Maps show many types of things. Maps can be on many different scales. Some are large-scale views of large areas. Some are small-scale views of minute features. Maps can have many different types of looks with lots of information or just a little.

The map above shows the population density of the United States, Canada and the northern part of Mexico. It’s easy to pick out cities based on population density. It’s also interesting to note the different settlement patterns in the eastern and western United States. In the west, much of the population is located in large towns. In the east, there are many large cities. There are also a lot of people spread out across the lands. Very few people live in Canada and most of those live in the southern portion of the country. The gray lines you see are not state boundaries but latitude and longitude lines.

Lesson Objectives

- Describe how you can find a location and direction on Earth’s surface.
- Describe topography.
- Identify various landforms and briefly describe how they form.

Vocabulary

- compass
- compass rose
- constructive forces
- continent
- destructive forces
- elevation
- relief
- topography

Introduction

Beautiful mountain ranges, deep canyons, flat plains. These can all be seen on Earth’s surface. Beneath the sea are other features that few people have seen directly. Understanding Earth’s surface is one of the important things Earth scientists can do. Knowing where they are on the planet is one of the first things they need to describe.

Location

To describe your location wherever you are on Earth’s surface, you could use a coordinate system. For example, you could say that you are at 1234 Main Street, Springfield, Ohio. Or you could use a point of reference. If you want to meet up with a friend, you could tell him the distance and direction you are from the reference point. An example is, “I am at the corner of Maple Street and Main Street, about two blocks north of your apartment.”

When studying Earth’s surface, scientists must be able to pinpoint a feature they are interested in. Scientists and others have a system to describe the location of any feature. Usually they use latitude and longitude as a coordinate system. Lines of latitude and longitude form a grid. The grid is centered on a reference point. You will learn about this type of grid when we discuss maps later in this chapter.
Direction

When an object is moving, it is not enough to describe its location. We also need to know direction. Direction is important for describing moving objects. For example, a wind blows a storm over your school. Where is that storm coming from? Where is it going?

The most common way to describe direction is by using a compass. A compass is a device with a floating needle (Figure 2.1). The needle is a small magnet that aligns itself with the Earth’s magnetic field. The compass needle always points to magnetic north. If you have a compass and you find north, you can then know any other direction. See the directions, such as east, south, west, etc., on a compass rose.

FIGURE 2.1
(A) A compass is a device that is used to determine direction. The needle points to Earth’s magnetic north pole. (B) A compass rose shows the four major directions plus intermediates between them.

A compass needle lines up with Earth’s magnetic north pole. This is different from Earth’s geographic north pole, or true north. The geographic north pole is the top of the imaginary axis around which Earth rotates. The geographic north pole is much like the spindle of a spinning top. The location of the geographic north pole does not change. However, the magnetic north pole shifts in location over time. Depending on where you live, you can correct for the difference between the two poles when you use a map and a compass (Figure below).

Some maps have a double compass rose. This allows users to make the corrections between magnetic north and true north. An example is a nautical chart that boaters use to chart their positions at sea (Figure 2.3).

Topography

As you know, the surface of Earth is not flat. Some places are high and some places are low. For example, mountain ranges like the Sierra Nevada in California or the Andes in South America are high above the surrounding areas. We can describe the topography of a region by measuring the height or depth of that feature relative to sea level (Figure 2.4). You might measure your height relative to your classmates. When your class lines up, some kids make high “mountains,” while others are more like small hills!

Relief, or terrain, includes all the landforms of a region. A topographic map shows the height, or elevation, of features in an area. This includes mountains, craters, valleys, and rivers. For example, Figure 2.5 shows the San Francisco Peaks in northern Arizona. Features on the map include mountains, hills and lava flows. You can recognize these features from the differences in elevation. We will talk about some different landforms in the next section.
FIGURE 2.2
Earth’s magnetic north pole is about 11 degrees offset from its geographic north pole.

FIGURE 2.3
Nautical maps include a double compass rose that shows both magnetic directions (inner circle) and geographic compass directions (outer circle).
Continents and Landforms

If you take away the water in the oceans (Figure 2.6), Earth looks really different. You see that the surface has two main features: continents and ocean basins. **Continents** are large land areas. **Ocean basins** extend from the edges of continents to the ocean floor and into deep trenches.
Continents are much older than ocean basins. Some rocks on the continents are billions of years old. Ocean basins are only millions of years old at their oldest. Because the continents are so old, a lot has happened to them!

As we view the land around us we see landforms. **Landforms** are physical features on Earth’s surface. Landforms are introduced in this section but will be discussed more in later chapters. **Constructive forces** cause landforms to grow. Lava flowing into the ocean can build land outward. A volcano can be a constructive force. **Destructive forces** may blow landforms apart. A volcano blowing its top off is a destructive force. The destructive forces of weathering and erosion change landforms more slowly. Over millions of years, mountains are worn down by rivers and streams.

