HS Studying Earth's Surface

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Printed: December 25, 2012

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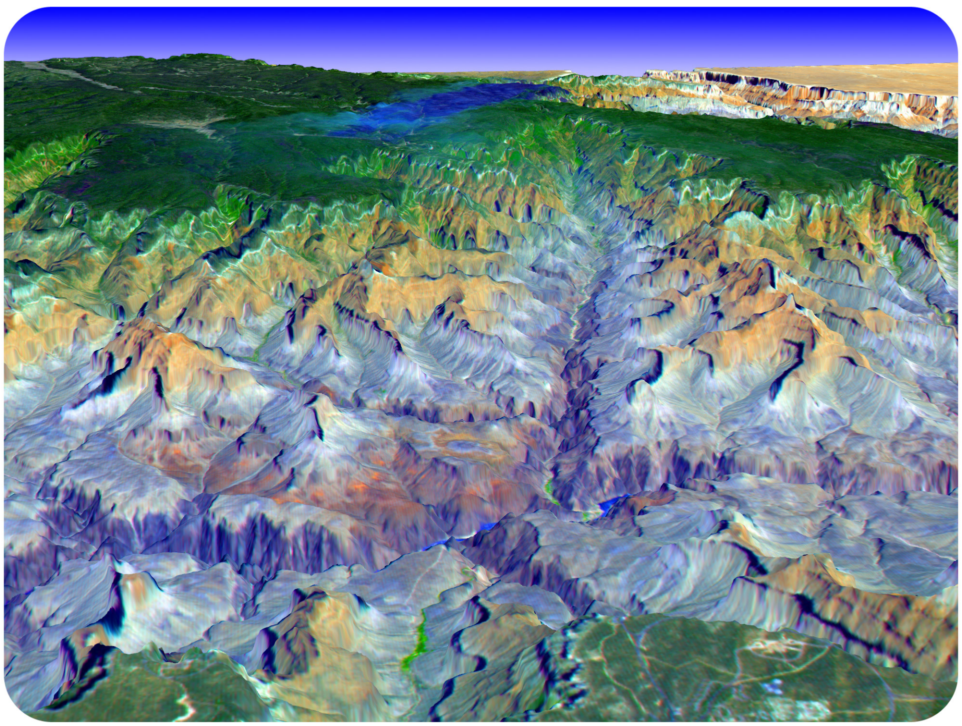
CHAPTER 1 HS Studying Earth's Surface

CHAPTER OUTLINE



If you've seen the Grand Canyon or a photo of the Grand Canyon, you'll know that this is not the Grand Canyon. Or is it? The rock colors seen above are not what a person standing at the rim on the canyon would see. From the rim, the Grand Canyon is mostly red with the prominent white stripe of the Coconino Sandstone near the top. The cliffs are more angular than the cliffs pictured here. NASA produced this image using data from the Advanced Spaceborne Thermal Emissions and Reflection Radiometer (ASTER), one of five remote sensing devices aboard the Terra spacecraft. ASTER measures 14 different wavelengths of the electromagnetic spectrum, ranging from visible to infrared light, to give information on land surface temperature, reflectance, and elevation. The resolution is between 15 and 90 meters.

So, is this the Grand Canyon? Any image or map of the Earth's surface is just a representation. All maps show the data the map maker intended at the best level of accuracy possible. Each representation is valuable in its own way but has limitations. The only real Grand Canyon is the one you are looking at from the rim of the canyon. Or is that image altered by the tint of your sunglasses?

1.1 Earth's Surface

Lesson Objectives

- Briefly identify different features of continents and ocean basins.
- Define constructive forces and give a few examples.
- Define destructive forces and give a few examples.

Vocabulary

- constructive forces
- continent
- continental margin
- destructive forces
- landform
- mid-ocean ridge
- ocean basin
- ocean trench

Introduction

Earth's surface features are the result of constructive and destructive forces. Constructive forces cause landforms to grow. The eruption of a new volcano creates a new landform. Destructive forces wear landforms down. The slow processes of mechanical and chemical weathering and erosion work over time to change once high mountains into smooth flat plateaus.

Earth's Features

Figure 1.1 is a slice through a relief map of Earth's surface without the water in the oceans. What are its two most distinctive features?

- The **continents** are large land areas extending from high mountaintops to sea level.
- The **ocean basins** extend from the edges of the continents down steep slopes to the ocean floor and into deep trenches.

Continents

The oldest continental rocks are billions of years old, so the continents have had a lot of time for things to happen to them. **Constructive forces** cause physical features on Earth's surface known as **landforms** to grow. Crustal deformation – when crust compresses, pulls apart, or slides past other crust – results in hills, valleys, and other landforms. Mountains rise when continents collide, when one slab of ocean crust plunges beneath another, or when a slab of continental crust creates a chain of volcanoes. Sediments are deposited to form landforms, such as deltas.

Volcanic eruptions can also be **destructive forces** that blow landforms apart. The destructive forces of weathering and erosion modify landforms. Water, wind, ice, and gravity are important forces of erosion.

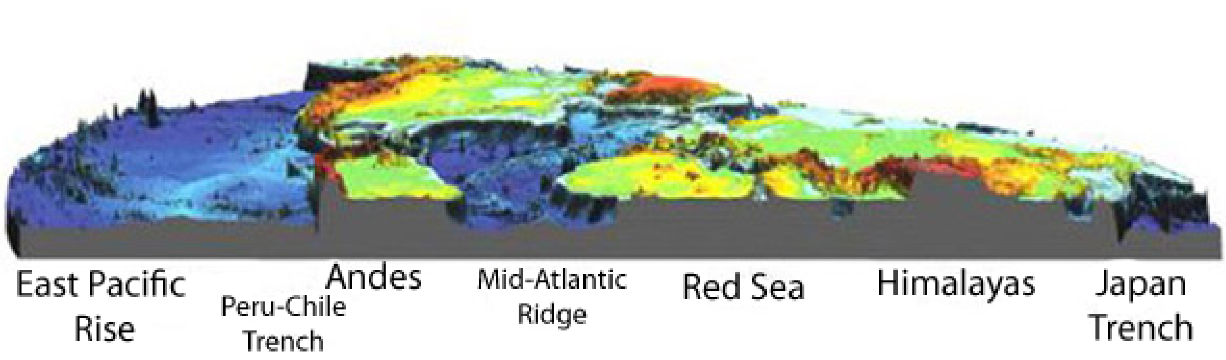


FIGURE 1.1
In this figure, color indicates elevation. Red represents the highest mountains with orange, yellow, and green indicating lower elevations. Light blue to darker blue to bluish-purple descends to the deepest ocean floor.

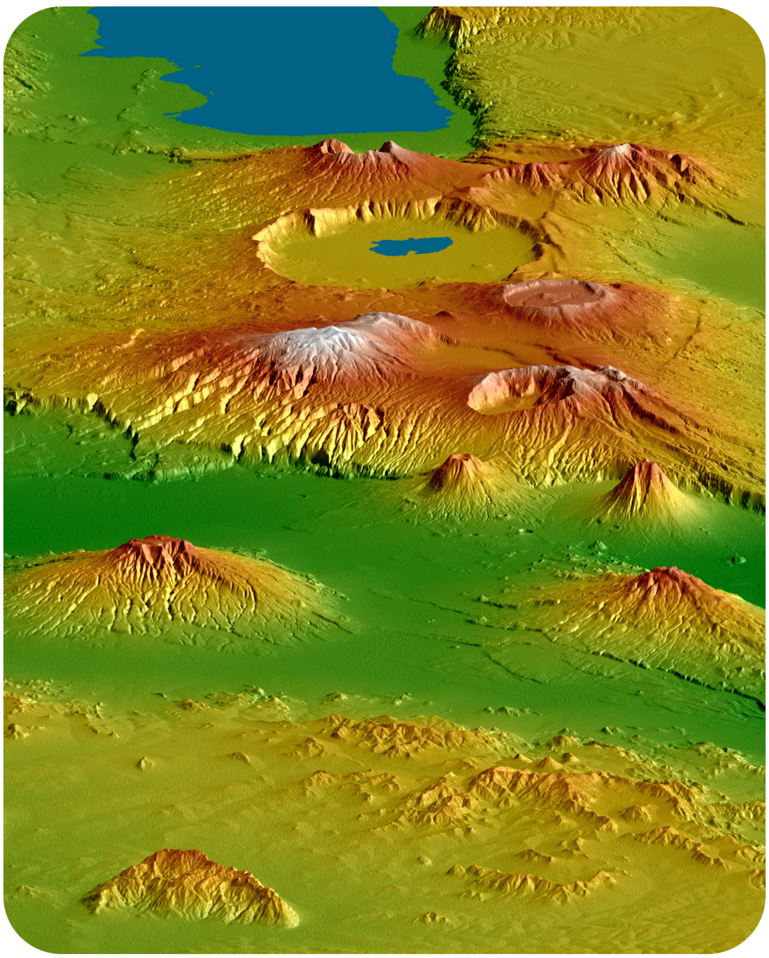


FIGURE 1.2
Landforms in this radar image of the Crater Highlands of Tanzania are accentuated by 2x vertical relief and also by color. The highest elevations are white and lowest elevations are green.

Look for constructive and destructive landforms in **Figure** 1.2. This scene is within the East African Rift where the crust is being pulled apart to form a large valley.

- Which features result from constructive forces? Volcanoes have been constructed within the valley by rising magma.
- Which features result from destructive forces? Volcanic explosions or collapses have destroyed volcanic mountains to form craters. Fractures caused by the rifting in the valley are signs that the valley is breaking apart. Streams are eroding downward into the slopes of the volcanoes. Landslides erode the steep volcanoes. A landslide scar is seen on left side of the small, very steep volcanic cone near the center of the image, and landslide deposits have traveled outward from the scar.

Ocean Basins

The **ocean basins** are all younger than 180 million years. Although the ocean basins begin where the ocean meets the land, the continent extends downward to the seafloor, so the **continental margin** is made of continental crust.

The ocean floor itself is not totally flat, as illustrated in **Figure** 1.3. The most distinctive feature is the mountain range that runs through much of the ocean basin, known as the **mid-ocean ridge**. The deepest places of the ocean are the **ocean trenches**, many of which are located around the edge of the Pacific Ocean. Chains of volcanoes are also found in the center of the oceans, such as in the area of Hawaii. Flat plains are found on the ocean floor with their features covered by mud.

