1.3 Representing Earth’s Surface

Reading Focus

Key Concepts
- What lines on a globe are used to indicate location?
- What problems do mapmakers face when making maps?
- How do topographic maps differ from other maps?

Vocabulary
- latitude
- longitude
- topographic map
- contour line
- contour interval

Reading Strategy

Monitoring Your Understanding
Preview the Key Concepts, topic headings, vocabulary, and figures in this section. List two things you expect to learn. After reading, state what you learned about each item you listed.

<table>
<thead>
<tr>
<th>What I Expect to Learn</th>
<th>What I Learned</th>
</tr>
</thead>
<tbody>
<tr>
<td>a.</td>
<td></td>
</tr>
<tr>
<td>b.</td>
<td></td>
</tr>
<tr>
<td>c.</td>
<td></td>
</tr>
<tr>
<td>d.</td>
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</tr>
</tbody>
</table>

Introduction to Earth Science

Determining Location

Today we use maps and computer programs to help us plan our routes. Long ago, people had to rely on maps that were made using data and information that were collected by travelers and explorers. Today, computer technology is available to anyone who wants to use it. Mapmaking has changed a lot throughout recorded history.

Scientists use two special Earth measurements to describe location. The distance around Earth is measured in degrees. Latitude is the distance north or south of the equator, measured in degrees. Longitude is the distance east or west of the prime meridian, measured in degrees. Earth is 360 degrees in circumference. Lines of latitude are east-west circles around the globe. All points on the circle have the same latitude. The line of latitude around the middle of the globe, at 0 degrees (°), is the equator. Lines of longitude run north and south. The prime meridian is the line of longitude that marks ° of longitude as shown in Figure 8.

Global Grid

Scientists use two special Earth measurements to describe location. The distance around Earth is measured in degrees.

a. Latitude is the distance north or south of the equator, measured in degrees.

b. Longitude is the distance east or west of the prime meridian, measured in degrees.

Reading Strategy

Paraphrase

Have students look up the vocabulary words for this section in the Glossary and then rewrite the definitions in their own words. Help students remember that latitude lines run horizontally across Earth with the mnemonic “Lat lies flat.” Similarly, help them see that longitude lines run the “long way” over Earth.

Reading Strategy

Sample answer:

a. I expect to learn about latitude and longitude.

b. Latitude lines measure degrees north and south of the equator; longitude lines measure degrees east and west of the prime meridian.

c. I expect to learn about different types of maps.

d. There are many different types of maps. Maps are hard to make accurately. Different map types have different advantages and disadvantages.

INSTRUCT

Determining Location

Use Visuals

Figure 8 Help students find point D on the global grid in this figure. Ask: What is the latitude and longitude of point D? (45°N, 75°W) What major city is near point D? (Montreal, Canada) If an earthquake occurred near point D, are people at point A likely to feel it? Why or why not? (No, point D is in the Western Hemisphere and point A is in the Eastern Hemisphere.)

Visual, Logical
Section 1.3 (continued)

Maps and Mapping

Use Visuals

Figure 9 Use this diagram to explain the concepts of latitude and longitude and how they are measured. Emphasize that although latitude and longitude are usually shown on Earth’s surface, they are actually measured inside Earth. Ask: From which point is latitude measured? (the equator) From which point is longitude measured? (the prime meridian)

Visual, Logical

Build Reading Literacy

Refer to p. 124D in Chapter 5, which provides guidelines for summarizing.

Summarize Have students write a summary of this section that includes each map type and its advantages and disadvantages. This can be done as a table. Here is an example:

<table>
<thead>
<tr>
<th>Map Type</th>
<th>Advantages</th>
<th>Disadvantages</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mercator projection</td>
<td>Rectangular; longitude lines are parallel; directions shown accurately</td>
<td>Sizes and distances distorted</td>
</tr>
<tr>
<td>Robinson projection</td>
<td>Most distances, sizes, and shapes are accurate</td>
<td>Distortions around the map edges</td>
</tr>
<tr>
<td>Conic projection</td>
<td>Great accuracy over small areas; good for road and weather maps</td>
<td>Lots of distortion on most of the map</td>
</tr>
<tr>
<td>Gnomonic projection</td>
<td>Reliably shows the shortest distance between two points</td>
<td>Exact distances and directions are distorted</td>
</tr>
</tbody>
</table>

Reading

As people explored Earth, they collected information about the shapes and sizes of islands, continents, and bodies of water. Mapmakers wanted to present this information accurately. The best way was to put the information on a model, or globe, with the same round shape as Earth itself. By using an accurate shape for Earth, mapmakers could show the continents and oceans of Earth much as they really are. The only difference would be the scale, or relative size.