Constructive and destructive forces work together to create landforms. Constructive forces create mountains and erosion may wear them away. Mountains are very large landforms. Mountains may wear away into a high flat area called a plateau, or a lower-lying plain. Interior plains are in the middle of continents. Coastal plains are on the edge of a continent, where it meets the ocean.

Rivers and streams flow across continents. They cut away at rock, forming river valleys (Figure 2.8). These are destructive forces. The bits and pieces of rock carried by rivers are deposited where rivers meet the oceans. These
can form deltas, like the Mississippi River delta. They can also form barrier islands, like Padre Island in Texas. Rivers bring sand to the shore, which forms our beaches. These are constructive forces.

Ocean Basins

The ocean basin begins where the ocean meets the land. The continental margin begins at the shore and goes down to the ocean floor. It includes the continental shelf, slope, and rise. The continental shelf is part of the continent, but it is underwater today. It is about 100-200 meters deep, much shallower than the rest of the ocean. The continental shelf usually goes out about 100 to 200 kilometers from the shore (Figure 2.9).

The continental slope is the slope that forms the edge of the continent. It is seaward of the continental shelf. In some places, a large pile of sediments brought from rivers creates the continental rise. The continental rise ends at the ocean floor. Much of the ocean floor is called the abyssal plain.
The ocean floor is not totally flat. In many places, small hills rise above the ocean floor. These hills are undersea volcanoes, called seamounts (Figure 2.10). Some rise more than 1000 m above the seafloor.

Besides seamounts, there are long, very tall (about 2 km) mountain ranges. These ranges are connected so that they form huge ridge systems called mid-ocean ridges (Figure 2.11). The mid-ocean ridges form from volcanic eruptions. Lava from inside Earth breaks through the crust and creates the mountains.

The deepest places of the ocean are the ocean trenches. Many trenches line the edges of the Pacific Ocean. The Mariana Trench is the deepest place in the ocean. (Figure 2.12). At about 11 km deep, it is the deepest place on Earth! To compare, the tallest place on Earth, Mount Everest, is less than 9 km tall.

Lesson Summary

- Earth scientists must be able to describe the exact locations of features on Earth’s surface.
- Locations often include distances and directions.
- A compass has a tiny magnetic needle that points toward Earth’s magnetic North Pole. Once you have found north, you can find east, west, and south, using your compass for reference.
2.1. Introduction to Earth’s Surface

- Topography describes how Earth’s surface varies in elevation.
- Constructive forces create landforms. Destructive forces wear landforms down.

Lesson Review Questions

Recall

1. What information might you need to describe the location of a feature on the Earth’s surface?
2. On the continents, which landforms rise the highest?
3. What is topography?

Apply Concepts

4. Why would you need to know direction if an object is moving?
5. Why do nautical charts have two compass roses on them?

Think Critically

6. Why do you think that the ocean basins are younger than the continents?
7. Explain what landforms on the continents are created by erosion from wind and water. How does erosion create a landform?

Points to Consider

- A new volcano rises in Mexico. How you would describe its position in a scientific report?
- Can you devise a system to show low areas and high areas on a map?
- Why do you think continents are higher areas on Earth than the ocean basins?
Lesson Objectives

- Describe what information a map can convey.
- Identify some major types of map projections. Discuss the advantages and disadvantages of each.
- Discuss the advantages and disadvantages of globes.

Vocabulary

- conic map
- coordinate system
- gnomonic map
- latitude
- longitude
- map
- Mercator projection
- projection

Introduction

Maps can convey a lot of different types of information. They can tell you where you are or they can tell you something about a location. Earth scientists often use maps that have coordinates so that they can locate themselves or the features they are interested in. Different types of maps show different things well. For example, some types of maps show the tropical areas really well but do a terrible job depicting the polar regions.

Maps as Models

Imagine you are going on a road trip. Perhaps you are going on vacation. How do you know where to go? Most likely, you will use a map. A map is a picture of specific parts of Earth’s surface. There are many types of maps. Each map gives us different information. Let’s look at a road map, which is the probably the most common map that you use (Figure 2.13).

Map Legends

Look for the legend on the top left side of the map. It explains how this map records different features. You can see the following:
2.2. Modeling Earth’s Surface

FIGURE 2.13
A road map of the state of Florida. What information can you get from this map?

