relief of the land. **Relief** is the difference in elevation between the highest and lowest points of the area being mapped. On maps of areas where the relief is high, such as the area shown in **Figure 2,** the contour interval may be as large as 50 or 100 m. Where the relief is low, the interval may be only 1 or 2 m.

To make reading the map easier, a cartographer makes every fifth contour line bolder than the four lines on each side of it. These bold lines, called *index contours*, are labeled by elevation. A point between two contour lines has an elevation between the elevations of the two lines. For example, if a point is halfway between the 50 and 100 m contour lines, its elevation is about 75 m. Exact elevations are marked by an × and are labeled.

contour line a line that connects points of equal elevation on a map

relief the difference between the highest and lowest elevations in a given area

Quick Lab — Topographic Maps

20 min

Procedure

1. Make a model mountain that is 6 to 8 cm high out of **modeling clay.** Work on a flat surface, and smooth out the mountain's shape. Make one side of the mountain slightly steeper than the other side.
2. Run a **paper clip** down one side of the model to form a valley that is several millimeters wide.
3. Place the model in the center of a **large waterproof container** that is at least 8 cm deep.
4. Use **tape** to hold a **ruler** upright in the container. One end of the ruler should rest on the bottom of the container. Make sure that the container is level.
5. Using the ruler as a guide, add **water** to the container to a depth of 1 cm. Use a **sharp pencil** to inscribe the clay by tracing around the model along the waterline.
6. Raise the water level 1 cm at a time until you reach the top of the model. Each time you add water to the container, inscribe another contour line in the clay along the waterline.
7. When you have finished, carefully drain the water and remove the model from the container.

Analysis

1. What is the contour interval of your model?
2. Observe your model from directly above. Try to duplicate the size and spacing of the contour lines on a sheet of paper to create a topographic map.
3. Compare the contour lines on a steep slope with those on a gentle slope. How do they differ?
4. How is a valley represented on your topographic map?

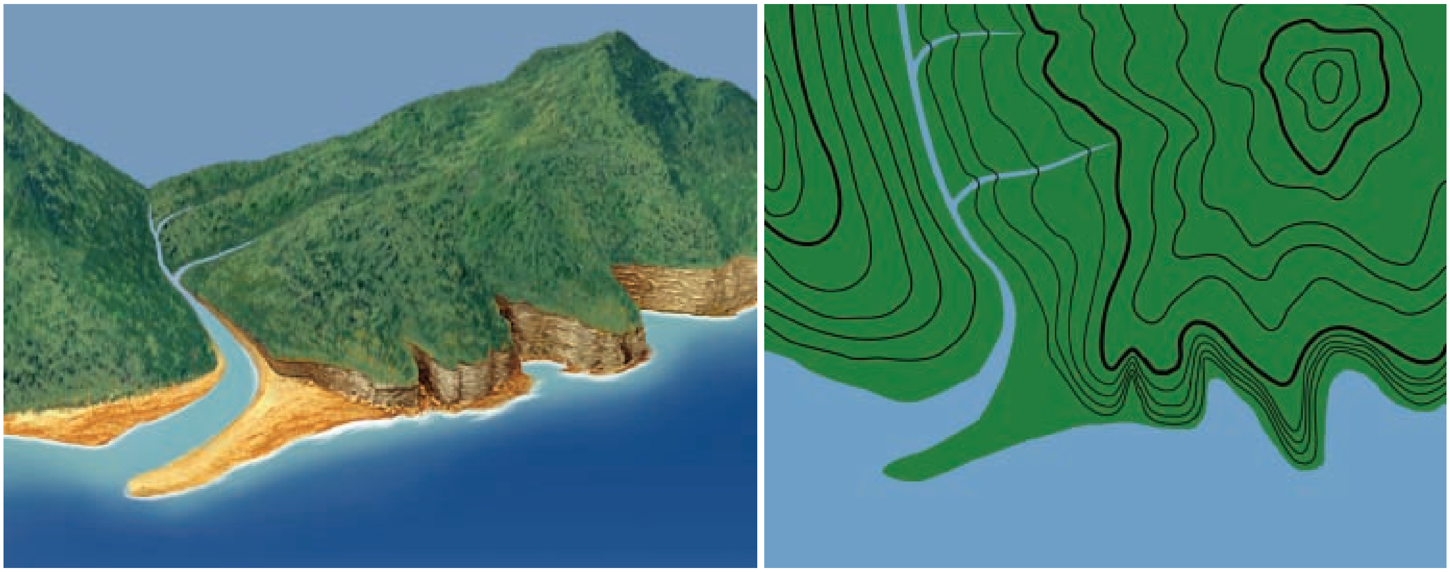


Figure 3 The features of the area's coastal valley are represented by contour lines on the topographic map of the area.