But there is a problem with globes. Try making a globe large enough to show the streets in your community. The globe might have to be larger than your school building! A globe can’t be complete enough to be useful for finding directions and at the same time small enough to be convenient for everyday use.

Maps and Mapping

A map is a flat representation of Earth’s surface. But Earth is round. Can all of Earth’s features be accurately represented on a flat surface without distorting them? The answer is no. No matter what kind of map is made, some portion of the surface will always look either too small, too big, or out of place. Mapmakers have, however, found ways to limit the distortion of shape, size, distance, and direction.

The Mercator Projection

In 1569, a mapmaker named Gerardus Mercator created a map to help sailors navigate around Earth. On this map, the lines of longitude are parallel, making this grid rectangular, as shown on the map in Figure 10. The map was useful because, although the sizes and distances were distorted, it showed directions accurately. Today, more than 400 years later, many seagoing navigators still use the Mercator projection map.

Figure 10 Mercator Map

To make a Mercator map, mapmakers have to carve an image of Earth’s surface into slices and then stretch the slices into rectangles. Stretching the slices enlarges parts of the map. The enlargement becomes greater toward the north and south poles.

Observing What areas on the map appear larger than they should?

Customize for Inclusion Students

Learning Disabled Students can more easily locate positions on a map using latitude and longitude coordinates by using the following procedure. First, help students orient themselves to the map by locating the equator and the prime meridian. Have students go over those two key points using a highlighter and extend the lines out to the edge of the paper. Next, have students write N in the left and right margins above the equator, and S in the left and right margins below the equator. Students should write W in the margins above and below the map west of the prime meridian, and write E in the margins above and below the map east of the prime meridian.
Different Projection Maps for Different Purposes

The best projection is always determined by its intended use. The Robinson projection map is one of the most widely used. Maps that use this projection show most distances, sizes, and shapes accurately. However, even a Robinson projection has distortions, especially in areas around the edges of the map. You can see this in Figure 11. Conic projection maps are made by wrapping a cone of paper around a globe at a particular line of latitude, as shown in Figure 13. Various points and lines are projected onto the paper. There is almost no distortion along the line of latitude that’s in contact with the cone, but there can be much distortion in areas away from this latitude. Because accuracy is great over a small area, these maps are used to make road maps and weather maps. Gnomonic projections, as shown in Figure 13, are made by placing a piece of paper on a globe so that it touches a single point on the globe’s surface. Various points and lines are then projected onto the paper. Although distances and directions are distorted on these maps, they are useful to sailors and navigators because they show with great accuracy the shortest distance between two points.

What major problem must mapmakers overcome?

Figure 11 Robinson Projection Map
Compare this map to the Mercator projection.
Comparing and Contrasting
How do the shapes in the continents differ between these maps? Are there any other differences?

Figure 12 Conic Projection Map
Because there is little distortion over small areas, conic projections are used to make road maps and weather maps.

Figure 13 Gnomonic Projection Map
Gnomonic projections allow sailors to accurately determine distance and direction across the oceans.

Conic and Gnomonic Projections

Purpose Students see how conic and gnomonic projections are made.

Materials small globe, blank transparency sheet

Procedure Use a photocopier to copy the maps in Figures 12 and 13 onto a blank transparency sheet. Make the figures as large as possible. Cut the transparency in half to separate the figures. Wrap the copy of Figure 12 around the globe in a cone shape as shown. Point out how the features of the globe line up with the projection. Hold the copy of Figure 13 flat on top of the North Pole as shown. Ask:
Where was the conic projection most accurate? (near the latitude where the cone touches the globe) Least accurate? (near the top and bottom)
Where was the gnomonic projection most accurate? (near the North Pole)

Expected Outcome Students will observe how the projections are related to round Earth.

