Studying Earth Science

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next generation textbooks

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Printed: September 26, 2014

CHAPTER 1 Studying Earth Science

CHAPTER OUTLINE

Introduction

Why do people study Earth science?

A lot of people are attracted to Earth science because they love to be outdoors. These people wonder how the magnificent rock formations that they see, like here in Yosemite in California, were formed. They want to study the processes that create and modify landforms. Some people want to go deeper, to learn about what drives the surface processes and other features of the planet; for example, why does Earth have a magnetic field? These people are interested in learning about the layers of material that lie beneath the surface, the mantle and the core. Since more than 70% of Earth is covered with oceans, it's not surprising that many people wonder what lies within and at the bottom of the seas. Although scientists say that we know more about the far side of the Moon than we do about the deep oceans, we know an awful lot considering how hostile the ocean environment is for humans. Some people look up and wonder what lies beyond our skies. These people are interested in applying what we know about Earth to our more distant surroundings. They want to understand our near neighbors, the planets and satellites of our Solar System, and objects that lie far beyond.

1.1 Branches of Earth Science

- Identify and define the major branches of Earth Science.

If science is the study of the natural world, what could be more obvious than to study the land, sky, water, and space surrounding us?

Earth scientists seek to understand the beautiful sphere on which we live. Earth is a very large, complex system or set of systems, so most Earth scientists specialize in studying one aspect of the planet. Since all of the branches of Earth science are connected, these researchers work together to answer complicated questions. The major branches of Earth science are described below.

Geology

Geology is the study of the Earth's solid material and structures and the processes that create them. Some ideas geologists might consider include how rocks and landforms are created or the composition of rocks, minerals, or various landforms. Geologists consider how natural processes create and destroy materials on Earth, and how humans can use Earth materials as resources, among other topics.

FIGURE 1.1
Geologists study rocks in the field to learn what they can from them.

Oceanography

Oceanography is the study of everything in the ocean environment, which covers about 70% of the Earth's surface. Recent technology has allowed people and probes to venture to the deepest parts of the ocean, but much of the ocean remains unexplored. Marine geologists learn about the rocks and geologic processes of the ocean basins.

Climatology and Meteorology

Meteorology includes the study of weather patterns, clouds, hurricanes, and tornadoes. Using modern technology such as radars and satellites, meteorologists are getting more accurate at forecasting the weather all the time.

Climatology is the study of the whole atmosphere, taking a long-range view. Climatologists can help us better understand how and why climate changes (**Figure** 1.2).

FIGURE 1.2
Carbon dioxide released into the atmosphere is causing the global climate to change.

Environmental Science

Environmental scientists study the effects people have on their environment, including the landscape, atmosphere, water, and living things. Climate change is part of climatology or environmental science.

Astronomy

Astronomy is the study of outer space and the physical bodies beyond the Earth. Astronomers use telescopes to see things far beyond what the human eye can see. Astronomers help to design spacecraft that travel into space and send back information about faraway places or satellites (**Figure** 1.3).

FIGURE 1.3
The Hubble Space Telescope.

Summary

- The study of Earth science includes many different fields, including geology, meteorology, oceanography, and astronomy.
- Each type of Earth scientist investigates the processes and materials of the Earth and beyond as a system.
- Geology, climatology, meteorology, environmental science, and oceanography are important branches of Earth science.

Making Connections

MEDIA
Click image to the left for use the URL below.
URL: http://gamma.ck12.org/flx/render/embeddedobject/55278

Explore More

Use this resource to answer the questions that follow.

https://www.youtube.com/watch?v=pEtg209pvdU

1. What do Earth scientists do?
2. What are the major topics geoscientists study that impact humans?
3. What do geoscientists do that other scientists do?
4. Why do some geoscientists study Earth's interior?
5. What processes continually refines our understanding of Earth?
6. How does the general public learn about scientific advances?

Explore More Answers

1. Earth scientists use repeatable observations and testable ideas to understand and explain our planet.
2. climate change, natural hazards, availability of natural resources, and human impacts on Earth
3. They do reproducible experiments with evidence that comes from field studies, analytical experiments,theoretical deductions and conclusions, and experimental and modeling studies.
4. Deep Earth processes can help us understand what's going on on Earth's surface.
5. Advances in technology, breakthroughs in observations and new interpretations.
6. the media and the internet

Review

1. What type of Earth scientist would be interested in understanding volcanic eruptions on the seafloor?
2. If it were to snow in Phoenix in July, which type of Earth scientist would be most surprised?
3. If people have been studying the natural world for centuries or even millennia, why are scientists learning so much about Earth science now?