THINK central
INTERACT ONLINE
Keyword: HQXMODF3

Landforms on Topographic Maps

As shown in **Figure 3,** the spacing and the direction of contour lines indicate the shapes of the landforms represented on a topographic map. Contour lines spaced widely apart indicate that the change in elevation is gradual and that the land is relatively level. Closely spaced contour lines indicate that the change in elevation is rapid and that the slope is steep.

A contour line that bends to form a V shape indicates a valley. The bend in the V points toward the higher end of the valley. If a stream or river flows through the valley, the V in the contour line will point upstream, the direction from which the water flows. A river always flows from higher to lower elevation. The width of the V formed by the contour line shows the width of the valley.

Contour lines that form closed loops indicate a hilltop or a depression. Generally, a depression is indicated by *depression contours,* which are closed-loop contour lines that have short, straight lines perpendicular to the inside of the loop. These short lines point toward the center of the depression.

Reading Check **Why do V-shaped contour lines along a river point upstream?**

Topographic Map Symbols

Symbols are used to show certain features on topographic maps. Symbol color indicates the type of feature. For example, constructed features, such as buildings, boundaries, roads, and railroads, are generally shown in black. Major highways are shown in red. Bodies of water are shown in blue, and forested areas are shown in green. Contour lines are brown or black. Often, areas whose map information has been updated based on aerial photography but not verified by field exploration are shown in purple. A key to common topographic map symbols is provided for your reference in Appendix E.

SCILINKS.
www.scilinks.org
Topic: Topographic Maps
Code: **HQX1536**

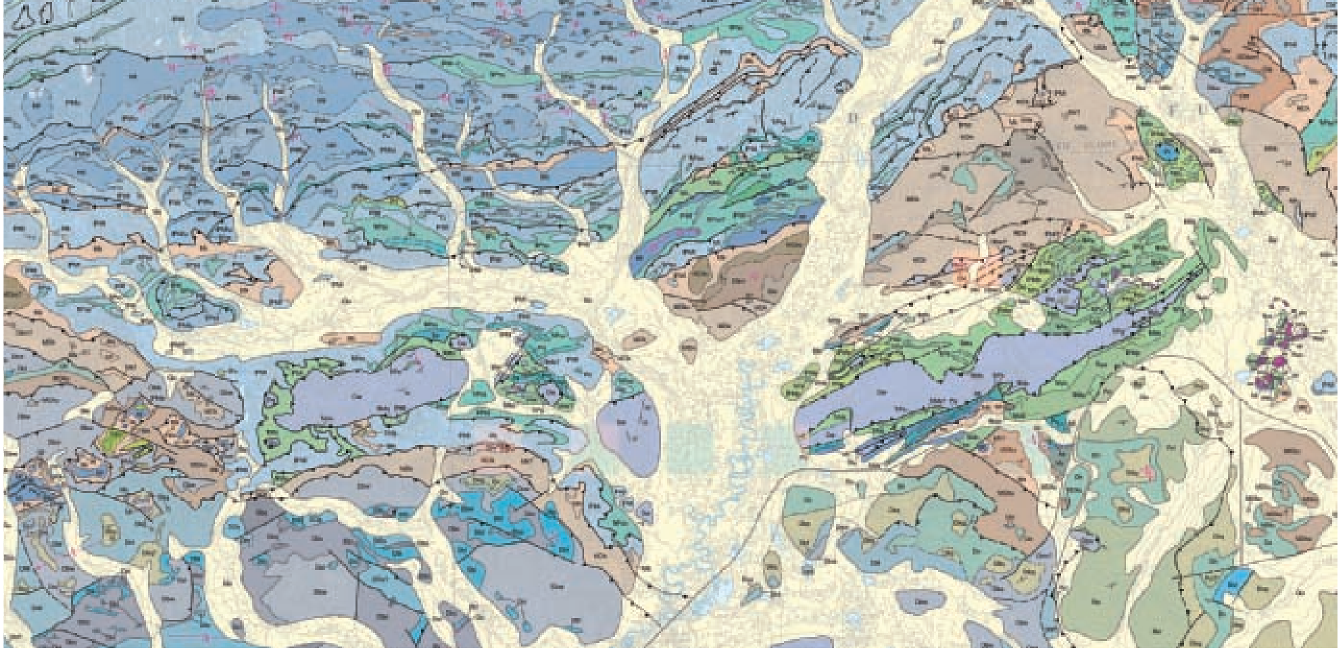


Figure 4 Each color on this geologic map represents a distinct type of rock and shows where in this region that type of rock occurs.

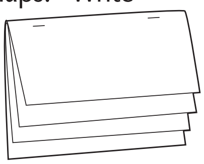
Geologic Maps

Geologic maps, such as the one shown in **Figure 4,** are designed to show the distribution of geologic features. In particular, geologic maps show the types of rocks found in a given area and the locations of faults, folds, and other structures.