- The boundaries of the state show its shape.
- Black dots represent the cities. Each city is named. The size of the dot represents the population of the city.
- Red and brown lines show major roads that connect the cities.
- Blue lines show rivers. Their names are written in blue.
- Blue areas show lakes and other waterways — the Gulf of Mexico, Biscayne Bay, and Lake Okeechobee. Names for bodies of water are also written in blue.
- A line or scale of miles shows the distance represented on the map — an inch or centimeter on the map represents a certain amount of distance (miles or kilometers).
- The legend explains other features and symbols on the map.
- It is the convention for north to be at the top of a map. For this reason, a compass rose is not needed on most maps.

You can use this map to find your way around Florida and get from one place to another along roadways.

Types of Maps

There are many other types of maps besides road maps. Some examples include:

- Political or geographic maps show the outlines and borders of states and/or countries.
- Satellite view maps show terrains and vegetation — forests, deserts, and mountains.
- Relief maps show elevations of areas, but usually on a larger scale, such as the whole Earth, rather than a local area.
- Topographic maps show detailed elevations of features on the map.
- Climate maps show average temperatures and rainfall.
- Precipitation maps show the amount of rainfall in different areas.
- Weather maps show storms, air masses, and fronts.
- Radar maps show storms and rainfall.
- Geologic maps detail the types and locations of rocks found in an area.

These are but a few types of maps that various Earth scientists might use. You can easily carry a map around in your pocket or bag. Maps are easy to use because they are flat or two-dimensional. However, the world is three-dimensional. So, how do map makers represent a three-dimensional world on flat paper?
Map Projections

Earth is a round, three-dimensional ball. In a small area, Earth looks flat, so it is not hard to make accurate maps of a small place. When map makers want to map the round Earth on flat paper, they use projections. What happens if you try to flatten out the skin of a peeled orange? Or if you try to gift wrap a soccer ball? To flatten out, the orange peel must rip and its shape must become distorted. To wrap a round object with flat paper requires lots of extra cuts and folds. A projection is a way to represent Earth’s curved surface on flat paper (Figure 2.14).

![Figure 2.14](A map projection translates Earth's curved surface onto two dimensions.)

There are many types of projections. Each uses a different way to change three dimensions into two dimensions. There are two basic methods that the map maker uses in projections:

- The map maker “slices” the sphere in some way and unfolds it to make a flat map, like flattening out an orange peel.
- The map maker can look at the sphere from a certain point and then translate this view onto a flat paper.

Let’s look at a few commonly used projections.

**Mercator Projection**

In 1569, Gerardus Mercator (1512-1594) (Figure 2.15) figured out a way to make a flat map of our round world, called the Mercator projection (Figure 2.16).

Imagine wrapping the round, ball-shaped Earth with a big, flat piece of paper. First you make a tube or a cylinder. The cylinder will touch Earth at its fattest part, the equator. The equator is the imaginary line running horizontally around the middle of Earth. The poles are the farthest points from the cylinder. If you shine a light from the inside of your model Earth out to the cylinder, the image projected onto the paper is a Mercator projection. Where does the projection represent Earth best? Where is it worst? Your map would be most correct at the equator. The shapes and sizes of continents become more stretched out near the poles. Early sailors and navigators found the Mercator map useful because most explorations were located near the equator. Many world maps still use the Mercator projection.

The Mercator projection is best within 15 degrees north or south of the equator. Landmasses or countries outside that zone get stretched out of shape. The further the feature is from the equator, the more out of shape it is stretched. For example, if you look at Greenland on a globe, you see it is a relatively small country near the North Pole. Yet, on a Mercator projection, Greenland looks almost as big the United States. Because Greenland is closer to the pole, the continent’s shape and size are greatly increased. The United States is closer to its true dimensions.
2.2. Modeling Earth’s Surface

Gerardus Mercator developed a map projection used often today, known as the Mercator projection.

A Mercator projection translates the curved surface of Earth onto a cylinder.

In a Mercator projection, all compass directions are straight lines. This makes it a good type of map for navigation. The top of the map is north, the bottom is south, the left side is west and the right side is east. However, because it is a flat map of a curved surface, a straight line on the map is not the shortest distance between the two points it connects.

**Conic Projection**

Instead of a cylinder, you could wrap the flat paper into a cone. **Conic map** projections use a cone shape to better represent regions near the poles (Figure 2.17). Conic projections are best where the cone shape touches the globe. This is along a line of latitude, usually the equator.

**Gnomonic Projection**

What if want to wrap a different approach? Let’s say you don’t want to wrap a flat piece of paper around a round object? You could put a flat piece of paper right on the area that you want to map. This type of map is called a **gnomonic map** projection (Figure 2.18). The paper only touches Earth at one point. The sizes and shapes of countries near that point are good. The poles are often mapped this way to avoid distortion. A gnomonic projection is best for use over a small area.
Two standard parallels define the map layout. (selected by mapmaker)

Areas equal to globe. Deformation of shapes increases away from those parallels.