Review Answers

1. A marine geologist: a cross between a geologist and an oceanographer.
2. Meteorologists and climatologists would be surprised.
3. Advances in technology and interpretations are constantly changing our understanding of the Earth.

1.2 Earth Science Field Work

Does this look like fun?

For many geologists, a day hiking in beautiful country to learn more about the interesting geology is about as good as it gets!

Field Work

Many Earth scientists collect data in the field. The data may be from observations or measurements. The scientists may create a geological map of the area, write detailed descriptions, or collect samples to analyze in the lab. Or a combination of all of these! Many Earth science laboratories contain high-tech equipment to reveal the chemistry or age of a rock sample. Field work is done to look for resources, for environmental cleanup, or for any number of other reasons. One common reason is just to understand the region better.

Field Trips

To really understand geology and some of the other branches of Earth science, it's best to go out in the field! Some of the concepts presented here focus on regions where geologically interesting features can be seen. In these cases, a location is presented and the phenomena of interest described. It's just like we're going on a field trip! These field trips are great because they don't involve long drives in a car, expensive airplane trips, or a passport! We can do things that are difficult or impossible to do on an ordinary field trip. We can go to any single location on Earth, we can hop along a latitude line, visit the bottom of the ocean, or look to different areas for a specific phenomenon.

Of course, we won't be enjoying the fresh air, exercise, camaraderie, or thrill of discovery in the same way we would on a real field trip, but, hey, you can't have everything! What follows is a brief synopsis of some of the places we'll be visiting. Where possible, we've tried to visit locations in the western United States, an area that may be familiar to you.

California

FIGURE 1.4
Major geographic features of California.

In the satellite image in the **Figure** 1.4, it is possible to identify the major geographic features of California.

- The Coast Range runs the length of the state along the Pacific coast. A tremendous amount of rain falls in the northern part of the range, so the region is heavily forested. Further south, rainfall and vegetation are more sparse.
- The Central Valley, made up of the Sacramento and San Joaquin river valleys, runs through about half of the central part of the state is located inland from the Coast Range. The collection of river sediments and the abundance of water has made the Central Valley one of the most important agricultural regions in the world.
- The Sierra Nevada Mountain range lies east of the Central Valley. In the winter the mountains are covered by snow, but in this image there is little to no snow and the bare rocks of the high peaks are showing, particularly in the southern portion of the range. Yosemite National Park lies within the Sierra Nevada.
- East of the Sierra Nevada and into the state of Nevada, the climate is very arid. Death Valley, the driest spot in the United States is found there.
- Mt Shasta, at the north end of the Sierra Nevada, is the southernmost remaining volcanic cone in the Cascades Range.

Nevada

East of the image of California is Nevada. Very different from California, Nevada is extremely arid. The Basin and Range province, which consists of a set of mountains and valleys, is best displayed in the state. You can see the ranges as dark brown rocky regions and the valleys as lighter brown. The ranges have been described as worms crawling northward across the state, which is what they look like in this image.

Pacific Northwest

FIGURE 1.5
North of California along the Pacific Coast is Oregon, Washington and then British Columbia in Canada. This region is similar to California in having a coastal range, a central valley (at least in part of Oregon) and very arid lands east of the high Cascades mountains.

The Cascades are volcanoes that begin with Lassen in California, run through Oregon and Washington, and continue into British Columbia. Some of them are easily spotted on this image as white spots in the midst of the green forests of the Cascades range.

Idaho, Montana, Wyoming

Glacier National Park

Glacier National Park in the northwestern part of Montana reaches to the Canadian border. North of the border the park becomes the Canadian Waterton Lakes National Park. Although Glacier National Park was established in 1910 to preserve the wild lands and wildlife, the glaciers have been reduced by a reduction in precipitation and higher summer temperatures. On glaciers, snowfields, or just rock, Glacier National Park is a fantastic place to see glacial features, beautiful scenery, and wildlife.

FIGURE 1.6
The closeup image of Mount Hood taken by an astronaut on the International Space Station shows one of the most distinctive of the Cascades composite volcanoes. Solidified lava makes up the summit of the mountain and glaciers are found on both the north and south sides of the peak. Mount Hood is the northernmost Cascade volcano in Oregon and is just south of Mt. St. Helens.