Geologic maps are created on top of another map, called a *base map*. The base map provides surface features, such as topography or roads, to help identify the location of the geologic units. The base map is commonly printed in light colors or as gray lines so that the geologic information on the map is easy to read and understand.

READING TOOLBOX

Layered Book
Make a layered book FoldNote, and label the tabs "Topographic Maps," "Geologic Maps," "Soil Maps," and "Other Maps." Write notes on the appropriate layer as you read Section 3.



Rock Units on Geologic Maps

A volume of rock of a given age range and rock type is a *geologic unit*. On geologic maps, geologic units are distinguished by color. Units of similar ages are generally assigned colors in the same color family, such as different shades of blue. In addition to assigning a color, geologists assign a set of letters to each rock unit. This set of letters is commonly one capital letter followed by one or more lowercase letters. The capital letter symbolizes the age of the rock, usually by geologic period. The lowercase letters represent the name of the unit or the type of rock.

Other Structures on Geologic Maps

Other markings on geologic maps are contact lines. A *contact line* indicates places at which two geologic units meet, called *contacts*. The two main types of contacts are faults and depositional contacts. Depositional contacts show where one rock layer formed above another. Faults are cracks where rocks have moved past each other. Also on geologic maps are strike and dip symbols for rock beds. *Strike* indicates the direction in which the beds run, and *dip* indicates the angle at which the beds tilt.

Soil Maps

Another type of map that is commonly used by Earth scientists is called a *soil map*. Scientists construct soil maps to classify, map, and describe soils. Soil maps are based on soil surveys that record information about the properties of soils in a given area. Soil surveys can be performed for a variety of areas, but they are most commonly performed for a county.

The government agency that is in charge of overseeing and compiling soil data is the Natural Resources Conservation Service (NRCS). The NRCS is part of the United States Department of Agriculture (USDA). The NRCS has been mapping the distribution of soils in the United States for more than a century.

Academic Vocabulary

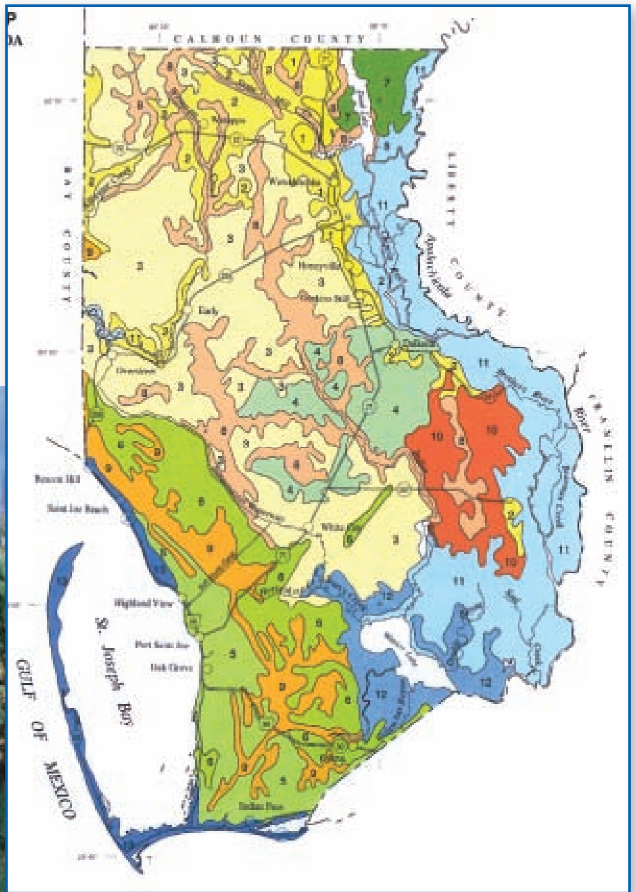
distribution (DIS tri BYOO shuhn) relative arrangement of objects or organisms in time or space

Reading Check **Why do scientists create soil maps?**

Soil Surveys

A soil survey consists of three main parts: text, maps, and tables. The text of soil surveys includes general information about the geology, topography, and climate of the area being mapped. The tables describe the types and volumes of soils in the area. Soil surveys generally include two types of soil maps. The first type is a very general map that shows the approximate location of different types of soil within the area, such as the one shown in **Figure 5.** The second type shows detailed information about soils in the area.

Figure 5 Scientists gather data to make a soil map by taking soil samples. Soil maps help scientists determine the potential abilities and limitations of the land to support development and agriculture.



Uses of Soil Maps

Soil maps are valuable tools for agriculture and land management. Knowing the properties of the soil in an area helps farmers, agricultural engineers, and government agencies identify ways to conserve and use soil and to plan sites for future development.