Visual, Logical

Use Visuals

Figures 10–13 Advise students to look carefully at Figures 10–13 to see how each map is created and why this process results in distortion. Ask: Based on Figure 10, how does the way a Mercator map is created cause distortion? (Since the Mercator map is made by slicing a globe, each section is rounded and the sections don’t fit together, so each piece must be stretched into a rectangle, causing distortion.) Using Figure 11, explain how a conic projection map is created. (A cone of paper is put over a globe, and the lines of the globe are projected onto the paper.) Visual

Answer to . . .

Figure 10 the areas near the poles
Figure 11 The continents are less distorted near the poles. The longitude lines are straight, not curved.

Representing round Earth on flat paper causes distortion in shape, size, distance.
**Topographic Maps**

*Use Community Resources*

A cartographer is someone who makes maps. While maps were once drawn entirely by hand based on aerial photographs, almost all modern mapmaking is done using computers. Training in GIS (geographic information systems) is usually required for the job. Ask a cartographer from a local college, university, or government office to talk to the class about how maps are made. Have students prepare questions in advance.

*Interpersonal*

**Build Science Skills**

*Applying Concepts* Have students answer the following questions by using Figure 15. Ask: Find an area with a steep slope. Name a feature in this area. (the southern part of the map; Sugar Loaf Mountain) How do you know that this area has a steep slope? (The contour lines are close together.) Find an area on the map with a gentle slope. Name a feature in this area. (the eastern edge of the map; Turquoise Lake) How can you tell that this area has a gentle slope? (The contour lines are far apart.) Discuss students’ answers and clarify if needed.

*Visual*

**Facts and Figures**

Topographic maps contain a great deal of information. Each map has a legend that gives information about the map and the symbols used on it. The legend lists the title of the map (usually a major feature), the dates the map was produced and revised, and the latitude and longitude. There is a small diagram showing the map’s location in the state and the names of adjacent maps. A small box contains the contour interval and the scale as a ratio and as scale bars in miles, feet, and kilometers/meters. A magnetic declination diagram shows the differences in degrees among true north, grid north, and magnetic north. A long list explains the symbols shown on the map, which can include contour lines, depressions, ocean depth lines, boundaries, survey markers, forests, fields, built-up areas, buildings, roads, and railways.

**Contour Lines** The elevation of the land is indicated by using contour lines. Every position along a single contour line is the same elevation. Adjacent contour lines represent a change in elevation. Every fifth line is bold and labeled with the elevation. It is called an index contour. The contour interval tells you the difference in elevation between adjacent lines. The steepness of an area can be determined by examining a map. Lines that are closer together indicate a steeper slope, while lines farther apart indicate a gentler slope. You can see this relationship on the illustration in Figure 14. Contour lines that form a circle represent a hill. A depression is represented by circular contours that have hachure marks, which are small lines on the circle that point to the center. Contour lines never touch or intersect.

**Topographic Maps**

A topographic map, like the one shown in Figure 15, represents Earth’s three-dimensional surface in two dimensions. Topographic maps differ from the other maps discussed so far because topographic maps show elevation. Topographical maps show elevation of Earth’s surface by means of contour lines. Most also show the presence of bodies of water, roads, government and public buildings, political boundaries, and place names. These maps are important for geologists, hikers, campers and anyone else interested in the three-dimensional lay of the land.
Scale  A map represents a certain amount of area on Earth’s surface. So it is necessary to be able to determine distances on the map and relate them to the real world. Suppose you want to build a scale model of a boat that is 20 feet long. If your model is a 1/5-scale model, then it is 4 feet long. 

In a similar way, a map is drawn to scale where a certain distance on the map is equal to a certain distance at the surface. Because maps model Earth’s surface, the scale must be larger than that of the model boat. Look at the scale on the map in Figure 16. The ratio reads 1:24,000. This means that 1 unit on the map is equal to 24,000 units on the ground. Because the ratio has no units, it may stand for anything. We usually use inches or centimeters for our units. If the 1 stands for 1 centimeter on the map, how many kilometers does the 24,000 stand for on the ground?

Another scale provided on a map is a bar scale. See Figure 15. This allows you to use a ruler to measure the distance on the map and then line the ruler up to the bar to determine the distance represented.