FIGURE 2.17
A conic map projection wraps Earth with a cone shape rather than a cylinder.

FIGURE 2.18
A gnomonic projection places a flat piece of paper on a point somewhere on Earth and projects an image from that point.

Robinson Projection

In 1963, Arthur Robinson made a map with more accurate sizes and shapes of land areas. He did this using mathematical formulas. The formulas could directly translate coordinates onto the map. This type of projection is shaped like an oval rather than a rectangle (Figure 2.19).

FIGURE 2.19
A Robinson projection better represents the true shapes and sizes of land areas.

Robinson’s map is more accurate than a Mercator projection. The shapes and sizes of continents are closer to true. Robinson’s map is best within 45 degrees of the equator. Distances along the equator and the lines parallel to it are true. However, the scales along each line of latitude are different. In 1988, the National Geographic Society began to use Robinson’s projection for its world maps.

Whatever map projection is used, maps help us find places and to be able to get from one place to another. So how do you find your location on a map?
Map Coordinates

Most maps use a grid of lines to help you to find your location. This grid system is called a geographic coordinate system. Using this system you can define your location by two numbers, latitude and longitude. Both numbers are angles between your location, the center of Earth, and a reference line (Figure 2.20).

**FIGURE 2.20**
Lines of latitude start with the equator. Lines of longitude begin at the prime meridian.

**Latitude**

Lines of **latitude** circle around Earth. The equator is a line of latitude right in the middle of the planet. The equator is an equal distance from both the North and South Pole. If you know your latitude, you know how far you are north or south of the equator.

**Longitude**

Lines of **longitude** are circles that go around Earth from pole to pole, like the sections of an orange. Lines of longitude start at the Prime Meridian. The Prime Meridian is a circle that runs north to south and passes through Greenwich, England. Longitude tells you how far you are east or west from the Prime Meridian (Figure 2.21).

You can remember latitude and longitude by doing jumping jacks. When your hands are above your head and your feet are together, say longitude (your body is long!). When you put your arms out to the side horizontally, say latitude (your head and arms make a cross, like the “t” in latitude). While you are jumping, your arms are going the same way as each of these grid lines: horizontal for latitude and vertical for longitude.
Using Latitude and Longitude on a Map

If you know the latitude and longitude of a place, you can find it on a map. Simply place one finger on the latitude on the vertical axis of the map. Place your other finger on the longitude along the horizontal axis of the map. Move your fingers along the latitude and longitude lines until they meet. For example, say the location you want to find is at 30°N and 90°W. Place your right finger along 30°N at the right of the map. Place your left finger along the bottom at 90°W. Move your fingers along the lines until they meet. Your location should be near New Orleans, Louisiana, along the Gulf coast of the United States.

What if you want to know the latitude and longitude of your location? If you know where you are on a map, point to the place with your fingers. Take one finger and move it along the latitude line to find your latitude. Then move another finger along the longitude line to find your and longitude.

Polar Coordinate System

You can also use a polar coordinate system. Your location is marked by an angle and distance from some reference point. The angle is usually the angle between your location, the reference point, and a line pointing north. The distance is given in meters or kilometers. To find your location or to move from place to place, you need a map, a compass, and some way to measure your distance, such as a range finder.

Suppose you need to go from your location to a marker that is 20°E and 500 m from your current position. You must do the following:

• Use the compass and compass rose on the map to orient your map with north.
2.2. Modeling Earth’s Surface

- Use the compass to find which direction is 20°E.
- Walk 500 meters in that direction to reach your destination.
- Polar coordinates are used in a sport called orienteering. People who do orienteering use a compass and a map with polar coordinates. Participants find their way along a course across wilderness terrain (Figure 2.22). They move to various checkpoints along the course. The winner is the person who completes the course in the fastest time.

![Figure 2.22](image.png)

**Globe**

Earth is a sphere and so is a globe. A globe is the best way to make a map of the whole Earth. Because both the planet and a globe have curved surfaces, the sizes and shapes of countries are not distorted. Distances are true to scale. (Figure 2.23).

Globes usually have a geographic coordinate system and a scale. The shortest distance between two points on a globe is the length of the portion of a circle that connects them. Globes are difficult to make and carry around. They also cannot be enlarged to show the details of any particular area. Globes are best sitting on your desk for reference.

Google Earth is a neat site to download to your computer. This is a link that you can follow to get there: earth.google.com/download-earth.html. The maps on this site allow you to zoom in or out, look from above, tilt your image and lots more.
Lesson Summary

- Maps and globes are models of Earth’s surface. There are many ways to project the three-dimensional surface of Earth onto a flat map. Each type of map has some advantages as well as disadvantages.
- Most maps use a geographic coordinate system to help you find your location using latitude and longitude.
- Globes are the most accurate representations, because they are round like Earth, but they cannot be carried around easily. Globes also cannot show the details of Earth’s surface that maps can.