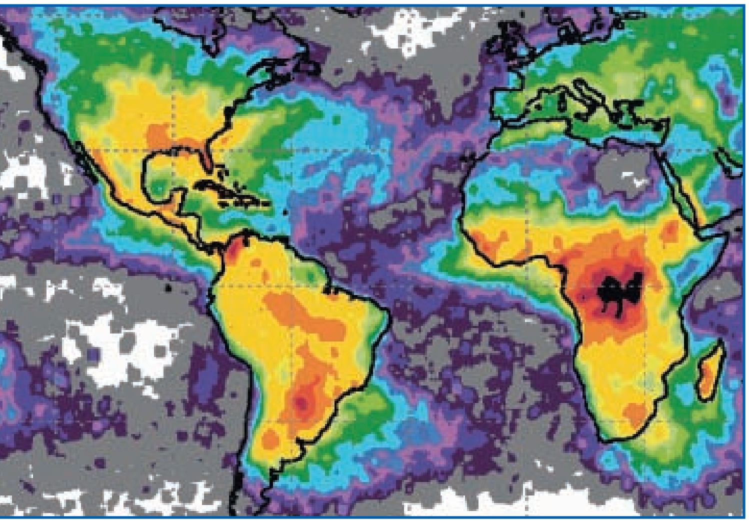


Figure 6 This map was created by using satellite data. The map shows the global distribution of lightning based on the average number of strikes per square kilometer. The highest frequency of strikes is shown in black, and the lowest frequency is shown in white.

Other Types of Maps

Earth scientists also use maps to show the location and flow of both water and air. These maps are commonly constructed by plotting data from various points around a region and then using isograms to connect the points whose data are identical.

Maps are useful to every branch of Earth science. For example, meteorologists use maps such as the one shown in **Figure 6** to record and predict weather events. Maps may be used to plot the amount of precipitation that falls in a given area. Maps are also used to show the locations of areas of high and low air pressure and the weather fronts that move across Earth's surface. These maps are updated constantly and are used by meteorologists to communicate to the public important information on daily weather conditions and emergency situations.

The location and direction of the flow of groundwater can be recorded on maps. Data from these maps can be used to determine where and when water shortages may occur. Scientists use map information to identify potential locations for power plants, waste disposal sites, and new communities.

Other types of Earth scientists use maps to study changes in Earth's surface over time. Such changes include changes in topography, changes in amounts of available resources, and changes in factors that affect climate. Maps generated by satellites are particularly useful for studying changes in Earth's surface.

Section 3 Review

Key Ideas

1. **Explain** how elevation is shown on a topographic map.
2. **Define** *contour interval.*
3. **Summarize** how you can use information on a topographic map to compare the steepness of slopes on the map.
4. **Describe** how geologic units of similar ages are shown on a geologic map.
5. **Identify** the three main parts of a soil survey.
6. **Identify** two primary uses for soil maps.
7. **Identify** three types of maps other than topographic maps, geologic maps, and soil maps.

Critical Thinking

8. **Applying Ideas** How can you use lines on a topographic map to identify the direction of river flow?
9. **Making Inferences** In what ways might topographic maps be more useful than simple map projections to someone who wants to hike in an area that he or she has never hiked in before?
10. **Identifying Patterns** What type of map would be the most useful to a scientist studying earthquake patterns: a geologic map or a topographic map?

Concept Mapping

11. Use the following terms to create a concept map: *topographic map, elevation, mean sea level, contour interval, contour line,* and *index contour.*

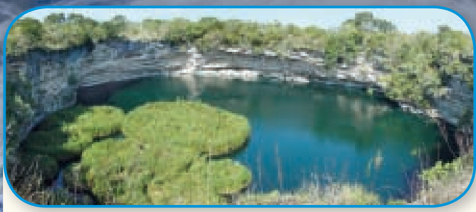
Why It Matters

Is There Anywhere That Isn't Mapped?

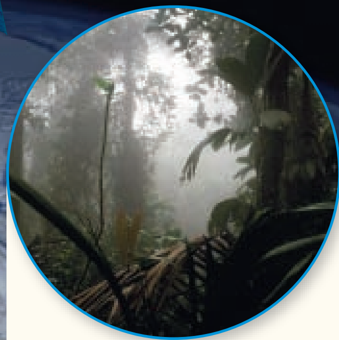
REAL WORLD

Lost in the city? Consult a map. Lost in the woods? Check your handy GPS receiver. With our ever-improving models of Earth, it is getting harder to "get lost"—harder, but not impossible. While much of Earth's surface is mapped, a detailed view of many features on and below its surface remains incomplete. Parts of rain forests around the world remain uncharted, and there are many kilometers of caves and sinkholes (cenotes) that no human has ever entered.

Mammoth Cave in Kentucky has more than 600 km of surveyed passages and perhaps twice as many that are still unmapped.



Inventor and explorer Bill Stone used a robotic submarine, DEPTHX, to survey Mexico's unexplored El Zacatón cenote in 2007. The same technology may one day be used to map the moons of the outer planets.



The Darien Gap borders Panama and Columbia. It is a dense, 26,000 km^2, area containing forest and swamp—and the only part of the Pan-American Highway that is not fully mapped.