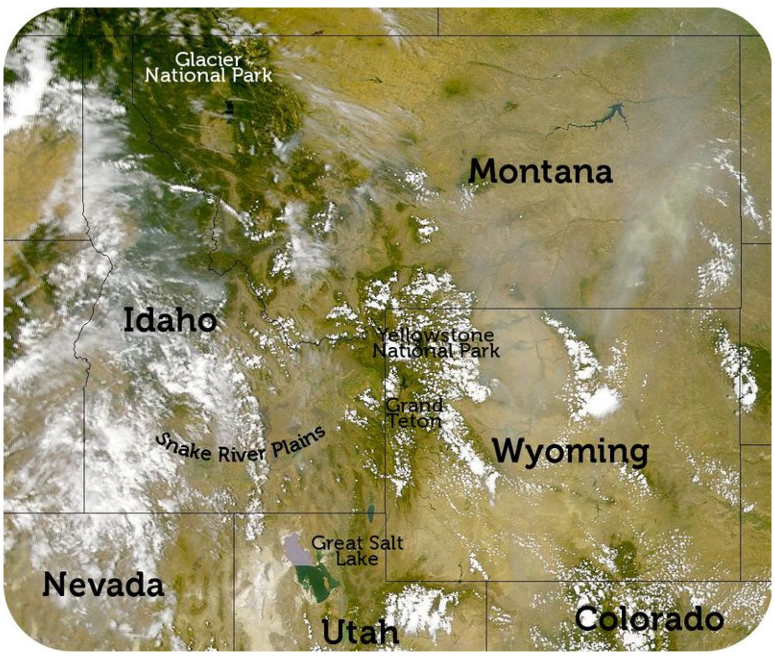


FIGURE 1.7
This image shows the states of Idaho, Montana, Wyoming, with a little of Utah and a few others. The northern part of Idaho and northwestern Montana is mountainous and forested. Arid lands lie to the east.

Yellowstone National Park

Yellowstone National Park is in the northwestern corner of Wyoming. Although Yellowstone is best known for its incredible geysers, the park also has gorgeous mountain scenery and fantastic wildlife, including herds of amazing bison. The best known feature is Old Faithful, a geyser that's not the highest, largest, or most beautiful, but is the most reliable.

Southwest

The Southwestern United States is a great place to study geology. The region is so arid that in most locations rocks and structures are easily seen. In several concepts we will visit parts of the Southwest to view geology in the field.

FIGURE 1.8
This satellite image of GNP in summer shows snow-capped peaks and glacial valleys, many of which are now lakes.

FIGURE 1.9
Naturalists enjoy the hike to Iceberg Lake in Glacier National Park.

Grand Canyon

Geologists say that the Grand Canyon has "layer cake geology" because the rock strata are so easy to see. Sedimentary rocks are like a book that tells of the environment in which they formed. Rock units can be traced across large expanses. Looking down into the Grand Canyon, you get a sense of the vastness of space and of time.

FIGURE 1.10
Grand Prismatic Spring is one of the spectacular features of Yellowstone National Park.

FIGURE 1.11
Bison are just some of the amazing creatures that roam around Yellowstone.

Hawaiian Islands

The Hawaiian Islands are in the central Pacific Ocean, a land of sun, exotic life, and volcanoes. The islands increase in age from the Big Island of Hawaii at the southeast end of the chain through Maui, Kahoolawe, Lanai, Molokai, Oahu, Kauai, and Niihau Islands through the northwest. Kilauea volcano on Hawaii has been erupting almost continuously since 1983 and eruptions are also going on at an underwater volcano called Loihi seamount. Hawaii is a fantastic place to see volcanic eruptions and features.

Summary

- Earth scientists learn about many aspects of their disciplines by going out into the field.
- Field trips are an important part of the education of a geology student.
- The western United States is a great place to see examples of many types of geological phenomena.

FIGURE 1.12
The Southwest is home to mountains, canyons, valleys, and flat lands. Many features discussed in the Earth Science concepts can be seen in the Southwest.

FIGURE 1.13
From the rim, the Grand Canyon gives a sense of the vastness of geologic time and the immensity of the planet.