Lesson Review Questions

Recall

1. Describe each of the following. What is each one good for? What is each one not good for?

   - Mercator projection map
   - Robinson projection map
   - Globe

2. What does it mean to say that your location is 52 degrees south and 143 degrees west?

3. Why were early explorers happy with Mercator projections?

Apply Concepts

4. Use Figure 2.24. In what country are you located, if your coordinates are 60°N and 120°W?

5. Which of the following map projections gives you the least distortion around the poles?
Think Critically

6. Imagine that you are going out into the field to do geology. What type of earth model (map projection, globe) would be best to take with you?

7. Would you choose a map that used a Mercator projection if you were going to explore Antarctica? Explain why. Is there another type of map that would be better?

Points to Consider

• How does a flight between two cities drawn on a globe compare with the same flight drawn on a map?
• How do people doing orienteering follow directions across wild terrain?
• Latitude and longitude give your location in two dimensions. How do you give your location in three dimensions? What is that third dimension?
Lesson Objectives

- Describe a topographic map.
- Explain what information a topographic map contains.
- Explain how to read and interpret a topographic map.
- Explain how various earth scientists use topographic maps to study Earth.

Vocabulary

- contour interval
- contour lines
- topographic map

Introduction

Anyone who knows how to read a topographic map can “see” the landscape of a region without being there. A mountaineer could plan the best route for a mountain climbing trip. An engineer could plan the best location for a road or power plant. A tourist can get an idea of what they are going to see on their vacation. Topographic maps are interesting and fun to use.

What is a Topographic Map?

Mapping is an important part of Earth Science. Topographic maps use a line, called a contour line, to show different elevations on a map. Contour lines show the location of hills, mountains and valleys. A regular road map shows where a road goes. But a road map doesn’t show if the road goes over a mountain pass or through a valley. A topographic map shows you the features the road is going through or past. Let’s look at topographic maps.

Look at this view of the Swamp Canyon Trail in Bryce Canyon National Park, Utah (Figure 2.25). You can see the rugged canyon walls and valley below. The terrain has many steep cliffs with high and low points between the cliffs.

Now look at the same section of the visitor’s map (Figure 2.26). You can see a green line that is the main road. The black dotted lines are trails. You see some markers for campsites, a picnic area, and a shuttle bus stop. The map does not show the height of the terrain. Where are the hills and valleys located? What is Natural Bridge? How high are the canyon walls? Which way do streams flow?

A topographic map represents the elevations in an area (Figure 2.27). We mentioned topographic maps in the section on orienteering above.
2.3. Topographic Maps

Contour Lines

Contour lines connect all the points on the map that have the same elevation. Let’s take a closer look at this (Figure 2.27).
Each contour line represents a specific elevation. The contour line connects all the points that are at the same elevation. Every fifth contour line is made bold. The bold contour lines have numbers to show elevation. Contour lines run next to each other and NEVER cross one another. If the lines crossed it would mean that one place had two different elevations. This cannot happen.

Contour Intervals

Since each contour line represents a specific elevation, two different contour are separated by the same difference in elevation (e.g. 20 ft or 100 ft.). This difference between contour lines is called the **contour interval**. You can calculate the contour interval by following these steps:

a. Take the difference in elevation between 2 bold lines.

b. Divide that difference by the number of contour lines between them.

Imagine that the difference between two bold lines is 100 feet and there are five lines between them. What is the contour interval? If you answered 20 feet, then you are correct (100 ft/5 lines = 20 ft between lines).

The legend on the map also gives the contour interval.

Interpreting Contour Maps

How does a topographic map tell you about the terrain? Let’s consider the following principles:

1. **The spacing of contour lines shows the slope of the land.** Contour lines that are close together indicate a steep slope. This is because the elevation changes quickly in a small area. Contour lines that seem to touch indicate a very steep slope, like a cliff. When contour lines are spaced far apart the slope is gentle. So contour lines help us see the three-dimensional shape of the land.

   Look at the topographic map of Stowe, Vermont (Figure 2.28). There is a steep hill rising just to the right of the city of Stowe. You can tell this because the contour lines there are closely spaced. The contour lines also show that the hill has a sharp rise of about 200 feet. Then the slope becomes less steep toward the right.

2. **Concentric circles indicate a hill.** Figure 2.29 shows another side of the topographic map of Stowe, Vermont.
2.3. Topographic Maps

When contour lines form closed loops, there is a hill. The smallest loops are the higher elevations on the hill. The larger loops encircling the smaller loops are downhill. If you look at the map, you can see Cady Hill in the lower left and another, smaller hill in the upper right.