Changing Earth

Earth's surface changes over short and long periods of time. Constructive forces cause new features to form by volcanic activity or uplift of the crust. Existing landforms are modified by destructive forces, perhaps even eroded away by water, wind, ice, and gravity. Beneath the oceans, volcanic activity forms new seafloor while old seafloor is destroyed at the trenches. You will explore many ways that the Earth's surface changes as you proceed through this book.

Lesson Summary

- For the most part, continents are much older than ocean basins.
- Both the continents and ocean basins are covered by many types of landforms, including mountains and flat plains.
- Constructive forces cause landforms to grow.
- Destructive forces modify or even destroy landforms.
- Earth's surface is constantly changing. Change can happen rapidly, as when a volcano blows itself apart, or slowly, as in the grain by grain erosion of a stream into a canyon.

Review Questions

1. What are constructive forces and what landforms do they create?
2. What are destructive forces and what landforms do they create?
3. In a single region, are only constructive or only destructive forces at work?
4. In terms of Earth's surface, what is the only thing that is constant?
5. What are some of the landforms found in the ocean basins?
6. Until recently, scientists thought the seafloor was just flat and muddy. Why do you think they thought this? What do they think now?

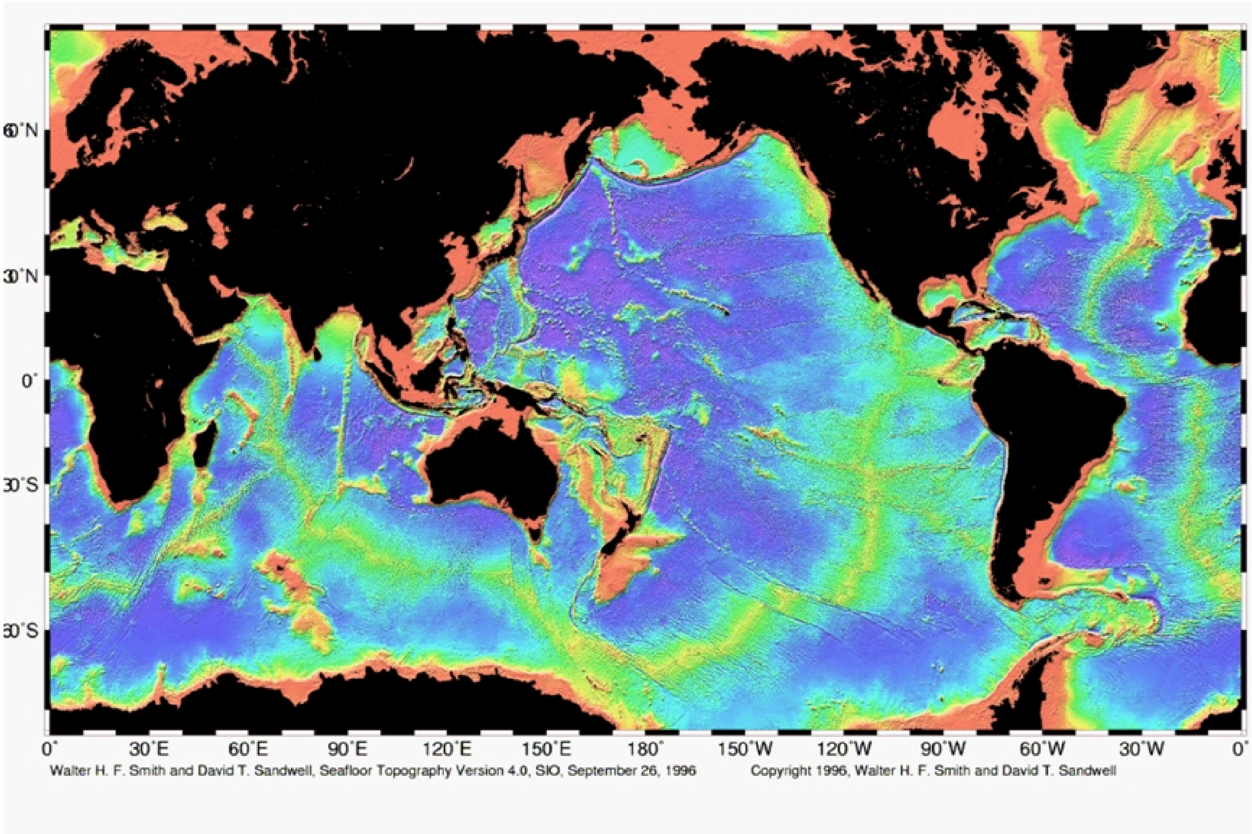


FIGURE 1.3
Major features of the world

Further Reading / Supplemental Links

- Current ocean research with videos and explanations is found at http://oceanexplorer.noaa.gov/.

Points to Consider

- If erosion is constantly eating away at landforms, why isn't Earth's land surface completely flat?
- Why do you think some regions of some continents, such as the middle part of the United States, are almost entirely flat?
- Why are continents higher than ocean basins?

1.2 Where in the World Are You?

Lesson Objectives

- Understand the difference between location and direction.
- Know how a compass works and how to use one.
- Know how to determine location using latitude and longitude.

Vocabulary

- compass
- compass rose
- direction
- elevation
- latitude
- location
- longitude
- relief
- sea level
- topography

Introduction

Without being able to pinpoint a location, understanding Earth's surface would be of little value. Scientists, and even people on the move, must have a system to locate themselves and important features on the Earth.

Location

Perhaps you are sitting in the front office at Clovis West High School in California (**Figure** 1.4). There are many ways to indicate your **location**, any of which can be used to find you.

1. Street address: 1070 East Teague, Fresno, California.
2. Latitude and longitude: 36.85926^{o}N, 119.76468^{o}W.
3. Triangulation: 168 miles from Santa Barbara, 122 miles from San Jose, and 24 miles from Auberry.

Any of these locations can be used and each has a different purpose. A postal worker might prefer to have a street address than to have to triangulate when delivering the mail. A geologist might want to know the latitude and longitude of an important feature. Triangulation is useful for locating where earthquakes and other things occur.

Direction

A line connecting two different locations has **direction**. Directions are expressed as north (N), east (E), south (S), and west (W) with gradations in between. Clovis West High School is north of Santa Barbara, east-southeast of San Jose, and southwest of Auberry. Direction is important for describing moving objects. For example, the wind may be blowing from southwest to northeast.

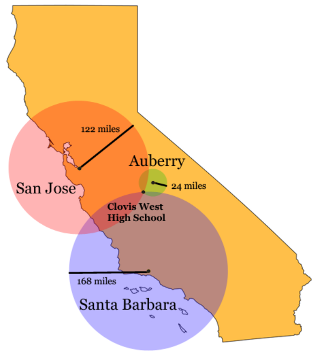


FIGURE 1.4

A triangulation map for Clovis West High School.

The most common way to describe direction in relation to the Earth's surface is with a **compass**, a device with a floating needle that is actually a small magnet. The compass needle aligns itself with the Earth's magnetic north pole, as demonstrated in the **Figure** 1.5. A **compass rose** (**Figure** 1.5) is a figure drawn on a map or nautical chart that shows directions or degrees.

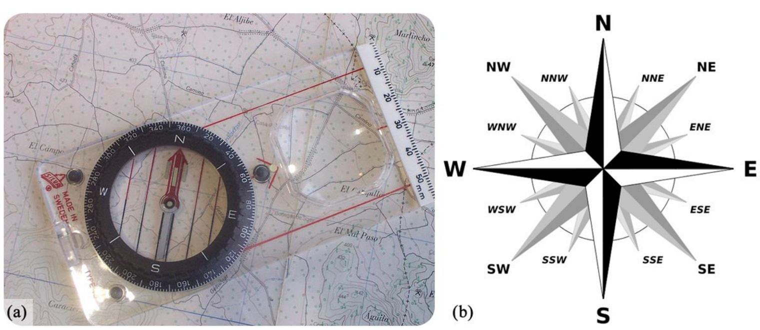


FIGURE 1.5

(a) A compass is used to determine direction. This compass needle is pointing north. A compass overlaid on a map can be used to show the directions the features are from each other. (b) This compass rose shows the major directions at 90 degrees and divides them into halves at 45 degrees

Earth's magnetic north pole is different from its geographic North Pole, known as true north. The geographic North Pole is the point where the axis upon which Earth rotates intersects the planet's surface in the north. To find directions on a map using a compass you must correct for this discrepancy. The **Figure** 1.6 illustrates this offset between geographic and magnetic north.

Latitude and Longitude

Any location on Earth's surface – or on a map – can be described by latitude and longitude. Latitude and longitude are expressed as degrees that are divided into 60 minutes. Each minute is divided into 60 seconds.

Latitude tells the distance north or south of the equator. Latitude lines start at the equator and circle around the planet. The equator is the line that falls equally between the North and South Poles. The latitude of the equator is 0^o. The North Pole is 90^oN, with 90 degree lines in the Northern Hemisphere. The South Pole is 90^oS, with 90 degree lines in the Southern Hemisphere. (**Figure** 1.7) The latitude of Clovis West High School (**Figure** 1.4) is 36.85926^oN expressed in degrees and fractions of degrees.

Longitude lines are circles that go around the Earth from north to south, like the sections of an orange. Longitude is measured perpendicular to the equator. The Prime Meridian is 0^o longitude and passes through Greenwich, England. The International Date Line is the 180^o meridian. The longitude of Clovis West High School is 119.76468^oW

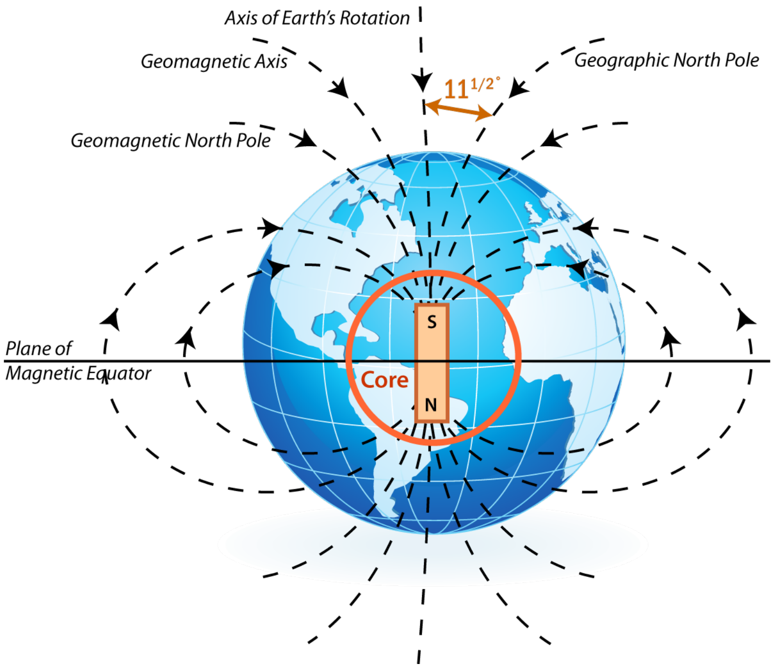


FIGURE 1.6
Earth

expressed in degrees and fractions of degrees.