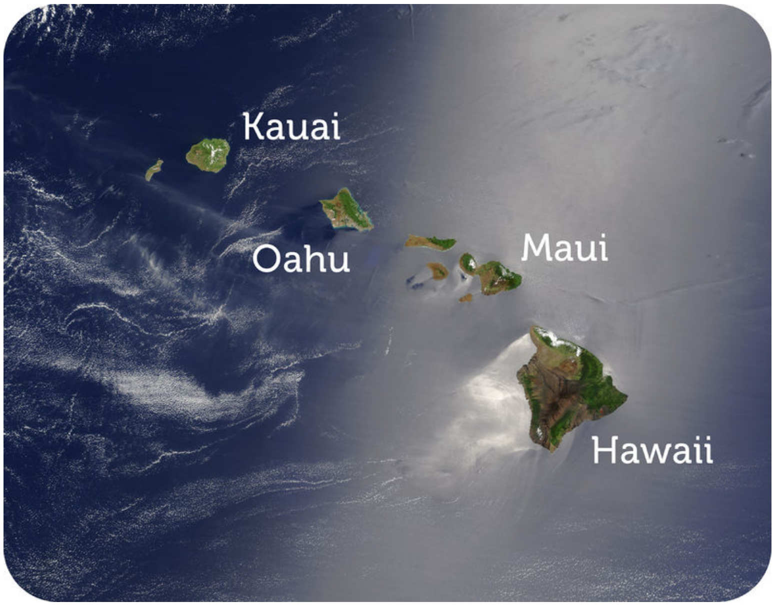


FIGURE 1.14
The Hawaiian Islands from space.

Explore More

Use this resources to answer the questions that follow.

Fieldwork in the School of Geography, Earth and Environmental Science

1. What is the best way to learn about the Earth in a broader context?
2. What can students see in the field that they can't see in a lab from just looking at samples?
3. What do students who are new to geology field work need to learn?
4. What basic geological skills are the students in this class learning?
5. How long a time period are the students seeing material from in Wales?

Explore More Answers

1. To learn in the field.
2. They can look at the relationships between units and at the structures between units.
3. They need to learn how to observe, how to record their observations and how to interpret the recordings.
4. How to produce a geological map on a 1:10,000 scale, how to log a sedimentary section to get more detail out of the sedimentary rocks and how they formed.
5. 200 million years.

Review

1. How does the geography of Oregon parallel the geography of California?
2. Where are the arid lands in the western United States and why are they important for understanding geology?
3. How do the satellite images of the western United States give you a sense of space and time?

Review Answers

1. Like California, Oregon has a long coastline, a coastal mountain range, a central valley, a mountain range (although in Oregon it is made of volcanoes and in California it is granite intrusions through most of the state and volcanoes in the north), and an arid region to the east of the mountains.
2. The arid lands are east of the large mountain ranges and also in much of Arizona, New Mexico, Texas and S. California. Without a lot of weathering and erosion, and trees to cover the landscape, the geology is well exposed and relatively unaltered. It is easy to see and so it is easier to understand.
3. It is easy to see features that were formed by processes that are no longer active or are reduced. For example, there is a lot of evidence of glaciers, but glaciers are currently retreating.

1.3 Principle of Uniformitarianism

- Explain how scientists use knowledge of Earth in the present to understand Earth's history.

What does this mean: "the present is the key to the past"?

How can what you see in this photo help you to figure out what happened in Earth's history? You can see the molten lava and what it looks like when it cools. If you see that type of rock in an outcrop you can assume that it formed from molten lava. This reveals the best tool for understanding Earth history that Earth scientists have. They use what they know about materials and processes in the present to figure out what happened in the past.

Ask a Question –Earth History

The outcrop in the **Figure** 1.15 is at Checkerboard Mesa in Zion National Park, Utah. It has a very interesting pattern on it. As a geology student you may ask: how did this rock form?

If you poke at the rock and analyze its chemistry you will see that it's made of sand. In fact, the rock formation is called the Navajo sandstone. But knowing that the rock is sandstone doesn't tell you how it formed. It would be hard to design an experiment to show how this rock formed. But we can make observations now and apply them to this rock that formed long ago.

Uniformitarianism

James Hutton came up with this idea in the late 1700s. The present is the key to the past. He called this the **principle of uniformitarianism**. It is that if we can understand a geological process now and we find evidence of that same process in the past, then we can assume that the process operated the same way in the past.