YOUR TURN

CRITICAL THINKING

What are three locations on or under Earth that you think have yet to be mapped?

ONLINE RESEARCH

Research these three locations to find out whether or not they have been mapped.

Contour Maps: Island Construction

What You'll Do

- **Build** a scale model based on a map.
- **Identify** contour intervals and landscape features based on a map.

What You'll Need

basin, flat (or large pan), 8 cm deep
clay, modeling (4 lb)
dowel, thick wooden (or rolling pin)
knife, plastic
paper, white
pencil
ruler, metric
scissors
topographic map from Reference Tables section of the Appendix
water

Safety

A map is a drawing that shows a simplified version of some detail of Earth's surface. There are many types of maps. Each type has its own special features and purpose. One of the most useful types of maps is the topographic map, or contour map. This type of map shows elevation and other important features of the landscape. Scientists make a contour map by using data obtained from a careful survey and photographic study of the area that the map represents.

Procedure

1. Study the topographic map in the Reference Tables section of the Appendix. Record the contour interval used on the island contour map. Then, count the number of contour lines that appear on the map.
2. Use the dowel to press out as many flat pieces of clay as there were contour lines counted in step 1. Each piece of clay should be 1 cm thick and large enough to cover the island shown on the map.
3. On a blank sheet of paper, trace the island contour map. Cut out the island from your copy of the contour map along the outermost contour line.
4. Place this cutout on top of one of the pieces of clay. Trace the edge of the cutout in the clay. Cut the piece of clay to match the shape of the island.

Step 2

5. Cut the paper tracing along the next contour line, making sure not to damage the outer ring of paper as you cut.
6. Using the new paper shape and a new layer of clay, repeat step 4.
7. Place the paper ring from the first cut on the first clay shape that you cut out so that the outer edges of the paper ring line up with the edges of the clay. Stack the second layer of clay on the first layer so that the second layer fits inside the paper contour ring. This gives you the same contour spacing as shown on the map. Remove the paper ring.
8. Continue steps 4–7 for each of the contour layers.
9. Use leftover clay to smooth the terraced edges into a more natural profile.
10. Make a mark inside a pan approximately 1 cm down from the rim. Put the clay model of the island into the pan, and add water to a depth of 1 cm.
11. Compare the shoreline of the model with the lines on the contour map. Continue to add water at 1 cm intervals until the water reaches the mark on the pan.

Step 5

Step 6

Analysis

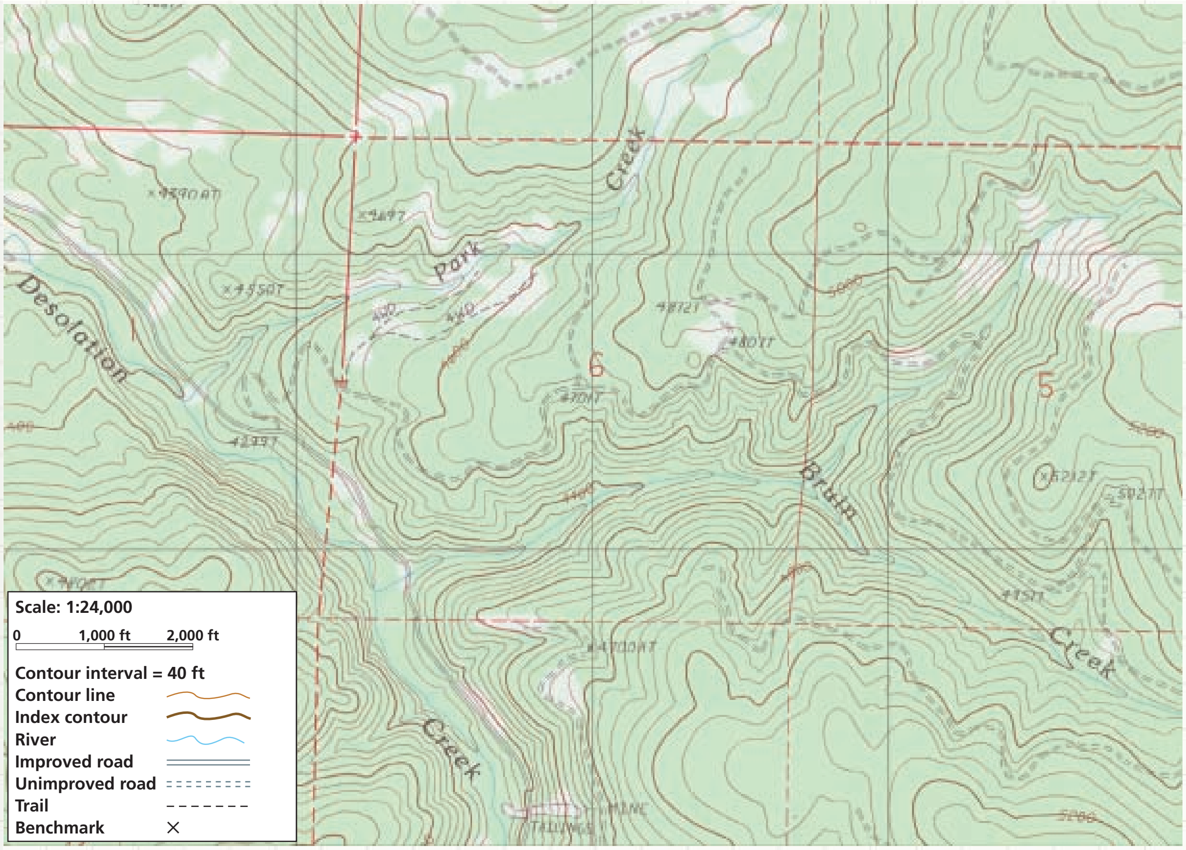
1. **Making Inferences** What is the contour interval of your map?
2. **Understanding Relationships** How could you tell the steepest slope from the gentlest slope by observing the spacing of the contour lines?
3. **Analyzing Data** What is the elevation above sea level for the highest point of your model?
4. **Applying Ideas** How do you know if your model contains any areas that are below sea level? If there are any such areas, where are they and what are their elevations?
5. **Evaluating Models** What landscape feature is located at point C on your model, as indicated on the original map? What is the elevation of point B on your model?