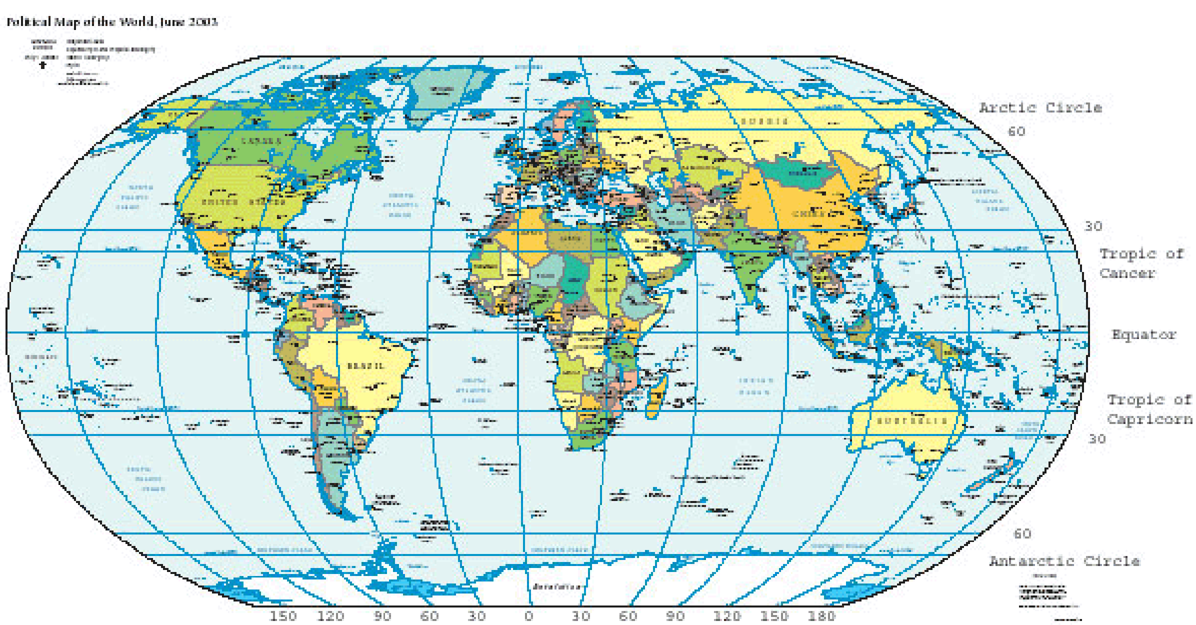


FIGURE 1.7
Lines of latitude and longitude form convenient reference points on a map.

An interactive globe from the Scripps Institution of Oceanography helps with orienting by longitude: http://earth guide.ucsd.edu/earthguide/diagrams/globe/globe.swf

Since Earth is not flat, an accurate location must take into account the third dimension. **Elevation** is the height above or below sea level. **Sea level** is the average height of the ocean's surface or the midpoint between high and low tide and is the same all around Earth. The **topography** of a region is the height or depth of that feature relative to sea level. **Relief** or terrain includes all the major features or landforms of a region. **Figure** 1.8 illustrates a topographic relief of California.

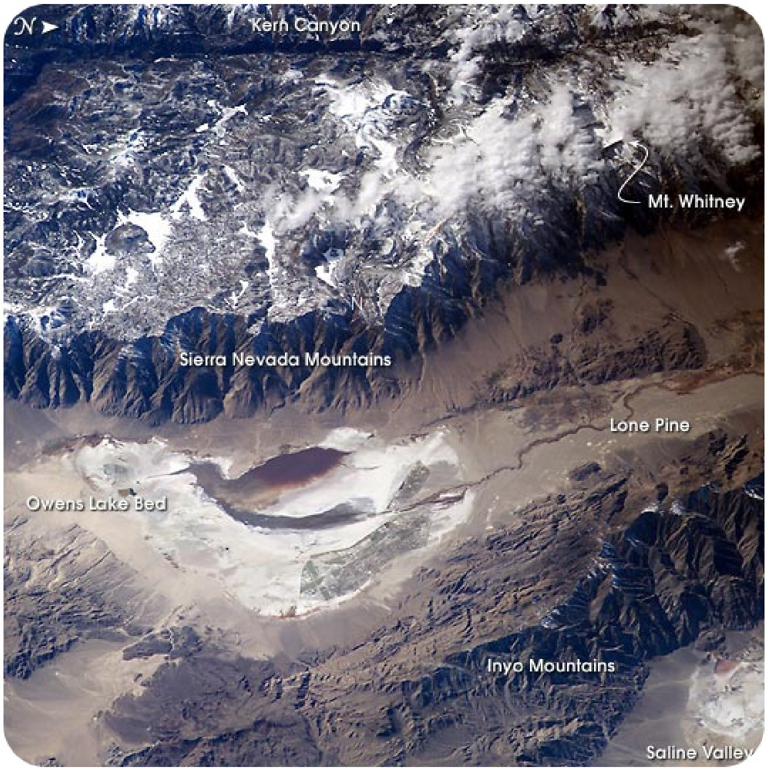


FIGURE 1.8
Topographic relief in California. Mt. Whitney is on the upper right, the highest point in the contiguous United States at 14,494 feet. Death Valley at -282 feet, the lowest contiguous point in the United States, does not appear in this figure but is SE of the Saline Valley, which it resembles.

Lesson Summary

- Location can be expressed in a variety of ways.
- Direction is useful for describing a moving object or the way to get between two locations.
- A compass needle aligns with magnetic north.
- Latitude indicates position north or south of the equator. Longitude indicates position relative to the International Date Line. Elevation is height above or below sea level.

Review Questions

1. What information could you use to describe the location of a feature on the Earth's surface?
2. Give an example of a situation where you might need to describe which direction an object is moving.
3. What type of instrument can you use to tell the direction an object is moving?
4. What is topography?
5. What landforms are highest on the continents?
6. Explain what landforms on the continents are created by erosion by wind and water. How does erosion create a landform?

7. A volcano creates a new landform in Mexico. As the Earth scientist assigned to study this feature, explain how you would describe its position in your report.
8. Think about how you would draw a map to show all the different elevations around the area where you live. How might you create such a map?

Further Reading / Supplemental Links

- A good explanation of latitude and longitude is found at National Atlas: http://www.nationalatlas.gov/articles/mapping/a_latlong.html.

Points to Consider

- How can a two-dimensional object, such as a map, express the features of an area in three dimensions?
- To locate yourself accurately, should you use a compass or a map?
- Why does California have such extreme relief?

1.3 Modeling Earth's Surface

Lesson Objectives

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

Vocabulary

- map
- projection

Introduction

Different representations of Earth's surface are valuable for different purposes. Accuracy, scale, portability, and features represented are among the many factors that determine which representation is most useful.

Globe

Earth is best represented by a globe like the one seen in **Figure** 1.9 because Earth is a sphere. Sizes and shapes of features are not distorted and distances are true to scale.

FIGURE 1.9
A globe is the most accurate way to represent Earth's curved surface.

Globes usually have a geographic coordinate system and a scale. The shortest distance between two points is the length of the arc (portion of a circle) that connects them.

Math problem: How would you measure the distance between two points on a globe in miles?

- Here's an idea: Pull a string taut between the two locations and mark both locations. Lay the string on the equator of the globe. Count the number of degrees between the marks, starting with one end at 0. The number of miles per degree at the equator is 69.17; now multiply the number of degrees by that number to get the distance in miles between the two locations.

A location on a globe must be determined using polar coordinates because a globe is curved (**Figure** 1.10).

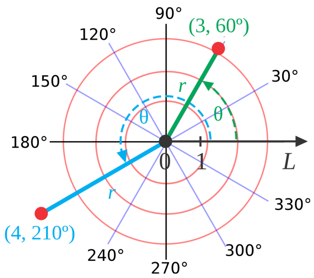


FIGURE 1.10

The polar coordinate system is useful for curved surfaces.

Globes are difficult to make and carry around, and they cannot be enlarged to show the details of any particular area. As a result, people need maps.

Maps as Models

A **map** is a visual representation of a surface with symbols indicating important features. Different types of maps contain different information. Examples of some maps that are important in Earth science are:

- Relief maps use color to show elevations of larger areas (**Figure** 1.1).
- Radar maps topography (**Figure** 1.2) or weather. National Weather Service Doppler Radar maps are found here: http://radar.weather.gov/.
- Satellite-view maps show terrains and vegetation, such as forests, deserts, and mountains (**Figure** 1.8).
- Climate maps show average temperatures and rainfall. Climate maps from the National Oceanic and Atmospheric Administration (NOAA) are found here: http://www.esrl.noaa.gov/psd/data/usclimate/states.fast.html .
- Weather maps show storms, air masses, and fronts. Weather maps, also from NOAA, are found here: http://www.nws.noaa.gov/.
- Topographic maps show elevations using contour lines to reveal landforms (**Figure** 1.18).
- Geologic maps detail the types and locations of rocks found in an area (**Figure** 1.25).

Map Projections

Maps are 2-dimensional (2D) representations of a 3-dimensional (3D) Earth. In a small area, Earth is essentially flat, so a flat map is accurate. But to represent a larger portion of Earth, map makers must use some type of projection to collapse the third dimension onto a flat surface. A **projection** is a way to represent the Earth's curved surface on flat paper. One example of a projection is shown in the **Figure** 1.11.

There are two basic methods for making 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 looks at the sphere from a certain point and then translates this view onto a flat paper.

Let's look at a few commonly used projections.