Let's go back to that outcrop. What would cause sandstone to have layers that cross each other, a feature called cross-bedding?

FIGURE 1.15
Checkerboard Mesa in Zion National Park, Utah.

Answer a Question –Earth History

In the photo of the Mesquite sand dune in Death Valley National Park, California (**Figure** 1.16), we see that wind can cause cross-bedding in sand. Cross-bedding is due to changes in wind direction. There are also ripples caused by the wind waving over the surface of the dune.

FIGURE 1.16
The Mesquite sand dune in Death Valley National Park, California.

This doesn't look exactly like the outcrop of Navajo sandstone, but if you could cut a cross-section into the face of the dune it would look very similar.

Since we can observe wind forming sand dunes with these patterns now, we have a good explanation for how the Navajo sandstone formed. The Navajo sandstone is a rock formed from ancient sand dunes in which wind direction changed from time to time.

This is just one example of how geologists use observations they make today to unravel what happened in Earth's past. Rocks formed from volcanoes, oceans, rivers, and many other features are deciphered by looking at the geological work those features do today.

Summary

- You may need to apply what you know about the present to determine what happened in the past.
- The idea that the present is the key to the past was recognized by James Hutton in the late 1700s.
- If you see something forming by a process today and then find the end results of that process in the rock record, you can assume that the the process operated the same way in the past.

Explore More

Use this resource to answer the questions that follow.

http://sciencestage.com/v/17802

1. What did James Hutton mean by uniformitarianism?
2. Are there forces from the past that we can't observe today? What is the rate of the forces?
3. Why couldn't Meteor Crater in Arizona be formed by a meteor impact?
4. Why is it catastrophic events that we mostly see in the geological record?
5. Was the carving of the Grand Canyon the result of a catastrophe? Explain your answer.

Explore More Answers

1. the only processes that have happened are the processes that we can see happening.
2. No. The forces that we see are slow.
3. A meteor impact is catastrophic.
4. Normal processes are so slow they aren't preserved. Only catastrophic things are preserved.
5. No. There were lots of floods and lots of slower processes that added up to create the Grand Canyon.

Review

1. What does an Earth scientist often need to answer a question about something that happened in Earth's distant past?
2. James Hutton is sometimes called the father of geology. Why does he merit that title?
3. If you found a layer of ancient lava rock within a sandstone outcrop, what could you say about that lava rock using the principle of uniformitarianism?

Review Answers

1. In order to understand the distant past, it is necessary to understand the processes that operate at the present and the clues they leave, which would help us to identify those processes in the past.
2. Hutton came up with the principle of uniformitarianism, which is crucial to our ability to understand Earth's past. This idea of his makes Hutton a very important person in geology.
3. If you see a lava flow cool and create a certain type of rock, and then you see that same type of rock in an old rock, you can conclude that there was an ancient lava flow that produced that rock.If the lava is in a sandstone you can say that the volcanic eruption interrupted the sedimentary processes that were ongoing in the region.

1.4 Location and Direction

- Identify and define latitude and longitude.
- Use latitude and longitude to find a location.

If you found this feature while out in the field, could you find it again?

If you're going to make observations of Earth systems, you're going to need to know the location where you are so you can mark it on a map. If you find a rock formation filled with gold, you'll want to be able to find the location again! You may need to tell someone when your truck gets stuck when you're in the field so you'll need a direction to give them.

The photo above is of Old Faithful Geyser in Yellowstone National Park. Let's explore just a few of the ways we can pinpoint the location of this famous geological icon.

Location

How would you find Old Faithful? One way is by using latitude and longitude. Any **location** on Earth's surface —or on a map —can be described using these coordinates. Latitude and longitude are expressed as degrees that are divided into 60 minutes. Each minute is divided into 60 seconds.