Extension

Making Predictions From observations of your model, what conclusions can you make about where people might live on this island? Explain your answer.

MAPS in Action

Topographic Map of the Desolation Watershed



Map Skills Activity

This map, produced by the United States Geological Survey (USGS), shows the topography of the area around the Desolation watershed located in eastern Oregon. Note that the USGS uses English and metric units when measuring distance. Use the map to answer the questions below.

1. **Using a Key** What is the distance between the location on the northwest corner of the map labeled “4681T” and the location on the eastern side of the map labeled “5212T”?
2. **Analyzing Data** In what direction does Park Creek flow? How are you able to determine this information by looking at the map?
3. **Making Comparisons** Which area has the steeper slopes: the area around Park Creek or the area around Bruin Creek? How are you able to determine this information by looking at the map?
4. **Inferring Relationships** What is the elevation of the contour line that circles the point 4550T, located on the northwest of the map?
5. **Identifying Trends** Desolation Creek, Park Creek, and Bruin Creek enter the map from different geographic directions. Use the information on the map to determine what these creeks have in common in terms of their direction of flow.
6. **Analyzing Relationships** What is the total change in elevation between two index contours?

Chapter 3 Summary

SUPER SUMMARY
Keyword: HQXMODS

Key Ideas | **Key Terms**

Section 1

Finding Locations on Earth

- Lines of latitude are parallels that run east and west around Earth. Lines of longitude are meridians that run north and south from pole to pole.
- Lines of latitude and longitude form a system of intersecting lines (a grid system). The points at which lines intersect may be used to identify places on Earth's surface.
- The needle of a compass points to the geomagnetic north pole. Once north is located, south, east, and west may be determined.

Key Terms

parallel, p. 57
latitude, p. 57
meridian, p. 58
longitude, p. 58

Section 2

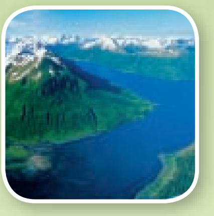
Mapping Earth's Surface

- Two ways that scientists get data to make maps are by using field surveys and by using images of Earth's surface obtained by remote sensing.
- For cylindrical projections, distances and sizes are accurate near the equator but distorted at the poles. Azimuthal projections are commonly used to map the poles, where distortion is minimal; distortion increases, however, farther from the poles. Conic projections are useful for mapping mid-latitude regions.
- The keys and legends of maps list map symbols and their meanings. Map scales show the relationship between distance shown on a map and actual distance.

Key Terms

remote sensing, p. 61
map projection, p. 62
legend, p. 65
scale, p. 65
isogram, p. 66

Section 3



Types of Maps

- Contour lines are used to show elevation and topography on a map.
- Geologic maps show the types and locations of rocks, faults, folds, and other geologic features.
- Soil maps are used to classify, map, and describe soils.

Key Terms

topography, p. 67
elevation, p. 67
contour line, p. 68
relief, p. 68

Chapter 3 Review

1. **Layered Book** You have made a layered book for concepts within a section. Now make a layered book with the names of the three sections themselves and summarize the key ideas in the chapter.

READING TOOLBOX

USING KEY TERMS

Use each of the following terms in a separate sentence.

2. *cartography*
3. *map projection*
4. *contour lines*

For each pair of terms, explain how the meanings of the terms differ.