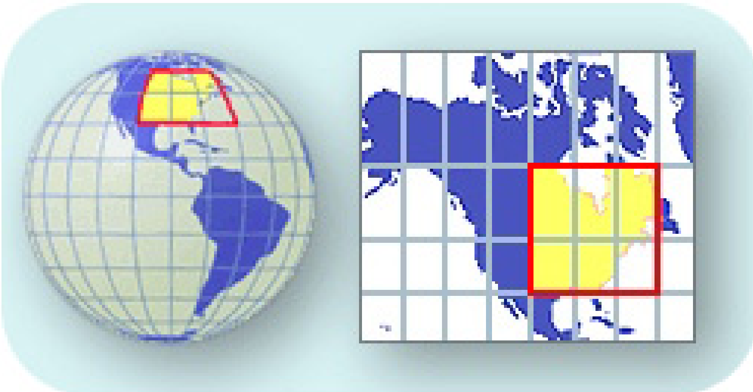


FIGURE 1.11
A map projection translates Earth's curved surface onto two dimensions.

Mercator Projection

In 1569, Gerardus Mercator (1512-1594) developed the Mercator projection (seen in the **Figure** 1.12). A flat piece of paper curves around the spherical Earth to make a cylinder. The paper touches the sphere at the equator, but the distance between the sphere and the paper increases toward the poles. The features of Earth's surface are projected out onto the cylinder and then unrolled, creating a Mercator projection map.

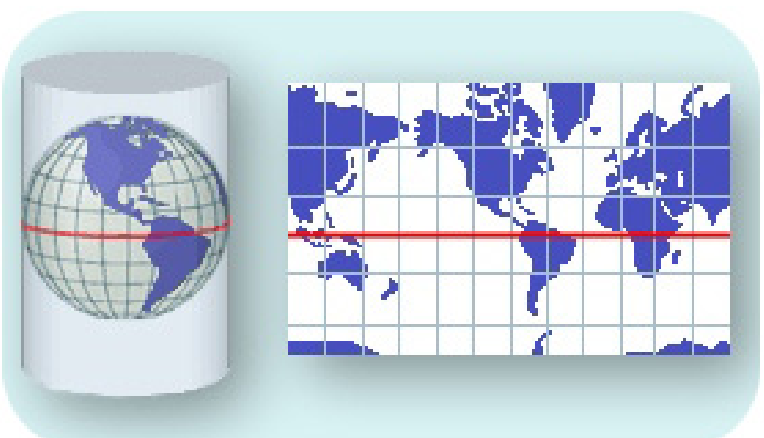


FIGURE 1.12
A Mercator projection translates the curved surface of Earth onto a cylinder.

Where do you think a Mercator map is most accurate? Where is it least accurate? Near the equator the shapes and sizes of features are correct, but features get stretched out near the poles. For example, on a globe, Greenland is fairly small, but in a Mercator map, Greenland is stretched out to look almost as big the United States.

In a Mercator projection, all compass directions are straight lines, but a curved line is the shortest distance between the two points. Many world maps still use Mercator projection today. Early explorers found Mercator maps useful because they visited the equatorial regions more frequently.

A good explanation of the distortion that results from the projection of a sphere onto a flat surface can be seen in Alternative World Maps: http://www.youtube.com/watch?v=cuuluAq4TtU&feature=related.

Conic Projection

A conic map projection uses a cone shape to better represent regions and best depicts the area where the cone touches the globe. Looking at **Figure** 1.13, what is the advantage of a conic projection over a Mercator projection?

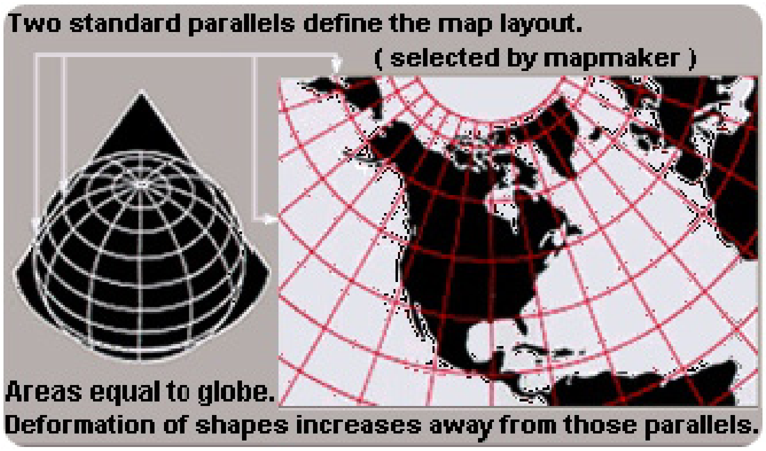


FIGURE 1.13
A conic map projection wraps the Earth with a cone shape rather than a cylinder.

Gnomonic Projection

A gnomonic map projection is illustrated in **Figure** 1.14. With a gnomonic map projection, paper is placed on the area that you want to map. The projection is good for features near that point. The poles are often mapped this way.

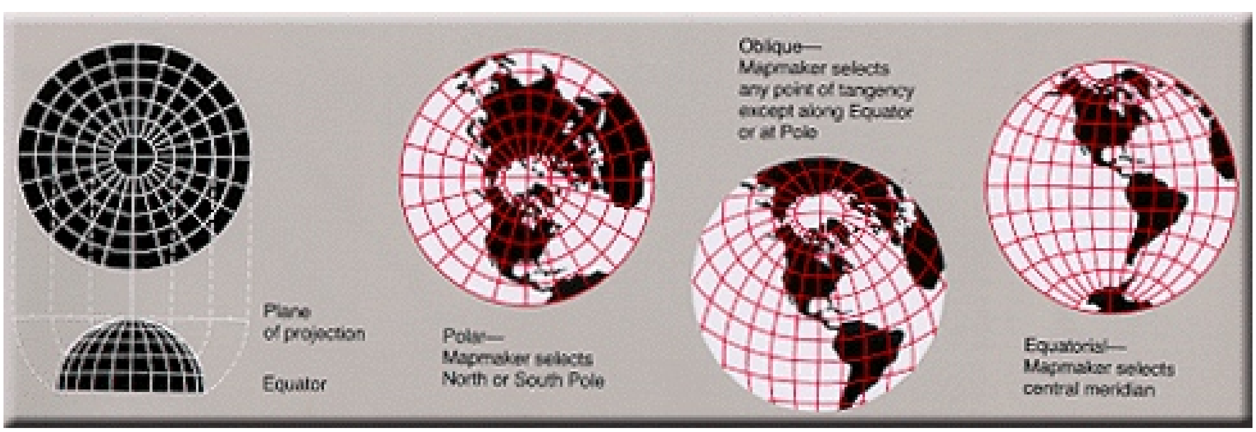


FIGURE 1.14
A gnomonic projection places a flat piece of paper on a point somewhere on Earth and projects an image from that point.

Robinson Projection

In 1963, Arthur Robinson created an attractive map projection in which latitude lines are projected but meridians are curved, resulting in a map that is an ellipse rather than a rectangle (see **Figure** 1.15 for an example). This projection has less distortion near the poles, and features within 45 degrees of the equator are closer to their true dimensions. The distances along latitude lines are true, but the scales along each line of latitude are different. Robinson projections are still commonly used.

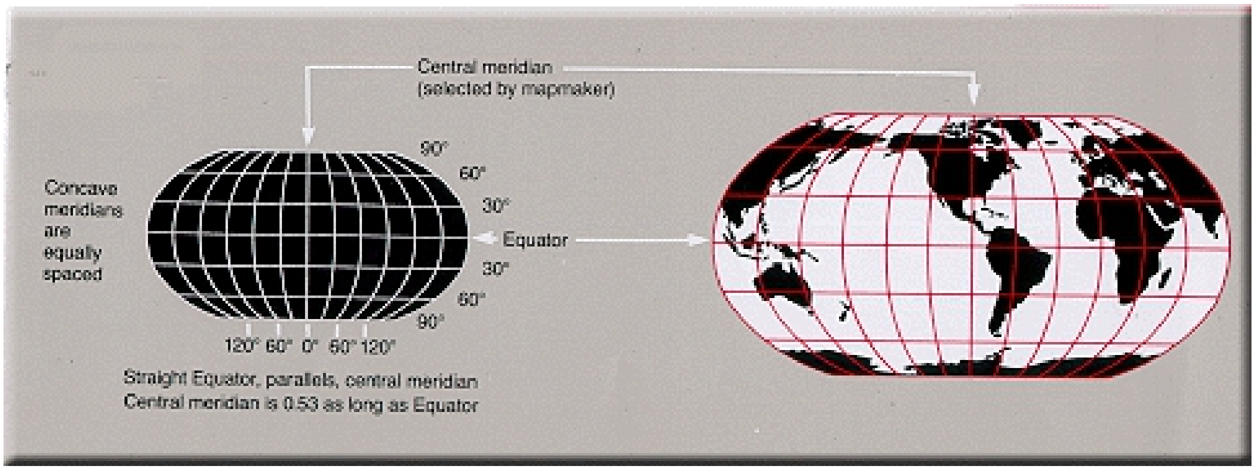


FIGURE 1.15
A Robinson projection more accurately reflects the size and shape of features near 45 degrees.

Winkel Tripel Projection

The National Geographic Society uses the Winkel Tripel Projection, which uses mathematical formulas to create a map projection that is also distorted at the edges (**Figure** 1.16).

Locations on a map are determined using rectangular coordinates (see **Figure** 1.17).

Google Earth is a neat site to download to your computer: http://www.google.com/earth/index.html. The maps on this site allow you to zoom in or out, look from above, tilt your image, and a lot more.

Lesson Summary

- Maps and globes are models of the Earth's surface.
- Globes are the most accurate representations because they are spherical like the Earth is, but using a globe as a map has practical disadvantages.
- There are many ways to project the three-dimensional surface of the Earth on to a flat map. Each type of map has some advantages as well as disadvantages.
- Most maps use latitude and longitude to indicate locations.