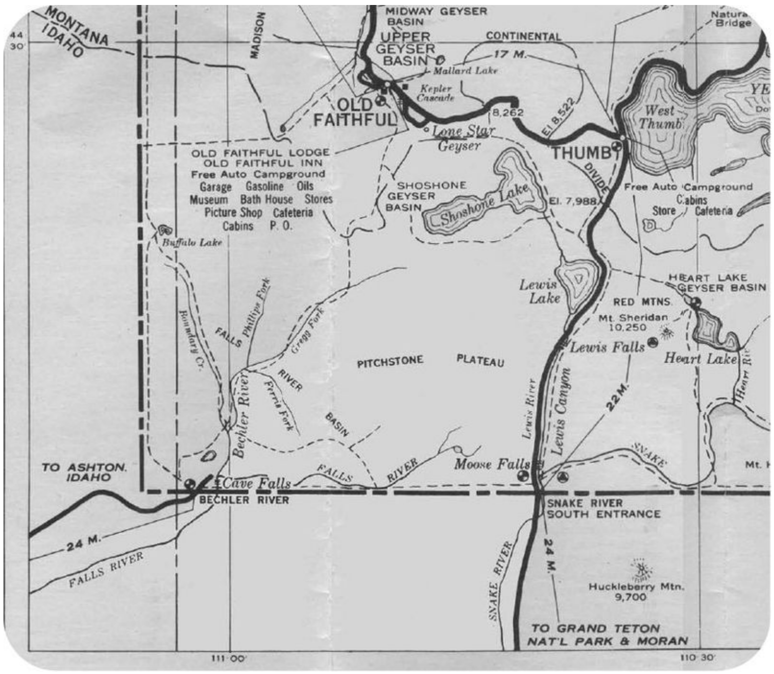


FIGURE 1.17

Latitude

A look on a reliable website shows us that Old Faithful Geyser is located at N44^{o}27' 43". What does this mean?

Latitude tells the distance north or south of the Equator. Latitude lines start at the Equator and circle around the planet. The North Pole is 90^{o}N, with 90 degree lines in the Northern Hemisphere. Old Faithful is at 44 degrees, 27 minutes and 43 seconds north of the Equator. That's just about exactly half way between the Equator and the North Pole!

Longitude

The latitude mentioned above does not locate Old Faithful exactly, since a circle could be drawn that latitude north of the Equator. To locate Old Faithful we need another point –longitude. At Old Faithful the longitude is W110^{o}49'57".

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. Old Faithful is in the Western Hemisphere, between the Prime Meridian in the east and the International Date Line in the west.

Elevation

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. Sea level is the same all around Earth.

Old Faithful is higher above sea level than most locations at 7,349 ft (2240 m). Of course, the highest point on Earth, Mount Everest, is much higher at 29,029 ft (8848 m).

Global Positioning System

Satellites continually orbit Earth and can be used to indicate location. A **global positioning system** receiver detects radio signals from at least four nearby GPS satellites. The receiver measures the time it takes for radio signals to travel from a satellite and then calculates its distance from the satellite using the speed of radio signals. By calculating distances from each of the four satellites the receiver can triangulate to determine its location. You can use a GPS meter to tell you how to get to Old Faithful.

Direction

Direction is important if you want to go between two places. **Directions** are expressed as north (N), east (E), south (S), and west (W), with gradations in between. 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. Since the magnetic north pole is 11.5 degrees offset from its geographic north pole on the axis of rotation, you must correct for this discrepancy.

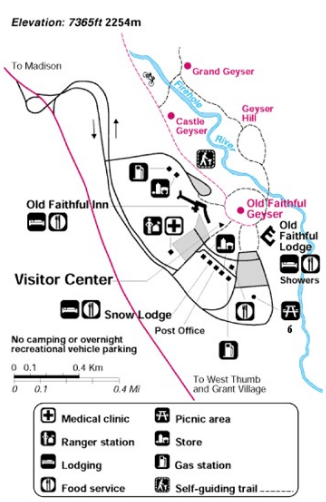


FIGURE 1.18

Map of the Visitor Center at Old Faithful, Yellowstone National Park, Wyoming.

Without using a compass, we can say that to get to Old Faithful, you enter Yellowstone National Park at the South Entrance, drive north-northeast to West Thumb, and then drive west-northwest to Old Faithful.

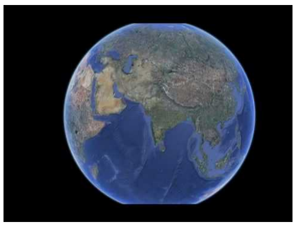
Summary

- Latitude is the distance north or south of the Equator and is expressed as a number between 0 and 90 degrees north or south.

- Longitude is the distance east or west of the Prime Meridian and is expressed as a number between 0 and 180 degrees east or west.
- Elevation is the height above sea level.
- Direction is expressed as north, south, east, or west, or some gradation between them.

Explore More

Use this resource to answer the questions that follow.