5. *parallel* and *latitude*
6. *meridian* and *longitude*
7. *legend* and *scale*
8. *topography* and *relief*
9. *index contour* and *contour interval*

UNDERSTANDING KEY IDEAS

10. The distance in degrees east or west of the prime meridian is
    a. latitude.
    b. longitude.
    c. declination.
    d. projection.
11. The distance covered by a degree of longitude
    a. is 1/180 of Earth's circumference.
    b. is always equal to 11 km.
    c. increases as you approach the poles.
    d. decreases as you approach the poles.
12. The needle of a magnetic compass points toward the
    a. geomagnetic pole.
    b. geographic pole.
    c. parallels.
    d. meridians.
13. The shortest distance between any two points on the globe is along
    a. the equator.
    b. a line of latitude.
    c. the prime meridian.
    d. a great circle.
14. If 1 cm on a map equals 1 km on Earth, the fractional scale would be written as
    a. 1:1. **c.** 1:100,000.
    b. 1:100. **d.** 1:1,000,000.
15. On a topographic map, elevation is shown by means of
    a. great circles.
    b. contour lines.
    c. verbal scale.
    d. fractional scale.
16. What type of map is commonly used to locate faults and folds in beds of rock?
    a. geologic map
    b. topographic map
    c. soil map
    d. isogram map
17. The contour interval is a measurement of
    a. the change in elevation between two adjacent contour lines.
    b. the distance between mean sea level and any given contour line.
    c. the length of a contour line.
    d. the time needed to travel between any two contour lines.

SHORT ANSWER

18. How much distance on Earth's surface does one second of latitude equal?
19. What is the difference between latitude and longitude?
20. What are the three main types of map projections? How do they differ?
21. Compare the advantages and disadvantages of the three main types of map projections.
22. How do legends and scales help people interpret maps?
23. How do contour lines on a map illustrate topography?

CRITICAL THINKING

24. Applying Ideas What is wrong with the following location: 135°N, 185°E?

25. Identifying Trends As you move from point A to point B in the Northern Hemisphere, the length of a degree of longitude progressively decreases. In which direction are you moving?

26. Understanding Relationships Imagine that you are at a location where the magnetic declination is 0°. Describe your position relative to magnetic north and true north.

27. Making Inferences You examine a topographic map on which the contour interval is 100 m. In general, what type of terrain is probably shown on the map?

28. Applying Ideas A topographic map shows two hiking trails. Along trail A, the contour lines are widely spaced. Along trail B, the contour lines are almost touching. Which path would probably be easier and safer to follow? Why?

CONCEPT MAPPING

29. Use the following terms to create a concept map: *latitude, longitude, relief, map projection, cylindrical projection, elevation, map, azimuthal projection, contour line, conic projection, topography, legend,* and *scale*.

MATH SKILLS

Math Skills

30. Making Calculations A topographic map has a contour interval of 30 m. By how many meters would your elevation change if you crossed seven contour lines?

31. Applying Quantities A map has a fractional scale of 1:24,000. How many kilometers would 3 cm on the map represent?

32. Making Calculations A city to which you are traveling is located along the same meridian as your current position but is 11° of latitude to the north of your current position. About how far away is the city?

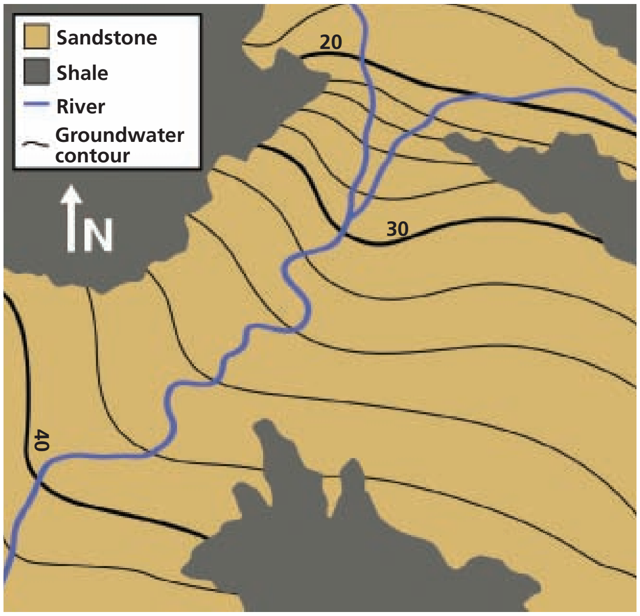
WRITING SKILLS

33. Writing from Research Research the navigation instrument known as the *sextant*. Make a diagram explaining how the sextant can be used to determine latitude.

34. Writing from Research Use the Internet and library resources to research global positioning systems. Write a short essay describing the different ways that GPS devices are currently being used in everyday situations. Then, make a prediction about how the technology might be used in the future.

INTERPRETING GRAPHICS

The map below shows contour lines of groundwater. The lines show elevation of the water table in meters above sea level. Use the map to answer the questions that follow.