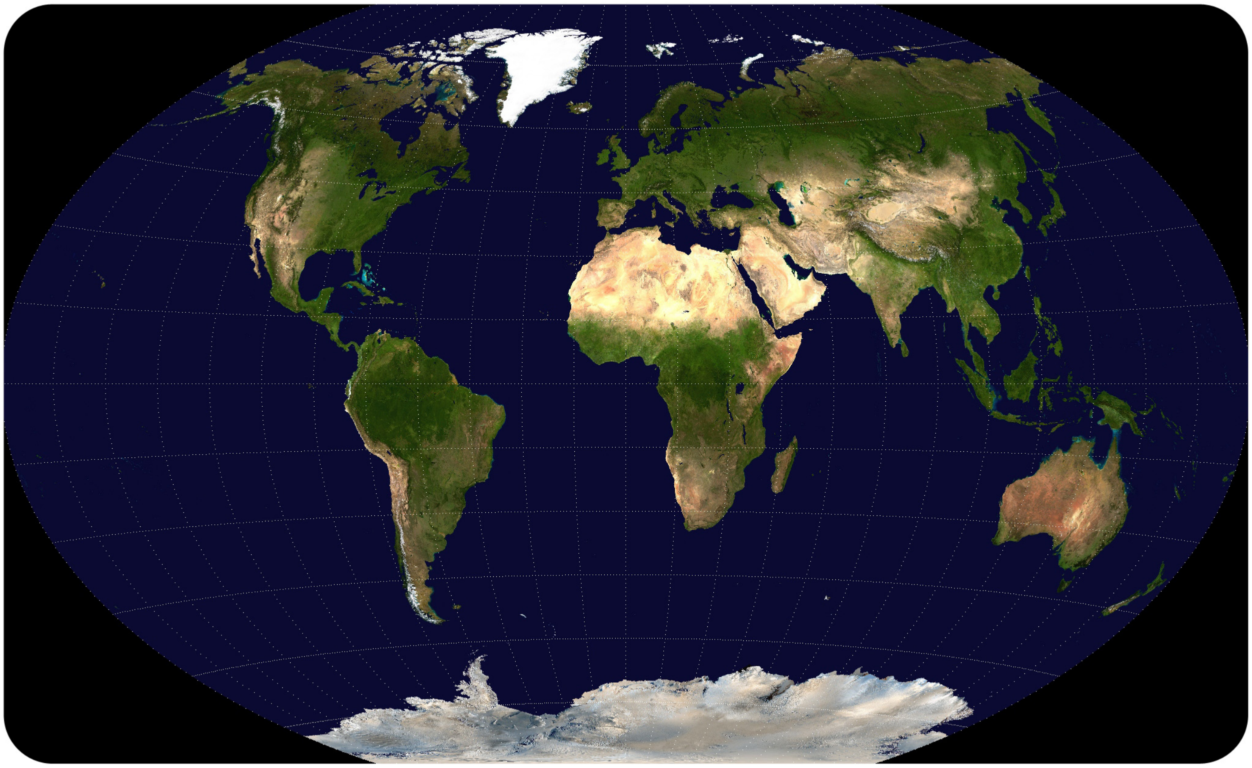


FIGURE 1.16
The Winkel Tripel Projection of Earth.

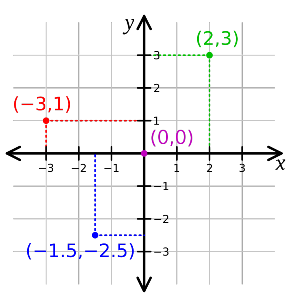


FIGURE 1.17
Rectangular coordinates are useful for flat surfaces.

Review Questions

1. Which of the following gives you the most accurate representations of distances and shapes on the Earth's surface?
   (a) Mercator projection map
   (b) Robinson projection map
   (c) globe
2. Explain the difference between latitude and longitude.

3. In what country are you located if your coordinates are 60^oN and 120^oW?
4. Which map projection is most useful for navigation, especially near the equator? Explain.
5. In many cases, maps are more useful than a globe. Why?
6. Which of the following map projections gives you the least distortion around the poles?
   (a) Mercator projection map
   (b) Robinson projection map
   (c) conic projection

Further Reading / Supplemental Links

- National Geographic has an introduction to maps: http://www.mywonderfulworld.org/toolsforadventure/usingmaps/index.html and http://www.mywonderfulworld.org/toolsforadventure/usingmaps/explorers.html.
- An atlas for the United States with many types of maps: http://www.nationalatlas.gov/.
- Location and relief on maps: http://www.fao.org/docrep/003/T0390E/T0390E04.htm.

Points to Consider

- Imagine you are a pilot and must fly from New York to Paris. Use a globe to determine the distance. Now do the same with a map. How are these activities the same and how are they different?
- Would you choose a map that used a Mercator projection if you were going to explore Antarctica? What other type of map could you use?
- Maps use a scale, which means a certain distance on the map equals a larger distance on Earth. Why are maps drawn to scale? What would be some problems you would have with a map that did not use a scale?

1.4 Topographic Maps

Lesson Objectives

- Explain how to read and interpret a topographic map.
- Explain how bathymetric maps are used to determine underwater features.
- Describe what a geologic map shows.

Vocabulary

- bathymetric map
- contour interval
- contour line
- geologic map
- topographic map

Introduction

Maps are extremely useful to Earth scientists to represent geographic features found above and below sea level and to show the geology of a region. Rock units and geologic structures are shown on geologic maps.

What is a Topographic Map?

Mapping is a crucial part of Earth science. **Topographic maps** represent the locations of geographical features, such as hills and valleys. Topographic maps use contour lines to show different elevations on a map. A **contour line** is a type of isoline; in this case, a line of equal elevation. If you walk along a contour line you will not go uphill or downhill. Mathematically, a contour line is a curve in two dimensions on which the value of a function f(x, y) is a constant.

Contour Lines and Intervals

Contour lines connect all the points on a map that have the same elevation and therefore reveal the location of hills, mountains, and valleys. While a road map shows where a road goes, a topographic map shows why. For example, the road bends in order to go around a hill or stops at the top of a mountain. On a contour map:

- Each contour line represents a specific elevation and connects all the points that are at the same elevation. Every fifth contour line is bolded and labeled with numerical elevations.
- The contour lines run next to each other and NEVER cross. After all, a single point can only have one elevation.
- Two contour lines next to one another are separated by a constant difference in elevation (such as 20 ft or 100 ft). This difference between contour lines is called the **contour interval**. The map legend gives the contour interval.

How would you calculate the contour interval on the map of Stowe, Vermont (see **Figure** 1.18)?

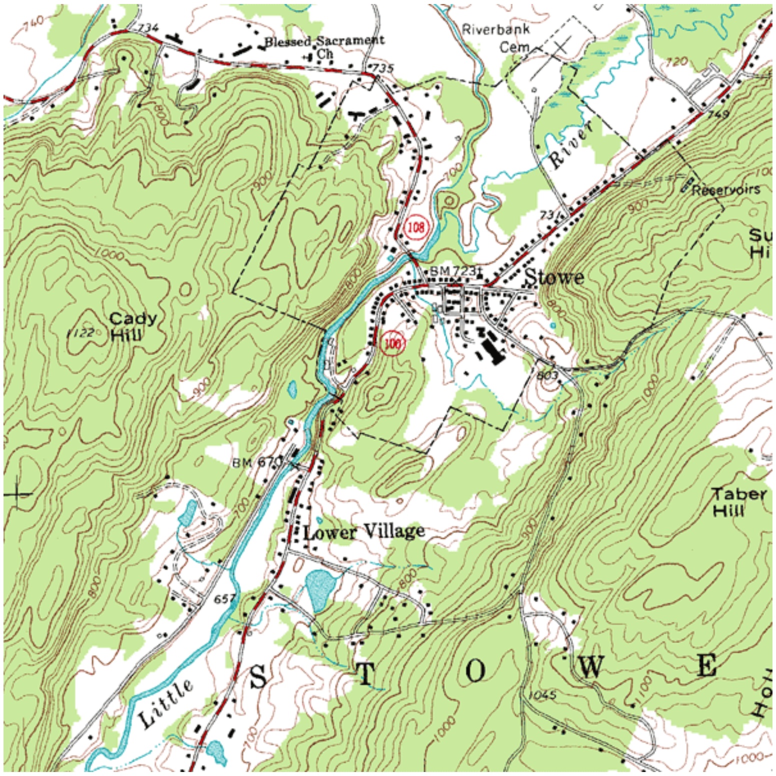


FIGURE 1.18
A topographic map of Stowe, Vermont.

- Calculate the difference in elevation between two bold lines.
- Divide that difference by the number of contour lines between them.

On the Stowe map, the difference between two bold lines is 100 feet and there are five lines between them, so the contour interval is 20 feet (100 ft/5 lines = 20 ft/line).

The Value of a Topographic Map

Swamp Canyon in Bryce Canyon National Park, Utah (shown in **Figure** 1.19) is very rugged, with steep canyon walls and a valley below.

The visitor's map of the area in **Figure** 1.20 shows important locations. What's missing from this map? This map does not represent the landscape.

With contour lines to indicate elevation, the topographic map in **Figure** 1.21 shows the terrain.

Interpreting Contour Maps

How does the map of Bryce Canyon reveal the terrain of the region? Several principles are important for reading a topographic map:

1. Contour lines show the 3-dimensional shape of the land (**Figure** 1.22). What does the spacing of contour lines indicate?

- Closely-spaced contour lines indicate a steep slope, because the elevation changes quickly in a small area.
- Contour lines that seem to touch indicate a very steep rise, like a cliff or canyon wall.
- Broadly spaced contour lines indicate a shallow slope.

FIGURE 1.19
View of Swamp Canyon in Bryce Canyon National Park.

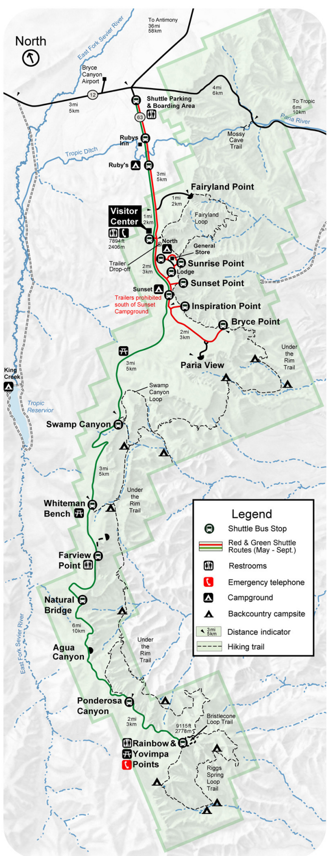


FIGURE 1.20
Swamp Canyon Loop in Bryce Canyon National Park. The green line indicates the main road, black dotted lines are trails, and there are markers for campsites, a picnic area, and a shuttle bus stop.