Geologic Maps  It is often desirable to know the type and age of the rocks that are exposed, or crop out, at the surface. This kind of map is shown in Figure 16.  A map that shows this information is called a geologic map. Once individual rock formations are identified, and mapped out, their distribution and extent are drawn onto the map. Each rock formation is assigned a color and sometimes a pattern. A key provides the information needed to learn what formations are present on the map. Contour lines are often included to provide a more detailed and useful map.

Integrate Math

Working With Ratios  Working with a map key to determine actual distances often requires the use of ratios, a topic taught in math class. Explain the following process to your students. If a map legend has 1:24,000, this suggests that 1 unit (centimeters or inches) on the map is equal to 24,000 units (centimeters or inches) on Earth. To determine how many kilometers 1 cm on the map would equal, set up a ratio (using the conversion factor 1 km = 100,000 cm), as follows: 1 km / 100,000 cm = x km / 24,000 cm, then solve the ratio by cross-multiplication. The result will be that 1 cm on the map represents 0.24 km on Earth. Because 1:24,000 represents a ratio, it does not matter what unit is used as long as the map’s unit matches the unit on Earth. This ratio would allow students to determine how many inches on Earth corresponded to inches on the map.

Logical

Direct students to the Math Skills in the Skills and Reference Handbook at the end of the student text for additional help.

Use Community Resources

Geologic maps are used by research scientists, government agencies, and mining companies. Ask a geologist from a local college, university, mining company, or government office to talk to the class about how geologic maps are made, what information they show, and how they are used. Ask students to prepare questions in advance.

Interpersonal

Download a worksheet on mapping for students to complete, and find additional teacher support from NSTA SciLinks.

Topographic maps indicate changes in elevation with contour lines. Lines closer together indicate a steeper slope.
Advanced Technology

Use Visuals

Figure 17 Tell students that the image shown is similar to a photograph, but taken from a satellite orbiting around Earth. Ask: What are the light blue areas? (moving sediment) Where is the sediment coming from? (It is carried down by the Mississippi River.) What is the area at the center right side of the image called and how do you think it was formed? (the Mississippi delta was formed from sediments deposited by the river.)

Visual, Logical

Integrate Social Studies

Space Age The successful launch of Sputnik by the Soviet Union was a significant event in the Cold War era. It marked the beginning of the Space Age and was the first victory in the space race between the United States and the Soviet Union. In response, the United States accelerated its efforts to launch its own satellite.

Advanced Technology

Today's technology provides us with the ability to more precisely analyze Earth's physical properties. Scientists now use satellites and computers to send and receive data. These data are converted into usable forms such as pictures and numerical summaries.

The process of collecting data about Earth from a distance, such as from orbiting satellites, is called remote sensing. Satellites use remote sensing to produce views of Earth that scientists use to study rivers, oceans, fires, pollution, natural resources, and many other topics. How might a scientist use the image shown in Figure 17?

We can use this technology in our daily lives too. For example, Global Positioning Systems (GPS) can provide maps in our cars to help us reach our destinations. GPS consists of an instrument that receives signals to compute the user's latitude and longitude as well as speed, direction, and elevation. GPS is an important tool for navigation by ships and airplanes. Scientists use GPS to track wildlife, study earthquakes, measure erosion, and many other purposes. Table 1 describes some of the technology that is particularly useful in the study of Earth science.

Facts and Figures

The first satellite to orbit Earth was called Sputnik. The Soviet Union launched it on October 4, 1957. It was a 23-inch, 184-pound metal ball containing a thermometer, a battery, and a radio transmitter. On its exterior, four whip antennas transmitted short-wave frequencies between 20 and 40 MHz, common frequencies intended to make Sputnik's presence obvious to the world, and particularly to the United States. Sputnik orbited Earth for 92 days before burning up in Earth's atmosphere.
Section 1.3 Assessment