3. **Hatched concentric circles indicate a depression**. The hatch marks are short, perpendicular lines inside the circle. The innermost hatched circle represents the deepest part of the depression. The outer hatched circles represent higher elevations (Figure 2.30).

4. **V-shaped portions of contour lines indicate stream valleys**. The “V” shape of the contour lines point uphill. There is a V shape because the stream channel passes through the point of the V. The open end of the V represents the downstream portion. A blue line indicates that there is water running through the valley. If there is not a blue line the V pattern indicates which way water flows. In Figure 2.31, you can see examples of V-shaped markings. Try to find the direction a stream flows.

5. **Like other maps, topographic maps have a scale so that you can find the horizontal distance**. You can use the horizontal scale to calculate the slope of the land (vertical height/horizontal distance). Common scales used in United States Geological Service (USGS) maps include the following:

- 1:24,000 scale – 1 inch = 2000 ft
- 1:100,000 scale – 1 inch = 1.6 miles
- 1:250,000 scale – 1 inch = 4 miles

Including contour lines, contour intervals, circles, and V-shapes allows a topographic map to show three-dimensional information on a flat piece of paper. A topographic map gives us a good idea of the shape of the land.
Information from Topographic Maps

As we mentioned above, topographic maps show the shape of the land. You can determine a lot of information about the landscape using a topographic map. These maps are invaluable for Earth scientists.
How Do Earth Scientists Use Topographic Maps?

Earth scientists use topographic maps for many things:

- Describing and locating surface features, especially geologic features.
- Determining the slope of the Earth’s surface.
- Determining the direction of flow for surface water, ground water, and mudslides.

Hikers, campers, and even soldiers use topographic maps to locate their positions in the field. Civil engineers use topographic maps to determine where roads, tunnels, and bridges should go. Land use planners and architects use topographic maps when planning development projects, such as housing projects, shopping malls, and roads.

Bathymetric Maps

Oceanographers use a type of topographic map that shows water depths (Figure 2.33). On this map, the contour lines represent depth below the surface. Therefore, high numbers are deeper depths and low numbers are shallow depths. These maps are made from depth soundings or sonar data. They help oceanographers understand the shape of bottoms of lakes, bays, and the ocean. This information also helps boaters navigate safely.

![Bathymetric map of Bear Lake, Utah.](image)

Geologic Maps

A geologic map shows the different rocks that are exposed at the surface of a region. Rock units are shown in a color identified in a key. On the geologic map of the Grand Canyon, for example, different rock types are shown in different colors. Some people call the Grand Canyon “layer cake geology” because most of the rock units are in layers. Rock units show up on both sides of a stream valley.

A geologic map looks very complicated in a region where rock layers have been folded, like the patterns in marble cake. Faults are seen on this geologic map cutting across rock layers. When rock layers are tilted, you will see stripes of each layer on the map. There are symbols on a geologic map that tell you which direction the rock layers slant, and often there is a cut away diagram, called a cross section, that shows what the rock layers look like below the surface. A large-scale geologic map will just show geologic provinces. They do not show the detail of individual rock layers.
Lesson Summary

- Topographic maps are flat maps that show the three-dimensional surface features of an area. Topographic maps help users see how the land changes in elevation.
- Contour lines on a topographic map connect points of equal elevation above sea level.
- Contour lines run next to each other. Each contour line is separated by a constant difference in elevation, usually noted on the map.
- Topographic maps have a horizontal scale to indicate horizontal distances.
- People use topographic maps to locate interesting landforms, to find their way through an area, and to determine the direction water flows in an area.
- Oceanographers use bathymetric maps to show the features of the bottom of a body of water.
- Geologic maps display rock units and geologic features. A small scale map displays individual rock units while a large scale map shows geologic provinces.

Lesson Review Questions

Recall

1. Describe what the following features would look like on a topographic map.
   - a stream channel
   - a hilltop
   - a valley
   - a cliff

2. How do you find a stream valley on a topographic map? How can you tell if the stream has water in it all year round? How can you determine which way the water is flowing?

3. If you were the captain of a very large boat, what type of map would you want to have to keep your boat traveling safely?

Apply Concepts

4. Draw a topographic map of a steep slow that slowly enters a valley. Draw a topographic map of a steep cliff that is almost perpendicular to a valley.

5. On a topographic map, six contour lines span a horizontal distance of 0.5 inches. The horizontal scale is 1 inch equals 2000 ft. How far apart are the first and sixth lines?
6. On a topographic map, five contour lines are very close together in one area. What is the shape of these lines if the feature is a hill? What is the shape of these lines if the feature is a cliff?