2. Concentric circles indicate a hill. When contour lines form closed loops all together in the same area, this is a hill. The smallest loops are the higher elevations and the larger loops are downhill. On the Stowe map, which hill has an elevation of 1122 feet? If you found Cady Hill, on the left side of the map, you are right.

3. Hatched concentric circles indicate a depression, as seen in the **Figure** 1.23. The hatch marks are short, perpendicular lines inside the circle. The innermost hatched circle would represent the deepest part of the depression,

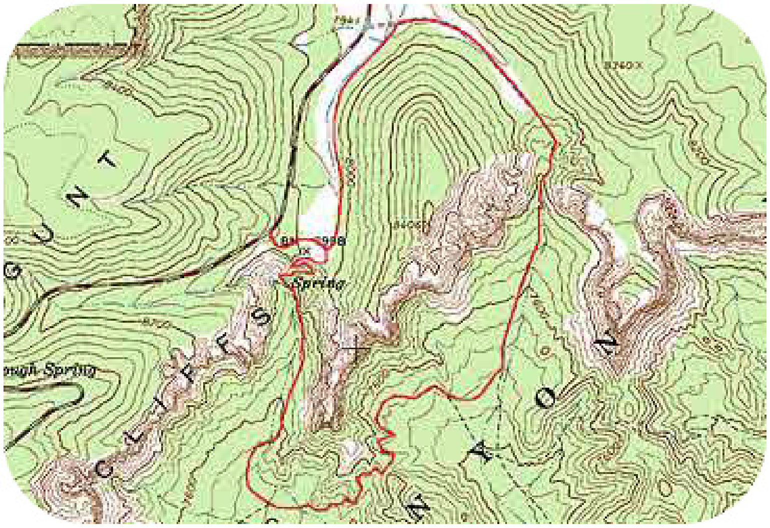


FIGURE 1.21

Topographic map of Swamp Canyon Trail portion of Bryce Canyon National Park.

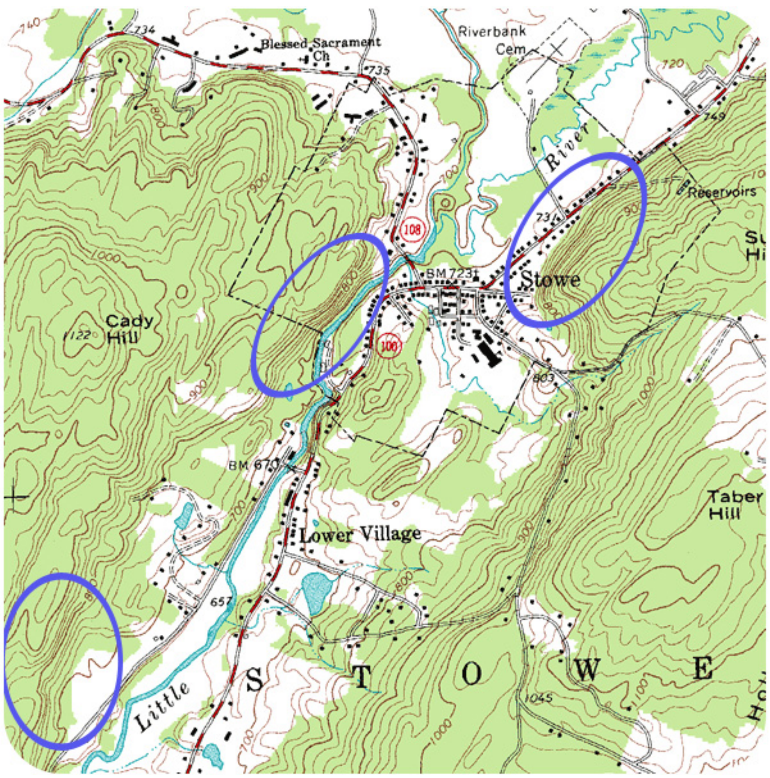


FIGURE 1.22

A portion of a USGS topographic map of Stowe, Vermont. Just to the right of the city of Stowe is a steep hill with a sharp rise of about 200 ft that becomes less steep toward the right.

while the outer hatched circles represent higher elevations.

4. V-shaped expanses of contour lines indicate stream valleys. Where a stream crosses the land, the Vs in the contour lines point uphill. The channel of the stream passes through the point of the V and the open end of the V represents the downstream portion. If the stream contains water, the line will be blue; otherwise, the V patterns indicate the direction water will flow. In the map of Stowe, where does a stream run downhill into a lake?

- Start at the "T" in Stowe. A blue stream goes downhill (northwest) into a lake. Coming out of the T on the

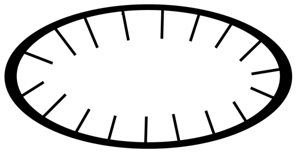


FIGURE 1.23
On a contour map, a circle with inward hatches indicates a depression.

other side, you can follow the blue stream uphill (southeast). Where the water flow is light or nonexistent, there is no longer a blue line, but the contour lines point uphill indicating that the stream channel is still there (see the map of Stowe in **Figure** 1.18).

5. Scales on topographic maps indicate horizontal distance. The horizontal scale can be used 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

An animation showing contour lines and the slopes they represent: http://www.youtube.com/watch?v=SkaXsSYKmw8.

Google Earth Topographic Map shows a 3D image with contour lines superimposed on it to show the relationship between the two **(1h - IE Stand.)**: http://www.youtube.com/watch?v=c_mxCN3Ez58&feature=related (0:43).

MEDIA
Click image to the left for more content.

Bathymetric maps

The **bathymetric map** in the **Figure** 1.24 is like a topographic map with the contour lines representing depth below sea level, rather than height above. Numbers are low near sea level and become higher with depth. Bathymetric maps help oceanographers visualize the landforms at the bottoms of lakes, bays, and the ocean as if the water were removed.

Geologic Maps

A **geologic map** shows the geological features of a region (see examples in **Figure** 1.25 and **Figure** 1.26). Rock units are color-coded and identified in a key. In the map of Yosemite (**Figure** 1.25), volcanic rocks are brown, the Tuolumne Intrusive Suite is peach, and the metamorphosed sedimentary rocks are green. Structural features, such as folds and faults, are also shown on a geologic map. The area around Mt. Dana on the east central side of the map has fault lines.

This video shows a 3-dimensional interpretation of a geologic map from the Green River in Utah **(1h - IE Stand.)**: http://www.youtube.com/watch?v=5CHd6_cIT44 (1:34).

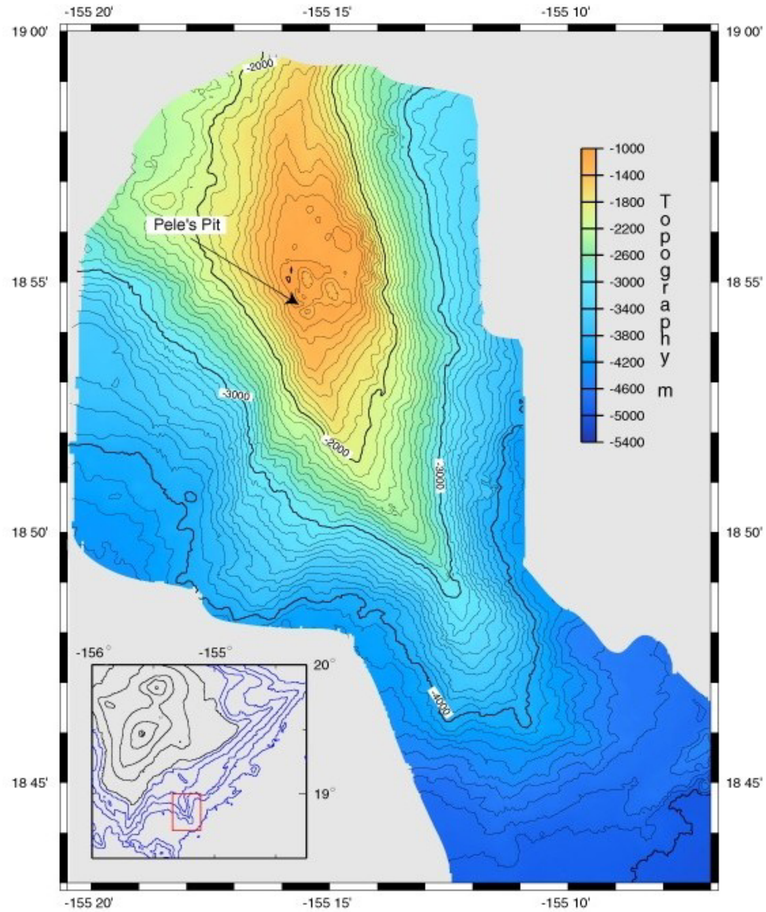


FIGURE 1.24

Loihi volcano growing on the flank of Kilauea volcano in Hawaii. Black lines in the inset show the land surface above sea level and blue lines show the topography below sea level.

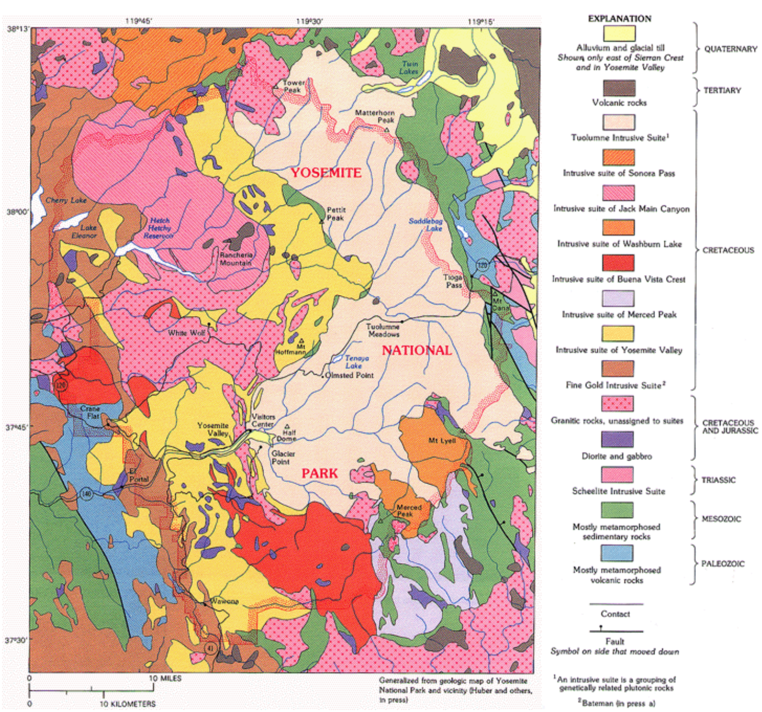


FIGURE 1.25

Geologic map of Yosemite National Park.