35. What is the contour interval for this map?

36. What is the highest measured level of the water table?

37. Groundwater flows from highest to lowest elevation. In which direction is the groundwater flowing?

Chapter 3 Standardized Test Prep

Understanding Concepts

Directions (1–5): For each question, write on a separate sheet of paper the letter of the correct answer.

1. How can you determine whether the contours on a topographic map show a gradual slope?
   A. Look for V-shaped contour lines.
   B. Look for widely spaced contour lines.
   C. Look for short, straight lines inside the loop.
   D. Look for tightly spaced, circular contour lines.
2. What is the difference in elevation between two successive index contours on a map with a contour interval of 5 m?
   F. 5 m
   G. 10 m
   H. 20 m
   I. 25 m
3. What part of a road map would you use in order to measure the distance from your current location to your destination?
   A. latitude lines
   B. map scale
   C. longitude lines
   D. map legend
4. For what reason do meteorologists use isobars on a weather map?
   F. to show differences in atmospheric air pressure
   G. to connect points of equal temperature
   H. to plot local precipitation data
   I. to show elevation above or below sea level
5. What is the angular distance, measured in degrees, east or west of the prime meridian?
   A. latitude
   B. longitude
   C. isogram
   D. relief

Directions (6–7): For each question, write a short response.

6. What is the longitude of the prime meridian?
7. What is the latitude of the North Pole?

Reading Skills

Directions (8–10): Read the passage below. Then, answer the questions.

Map Projections

Earth is a sphere, and thus its surface is curved. When a curved surface is transferred to a flat map, distortions in size, shape, distance, and direction occur. To limit these distortions, cartographers have developed many ways of transferring a three-dimensional curved surface to a flat map. On cylindrical projections, meridians and parallels appear as straight lines. These lines cross each other at 90° angles and form a grid. On azimuthal projections, there is little distortion at one contact point on the map, which is often one of the poles. But distortion in direction and distance increases as distance from the point of contact increases. On conic projections, the map is accurate along one parallel of latitude. Areas near this parallel are distorted the least. However, none of these maps is an entirely accurate representation of Earth's surface.

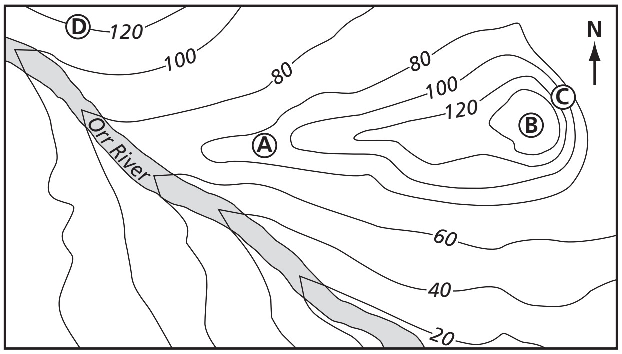
8. Which of the following appears as a straight line on an azimuthal projection, where the point of contact is the North Pole?
   F. great circles
   G. parallels
   H. the equator
   I. coastlines
9. Which of the following statements about cylindrical projections is true?
   A. Because latitude and longitude form a grid, plotting great circles can be done by using a straight-edged ruler.
   B. Because latitude and longitude form a grid, finding specific locations is easy on a cylindrical-projection map.
   C. Maps made by cylindrical projection often show the greatest distortion where the projection touched the globe.
   D. Cylindrical projections often show polar regions as being much smaller than they actually are.
10. Why does each map described display some sort of distortion?

Interpreting Graphics

Directions (11–14): For each question below, record the correct answer on a separate sheet of paper.

Use the topographic map below to answer questions 11 and 12.

Topographic Map of the Orr River



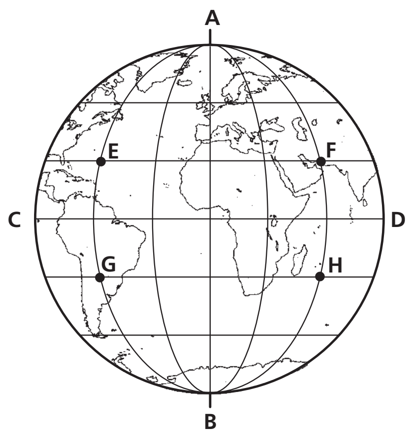
11. What location on the map has the steepest gradient?

F. location A
G. location B
H. location C
I. location D

12. In which direction is the river in the topographic map flowing? What information on the map helped you determine your answer?

The diagram below shows Earth's system of latitude and longitude lines. Lines are shown in 30° increments. Use this diagram to answer questions 13 and 14.

Latitude and Longitude



13. Which point is located at 30°N, 60°E?

A. point E
B. point F
C. point G
D. point H

14. The distance between two lines of parallel that are 1° apart is about 111 km. What is the approximate distance between points G and E?

Test Tip

Choose an answer to a question based on both what you already know as well as any information presented in the question.