7. On a topographic map, a river is shown crossing from Point A in the northwest to Point B in the southeast. Point A is on a contour line of 1800 ft and Point B is on a contour line of 2400 ft. In which direction does the river flow?

8. On the geologic map of the Grand Canyon, a rock unit called the Kaibab Limestone takes up the entire surface of the region. Down some steep topographic lines is a very thin rock unit called the Toroweap Formation and just in from that is another thin unit, the Coconino sandstone. Describe how these three rock units sit relative to each other.

Points to Consider

- Imagine that you are a civil engineer. How could you use a topographic map to build a road, bridge, or tunnel through an area like the one shown in Figure 2.29? Would you want your road to go up and down or remain as flat as possible? What areas would need a bridge in order to cross them easily? Can you find a place where a tunnel would be helpful?
- If you wanted to participate in orienteering, would it be better to have a topographic map or a regular road map? How would a topographic map help you?
Lesson Objectives

- Describe various types of satellite images and the information that each provides.
- Explain how a Global Positioning System (GPS) works.
- Explain how computers can be used to make maps.

Vocabulary

- Geographic Information System (GIS)
- geostationary orbit
- polar orbit

Introduction

If you look at the surface of the Earth from your yard or street, you can only see a short distance. If you climb a tree or go to the top floor of your apartment building, you can see further. If you flew over your neighborhood in a plane, you could see still further. Finally, if you orbited the Earth, you would be able to see a very large portion of the planet. This is why scientists use satellites to get a good view of Earth. To see things on a large scale, you need to get the highest view.

What Satellites Can Do

To understand what satellites can do, let’s look at an example. One of the deadliest hurricanes in United States history hit Galveston, Texas in 1900. The storm was first spotted at sea on Monday, August 27th, 1900. It was a tropical storm when it hit Cuba on September 3rd. By September 8th, it had intensified to a hurricane over the Gulf of Mexico. It came ashore at Galveston (Figure 2.34). Because there was not advanced warning, more than 8000 people lost their lives.

Today, we have satellites with many different types of instruments that orbit the Earth. With these satellites, satellites can see hurricanes form at sea. They can follow hurricanes as they move from far out in the oceans to shore. Weather forecasters can warn people who live along the coasts. These advanced warning give people time to prepare for the storm. They can find a safe place or even evacuate the area, which helps save lives.
2.4. Using Satellites and Computers

Satellite Orbits

Satellites orbit high above the Earth in several ways. Different orbits are important for viewing different things about the planet.

Geostationary Orbit

A satellite in a geostationary orbit flies above the planet at a distance of 36,000 km. It takes 24 hours to complete one orbit. The satellite and the Earth both complete one rotation in 24 hours. This means that the satellite stays over the same spot. Weather satellites use this type of orbit to observe changing weather conditions over a region. Communications satellites, like satellite TV, use this type of orbit to keep communications going full time.

Polar Orbit

Another useful orbit is the polar orbit (Figure 2.35). The satellite orbits at a distance of several hundred kilometers. It makes one complete orbit around the Earth from the North Pole to the South Pole about every 90 minutes. In this same amount of time, the Earth rotates only slightly underneath the satellite. So in less than a day, the satellite can see the entire surface of the Earth. Some weather satellites use a polar orbit to see how the weather is changing globally. Also, some satellites that observe the land and oceans use a polar orbit.

Scientific Satellites

The National Aeronautics and Space Administration (NASA) has launched a fleet of satellites to study the Earth (Figure 2.36). The satellites are operated by several government agencies, including NASA, the National Oceano-
graphic and Atmospheric Administration (NOAA), and the United States Geological Survey (USGS). By using different types of scientific instruments, satellites make many kinds of measurements of the Earth.

- Some satellites measure the temperatures of the land and oceans.
- Some record amounts of gases in the atmosphere, such as water vapor and carbon dioxide.
- Some measure their height above the oceans very precisely. From this information, they can measure sea level.
- Some measure the ability of the surface to reflect various colors of light. This information tells us about plant life.

Some examples of the images from these types of satellites are shown in Figure 2.37.
2.4. Using Satellites and Computers

Global Positioning System

In order to locate your position on a map, you must know your latitude and your longitude. But you need several instruments to measure latitude and longitude. What if you could do the same thing with only one instrument? Satellites can also help you locate your position on the Earth’s surface.

By 1993, the United States military had launched 24 satellites to help soldiers locate their positions on battlefields. This system of satellites was called the Global Positioning System (GPS). Later, the United States government allowed the public to use this system. Here’s how it works.