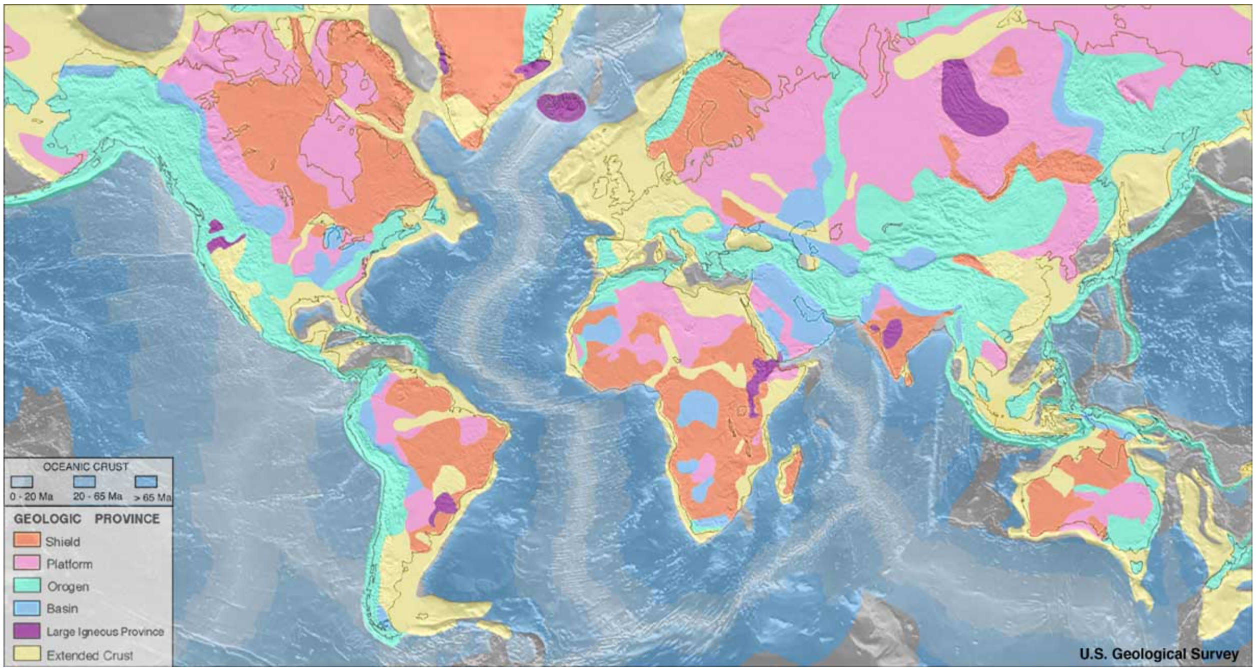
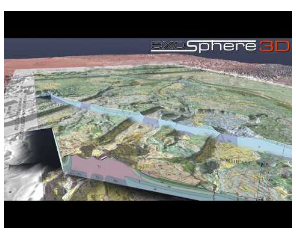


FIGURE 1.26
On a large scale geologic map, colors represent geological provinces.



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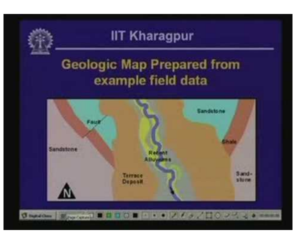
Click image to the left for more content.

This hour-long video is a tutorial on how to interpret a geologic map and construct a geological cross-section **(1h - IE Stand.)**: http://www.youtube.com/watch?v=sTY-ao4RZck (59:56).



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Click image to the left for more content.

Lesson Summary

- Topographic maps are 2-dimensional representations of the 3-dimensional surface features of an area.
- Topographic maps have contour lines that connect points of identical elevation above sea level.
- Contour lines run next to each other. Adjacent contour lines are 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 surface features in a given area, to find their way through a particular area, and to determine the direction of water flow in a given area.
- Oceanographers use bathymetric maps to depict the features beneath a body of water.
- Geologic maps display rock units and geologic features of a region of any size. A small scale map displays individual rock units; a large scale map shows geologic provinces.

Review Questions

1. On a topographic map, contour lines create a group of concentric, closed loops. Which of the following features could this indicate?
   (a) a stream channel
   (b) a hilltop
   (c) depression
   (d) a cliff
2. Describe the pattern on a topographic map that would indicate a stream valley. How do you determine the direction of water flow?
3. On a topographic map, five contour lines are very close together in one area. The contour interval is 100 ft. What feature does that indicate? How high is this feature?
4. On a topographic map, describe how you can tell a steep slope from a shallow slope.
5. 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 800 ft and Point B is on a contour line of 900 ft. In which direction does the river flow?
6. On a topographic map, six contour lines span a horizontal map distance of 0.5 inches. The horizontal scale is 1 inch equals 2,000 ft. How far apart are the first and sixth lines?
7. On a 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 down more topographic lines into the canyon from that is another thin unit, the Coconino Sandstone. Describe how these three rock units sit relative to each other. Which is oldest and which is youngest?

Further Reading / Supplemental Links

- A key of topographic map symbols by the USGS is found here: http://erg.usgs.gov/isb/pubs/booklets/symbols/topomapsymbols.pdf.
- How to construct a topographic profile: http://www.uwsp.edu/geo/faculty/ritter/geog101/textbook/manuals/instructor_manual/how_to/topographic_profile.html.
- More about reading topographic maps: http://www.globalsecurity.org/military/library/policy/army/fm/3-25-26/ch10.htm; http://www.map-reading.com/intro.php; http://egsc.usgs.gov/isb/pubs/booklets/topo/topo.html.

Points to Consider

- How might a civil engineer use a topographic map to build a road, bridge, or tunnel through the area such as that shown in **Figure** 1.22? What topography would be best for a bridge? Which areas might need a bridge? Where might a tunnel be helpful?
- If you wanted to participate in orienteering, would it be better to have a topographic map or a road map? How would a topographic map help you?
- If you were the captain of a ship, what type of map would you want and why?

1.5 Using Satellites and Computers

Lesson Objectives

- Describe 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
- Global Positioning System (GPS)
- polar orbit
- satellite

Introduction

Modern technology is very useful for Earth scientists. Satellites give researchers a global perspective and can be used to monitor changes. Computers are used for making maps.

Satellite Data

A **satellite** is a small object that orbits a larger object. Satellites orbit Earth to get a large view of the planet's surface and for hauling many different types of instruments to monitor all types of conditions (**Figure** 1.27). Satellite views are important for visualizing global change; for example, the amount of sea ice that is present in the Arctic from winter to winter.

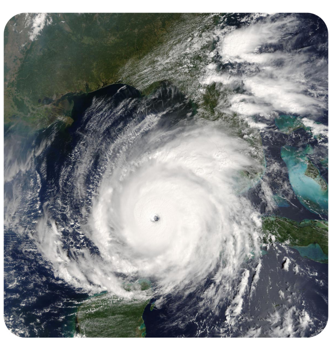

FIGURE 1.27
Satellites monitor and track hurricanes, reducing property damage and saving lives. This image shows Hurricane Rita on September 23, 2005 as it approaches Texas and Louisiana.

Satellites travel in different orbits:

- In a **geostationary orbit** (illustrated in **Figure** 1.28), the satellite orbits at a distance of 36,000 km. Since it takes 24 hours to complete one orbit, which is the same amount of time it takes Earth to complete one rotation, the satellite hangs in the sky over the same spot. What is the value of a satellite in this type of orbit? From this orbit, weather satellites can observe changing weather conditions and communications satellites can relay signals.

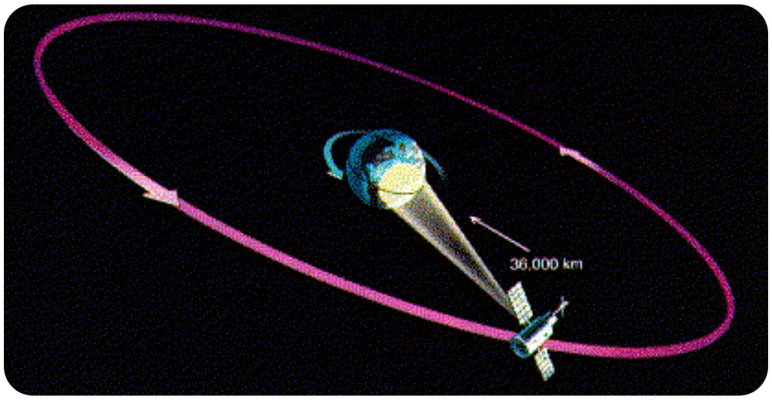

FIGURE 1.28
Satellite in a geostationary orbit.

- In a **polar orbit**, seen in **Figure** 1.29, 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. Earth rotates only slightly underneath the satellite, so the satellite can see the entire surface of the Earth in less than a day. What would be the value of this type of orbit? Weather satellites can get a picture of how the weather is changing globally. Some satellites that observe the lands and oceans use a polar orbit.

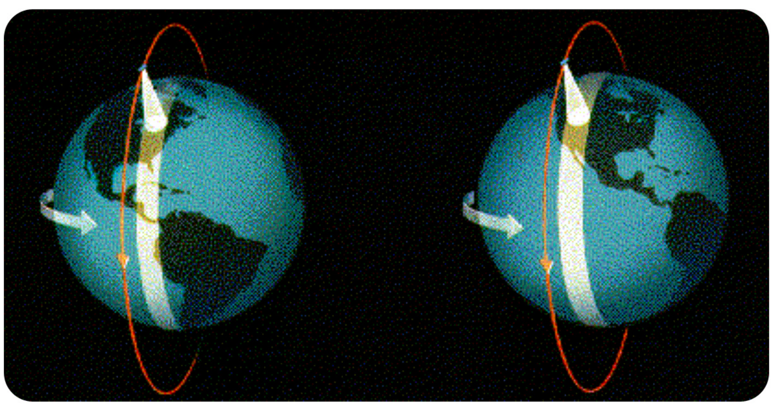

FIGURE 1.29
Satellite in a polar orbit.