### Table 1 Technology and Earth Science

<table>
<thead>
<tr>
<th>Type of Equipment</th>
<th>Capabilities</th>
</tr>
</thead>
<tbody>
<tr>
<td>Weather Satellites</td>
<td>• These monitor atmospheric temperature and humidity, ground and surface</td>
</tr>
<tr>
<td></td>
<td>seawater temperature, cloud cover, and water-ice boundaries.</td>
</tr>
<tr>
<td></td>
<td>• They can help locate sources of distress signals.</td>
</tr>
<tr>
<td></td>
<td>• They are able to scan Earth’s surface in one 24-hour period.</td>
</tr>
<tr>
<td>Navigation Satellites</td>
<td>• These assist ships and submarines to determine their exact location at any time.</td>
</tr>
<tr>
<td>Landsat Satellites</td>
<td>• The first Landsat satellite was launched in 1972. Landsat 7 was launched in 1999.</td>
</tr>
<tr>
<td></td>
<td>• They provide data on Earth’s landmasses, coastal boundaries, and coral reefs.</td>
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<tr>
<td></td>
<td>• Pictures taken are transmitted to ground stations around the world.</td>
</tr>
<tr>
<td></td>
<td>• They orbit Earth every 99 minutes and complete 14 orbits per day.</td>
</tr>
<tr>
<td></td>
<td>• Total coverage of Earth is achieved in 16 days.</td>
</tr>
<tr>
<td>Global Positioning System (GPS)</td>
<td>• This system combines satellite information with computer technology to provide location information in three dimensions: latitude, longitude, and altitude.</td>
</tr>
<tr>
<td></td>
<td>• Three satellite signals are detected by a receiver. The distance from the satellites to the receiver is calculated, and the location is determined using the triangulation method. A fourth signal is then used to mathematically determine exact position.</td>
</tr>
<tr>
<td>Very Long Baseline Interferometry (VLBI)</td>
<td>• VLBI utilizes a large network of antennas around the world to receive radio waves from space objects such as quasars.</td>
</tr>
<tr>
<td></td>
<td>• In Earth science, VLBI is used in geodesy, or the measurement of the geosphere.</td>
</tr>
<tr>
<td></td>
<td>• Using the arrival times of radio waves from quasars, the position of radio telescopes on Earth are determined to within millimeters of their position.</td>
</tr>
<tr>
<td></td>
<td>• Small changes in the telescope positions allow scientists to study tectonic plate motions and other movements of Earth’s crust with great precision and accuracy.</td>
</tr>
</tbody>
</table>

### Reviewing Concepts

1. Describe the two sets of lines that are used on globes and some maps.
2. What happens to the images on the globe when they are transferred to a flat surface?
3. What is the purpose of contour lines on topographic maps?
4. What two lines mark zero degrees on the globe? In which directions do these lines run?
5. Why is the Mercator projection map still in use today?
6. What types of advanced technology are used in mapmaking today?
7. **Applying Concepts** Why are there so many different types of maps?

### Critical Thinking

8. **Drawing Conclusions** How can data from VLBI be used in mapmaking today?
9. **Conceptualizing** An area on a topographic map has the following contour line configuration: First, the lines are fairly widely spaced. Then they are closely spaced. Finally, they are circular. Describe the topography represented by these lines.

### Math Practice

Use the bar scale on Figure 15 to answer the following question.

10. Determine the distance along the shoreline of Turquoise Lake from the gaging station on the west shore to the gaging station on the south shore. Record your answer in kilometers.

### Solution

10. The distance in centimeters on the map is approximately 5.5 cm. The distance on the ground is approximately 3.43 km.

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### Build Science Skills

#### Posing Questions

Have students select one type of equipment described in Table 1 to research. Encourage students to make a list of questions about the equipment, such as when and where it was invented and by whom. Then have them research how the technology works and close with some applications of the technology they selected. Students can present their work as a written report, an oral report, or a poster to share with the class.

#### Evaluate Understanding

Give students a topographic map that includes latitude and longitude. Have them locate specific features on the map, such as hills and depressions, based on the shapes of the contour lines. Have students determine the latitude and longitude of these features. Give students the latitude and longitude of a few sites of interest on the map and have them tell you what they find at each of those locations.

#### Reteach

Have students answer the Assessment questions in small groups. Assign the lower ability students to answer the Reviewing Concepts questions and the higher ability students to answer the Critical Thinking questions. Have partners then share and discuss their answers. Once all groups are finished, have students report their answers to the class. Clarify concepts as needed.

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### Math Practice

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### Solution

10. The distance in centimeters on the map is approximately 5.5 cm. The distance on the ground is approximately 3.43 km.