You must have a GPS receiver to use the system (Figure 2.38). You can buy many types of these in stores. The
GPS receiver detects radio signals from nearby GPS satellites. There are precise clocks on each satellite and in the receiver. The receiver measures the time for radio signals from satellite to reach it. The receiver uses the time and the speed of radio signals to calculate the distance between the receiver and the satellite. The receiver does this with at least four different satellites to locate its position on the Earth’s surface (Figure 2.38). GPS receivers are now being built into many items, such as cell phones and cars.

Computer-Generated Maps

Prior to the late 20th and early 21st centuries, mapmakers sent people out in the field to determine the boundaries and locations for various features for maps. State or county borders were used to mark geological features. Today, people in the field use GPS receivers to mark the locations of features. Map-makers also use various satellite images and computers to draw maps. Computers are able to break apart the fine details of a satellite image, store the pieces of information, and put them back together to make a map. In some instances, computers can make 3-D images of the map and even animate them. For example, scientists used computers and satellite images from Mars to create a 3-D image of Mars’ ice cap (Figure 2.39). The image makes you feel as if you are looking at the ice cap from the surface of Mars.

When you link any type of information to a location, you can put together incredibly useful maps and images. The information could be numbers of people living in an area, types of plants or soil, locations of groundwater or levels of rainfall. As long as you can link the information to a position with a GPS receiver, you can store it in a computer for later processing and map-making. This type of mapping is called a Geographic Information System (GIS). Geologists can use GIS to make maps of natural resources. City leaders might link these resources to where people live and help plan the growth of cities or communities. Other types of data can be linked by GIS. For example, Figure 2.40 shows a map of the counties where farmers made insurance claims for crop damage in 2008.

Computers have improved how maps are made. They have also increased the amount of information that can be displayed. During the 21st century, computers will be used more and more in mapping.
Lesson Summary

- Satellites give a larger view of the Earth’s surface from high above. They carry instruments that make many types of measurements for earth scientists.
- Satellites can enter different types of Earth orbits to gather different types of information.
- A group of specialized satellites called Global Positioning Satellites help people to pinpoint their location.
- Location information, satellite views, and other information can be linked together in Geographical Information Systems (GIS).

Lesson Review Questions

Recall

1. What is the use of each of these types of satellites?

   - weather satellite
   - communications satellite
   - global positioning satellite
   - climate satellite

2. What is Geographical Information System, or GIS, used for?

Apply Concepts

3. Explain the difference between geostationary orbits and polar orbits.

4. What if you had a GPS that could track only one satellite? Two satellites? How many satellites do you need for a good estimate of your location? Why that number?
Thinking Critically

5. What would have happened if there had been satellites during the time of the 1900 Galveston earthquake?

6. What would have happened if there had been no satellites when hurricane Katrina struck the Gulf of Mexico coast in 2005?

Points to Consider

- How is tracking a hurricane different from trying to predict where a tornado will strike?
- People have GPS units in their cars. What skills are they no longer using if they use a GPS?
- What do images of objects in space do for our view of humans and of the universe?
2.5 References

1. (A) Alan Klim; (B) Margaret W. Carruthers. (A) http://www.flickr.com/photos/61203681@N08/8231264538/
   ; (B) http://www.flickr.com/photos/64167416@N03/7022634029/. CC BY 2.0
2. Laura Guerin. CK-12 Foundation. CC BY-NC 3.0
5. Courtesy of NASA. San Francisco Mountain and surrounding areas. Public Domain
7. Laura Guerin. CK-12 Foundation. CC BY-NC 3.0
8. Laura Guerin. CK-12 Foundation. CC BY-NC 3.0
10. Courtesy of the National Oceanic and Atmospheric Administration. (left) http://oceanexplorer.noaa.gov/explorations/03mountains/background/plan/media/sites.html; (right) http://oceanexplorer.noaa.gov/explorations/deepeast01/logs/sep13/media/bear_seamount.html. Public Domain
12. User:Kmusser/Wikimedia Commons. Mariana Trench in the Pacific Ocean. CC BY 2.5
25. Flickr:baka_san. http://www.flickr.com/photos/33765079@N08/4953089890/. CC BY 2.0
30. Craig Freudenrich.  CK-12 Foundation.  CC BY-NC 3.0
37.Courtesy of (a) National Oceanic and Atmospheric Administration and (b-c) NASA. (a) Vapor image taken on July 16, 2013 17:15 UTC from http://www.weather.gov/satellite#wv; (b) http://stargazers.gsfc.nasa.gov/students/how_astronomers.htm; (c) http://visibleearth.nasa.gov/view_rec.php?id=274. Public Domain
38. (a) Courtesy of the US Geological Survey; (b) Courtesy of the National Oceanic and Atmospheric Administration. GPS receiver and four satellites. Public Domain