The National Aeronautics and Space Administration (NASA) has launched a fleet of satellites to study Earth. The satellites are operated by several government agencies, including NASA, the National Oceanographic and Atmospheric Administration (NOAA), and the United States Geological Survey (USGS).

Using different types of scientific instruments, satellites measure many things, including the temperatures of the land and oceans, amounts of gases such as water vapor and carbon dioxide in the atmosphere, the ability of the surface to reflect various colors of light, which indicates plant life, and even the height of the ocean's surface.

You can have lots of fun with satellite maps by playing around with Google maps: http://maps.google.com/. Try searching for these interesting features: Goosenecks State Park, Utah; Mt. Whitney, Lone Pine, California; Empire State Building, New York; or your home. Note that you can zoom in and out to see features in more detail or to see how they fit into the area.

Global Positioning System

Satellites help people locate their position on 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. GPS receivers, like the one pictured in image A of **Figure** 1.30, are now common.

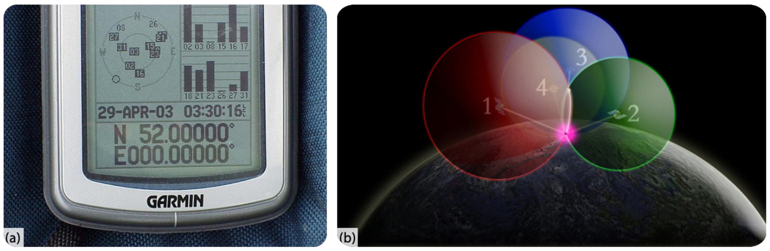

FIGURE 1.30
(a) This GPS receiver is located at 52 degrees N and 0 degrees E, on the Prime Meridian. (b) The receiver takes signals from 4 GPS satellites to calculate your location precisely.

The GPS receiver detects radio signals from at least four nearby GPS satellites. There are precise clocks on each satellite and in the receiver. The receiver measures the time for radio signals from the satellite to reach it and then calculates the distance between the receiver and the satellite using the time and the speed of radio signals. The receiver triangulates by calculating distances from each of the four satellites. It then determines the location of the GPS receiver, as illustrated in image B of **Figure** 1.30.

Computer-Generated Maps

Computers have improved how maps are made and have increased the amount of information that can be displayed. Map makers use satellite images and computers to draw maps. Computers break apart the fine details of a satellite image, store the pieces of information, and put them back together in a 2D or 3D image (**Figure** 1.31).

Geographic Information Systems (GIS) use exact geographic locations from GPS receivers along with any type of spatial information to create maps and images (**Figure** 1.32). The information might be of people living in an area, types of plants or soil, locations of groundwater, or levels of rainfall. Geologists use GIS to make maps of natural resource distributions.

Lesson Summary

- Satellites give a larger view of the Earth's surface and make many types of measurements that are of interest to Earth scientists.
- A group of specialized satellites called Global Positioning Satellites help people to pinpoint their location.
- Location information, satellite views, and other information are linked together in Geographical Information Systems (GIS).
- GIS are powerful tools that Earth scientists and others can use to study Earth and its resources.

Review Questions

1. Which type of satellite can be used to pinpoint your location on Earth?
   (a) weather satellite
   (b) communications satellite
   (c) global positioning satellite
   (d) climate satellite

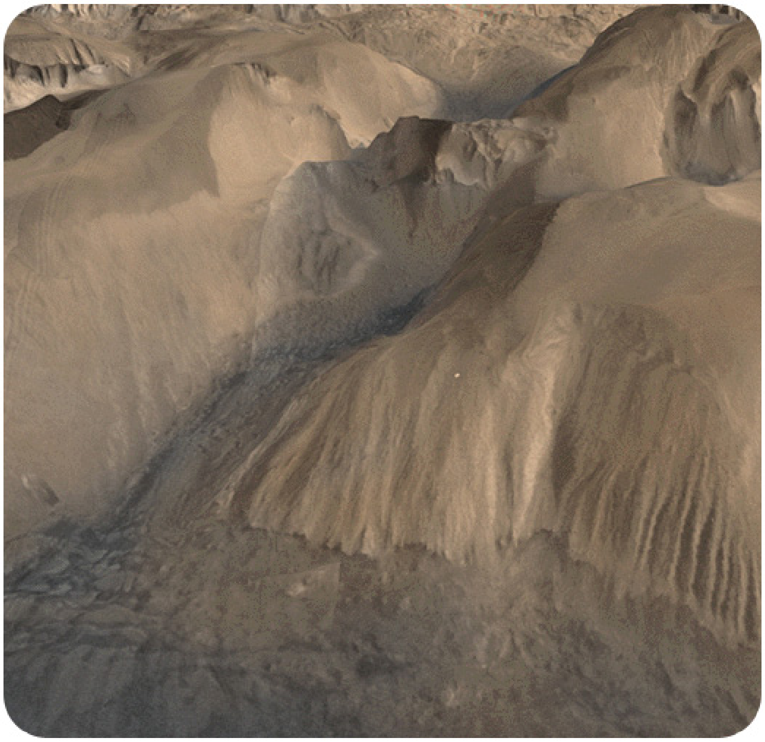

FIGURE 1.31
Scientists used computers and satellite images from Mars to create a 3D image of Valles Marineris.

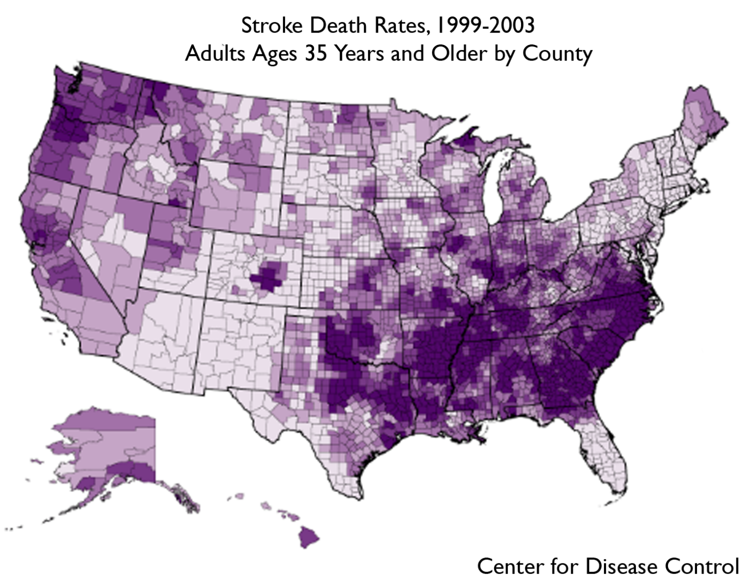

FIGURE 1.32
A GIS map of stroke death rates in the United States. Health rates may be affected by geographic region.

2. Explain the difference between geostationary orbits and polar orbits.
3. Describe how GPS satellites can find a location in which there is a transmitter on Earth.
4. What is a Geographical Information System (GIS)?
5. To map the entire Earth's surface from orbit, which type of orbit would you use? Explain why this would be your best choice.
6. Explain how weather satellites can track a tropical storm from its beginnings.

Further Reading / Supplemental Links

- "Isaac's Storm": http://www.randomhouse.com/features/isaacsstorm/.
- About Geographic Information Systems: http://erg.usgs.gov/isb/pubs/gis_poster/.
- Wonderful satellite images of Earth are found at: http://earthobservatory.nasa.gov/.
- How NOAA uses satellites: http://www.noaa.gov/satellites.html.

Points to Consider

- Imagine tracking a hurricane across the Atlantic Ocean. What information would you need to follow its path? What satellite images might be most useful? Research how the National Weather Service tracks and monitors hurricanes.
- What information and type of map would be most useful for understanding the distribution of natural resources for a particular state?
- What are some ways that people use Global Positioning Systems? What problems are easier to solve using GPS?

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- Courtesy of National Park Service. http://www.nps.gov/brca/planyourvisit/swampcanyontrail.htm. Public Domain.
- Courtesy of Peter W. Sloss, NOAA/NGDC. http://www.magazine.noaa.gov/stories/mag26.htm. Public Domain.
- Image courtesy of US Geological Survey. *Robinson projection*. Public Domain.
- Maksim, modified by CK-12 Foundation. *Example of polar coordinates*. GNU-FDL 1.2.
- Courtesy of WHF Smith and DT Sandwell/National Oceanic and Atmospheric Administration. http://www.ngdc.noaa.gov/mgg/fliers/97mgg03.html. Public Domain.
- Courtesy of NASA. *Winkel Tripel Projection*. Public Domain.
- Courtesy of the US Geological Survey. *Geologic map of the world, with colors representing geological provinces*. Public Domain.
- Courtesy of US Geological Survey. *A topographic map of Stowe, Vermont*. Public Domain.
- CK-12 Foundation. . CC-BY-NC-SA 3.0.
- (a) Quique251; (b) Brosen. *[(a) http://commons.wikimedia.org/wiki/File:Brujula.jpg; (b) http://commons.wikimedia.org/wiki/File:Brosen_windrose.svg]*. (a) GNU-FDL 1.2; (b) CC-BY 2.5.

Opening image courtesy of NASA/GSFC/MITI/ERSDAC/JAROS, and U.S./Japan ASTER Science Team, http://www.nasa.gov/multimedia/imagegallery/image_feature_769.html, and is in the public domain.

1.6 References

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5. . HS-ES-2-05-Compass-composite.
6. . HS-ES-02-02-6-Earth-Magnetic-North-Offset.
7. . HS-ES-02-02-7.
8. . HS-ES-02-02-8-Topographic-relief-California.
9. . HS-ES-02-03-9-Globe.
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11. . HS-ES-02-03-11-Map-projection-Earth.
12. . HS-ES-02-03-11-Mercator-projection.
13. . HS-ES-02-03-13-Conic-map-projection.
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25. . HS-ES-02-04-26-Geologic-Map-Yosemite.
26. . HS-ES-02-04-27-World-geologic-map.
27. . HS-ES-02-05-28-Hurricane-Rita.
28. . HS-ES-02-05-29-Satellite-Geostationary.
29. . HS-ES-02-05-30-Satellite-Polar-Orbit.
30. . HS-ES-02-05-31-GPS-receiver-satellites.
31. . HS-ES-02-05-32-Mars-3D-Valles-Marineris.
32. . HS-ES-02-GIS_Map.