MEDIA

Click image to the left for use the URL below.

URL: http://gamma.ck12.org/flx/render/embeddedobject/1643

1. What are lines of latitude?

2. How far apart are the lines of latitude, in degrees, in miles?

3. What are the latitudes of the Equator, the Tropic of Cancer, and the Tropic of Capricorn? What are the characteristics of the regions found between the Tropic of Cancer and Tropic of Capricorn?

4. Where are the Arctic and Antarctic circle? What are the characteristics of the regions that are found poleward of these circles?

5. What are lines of longitude?

6. Where do the meridians meet?

7. What is the Prime Meridian? Where is it located?

8. How are longitude and latitude measured?

Practice your skills at identifying latitude and longitude at the following website - **Latitude and Longitude Map Match Game** at KidsGeo.com. The game is simple to start but becomes more challenging (and fun!) as you progress through the levels. Can you get to level 10? http://www.kidsgeo.com/geography-games/latitude-longitude-map-game.php

Review

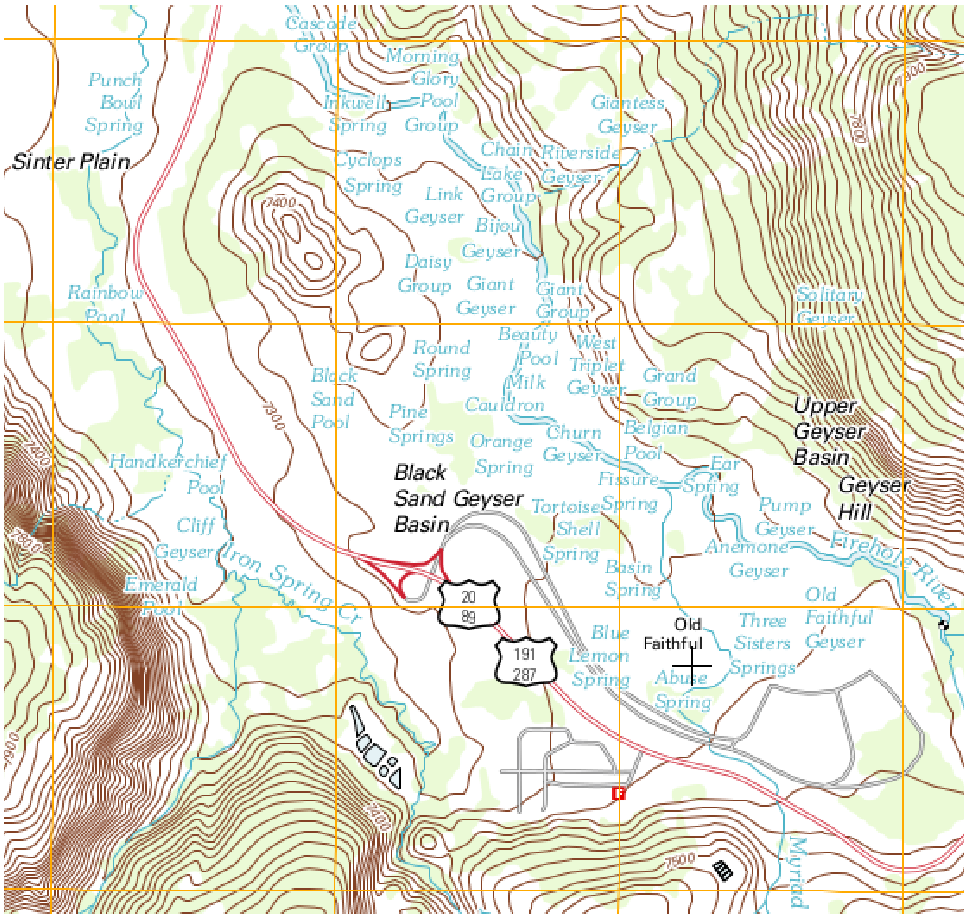
1. Where would a feature at N44^o 27' 43"and W110^{o}49'57"be located?
2. How else might you describe where Old Faithful is?
3. Define latitude and longitude.

Review Answers

1. It would be in the Northern Hemisphere and the Western Hemisphere, in the United States, in the state of Montana. That is the exact location of Old Faithful in Yellowstone National Park.
2. You could describe Old Faithful's location using latitude, longitude and elevation; or by directions on how to get there by roads and on walking paths.
3. Latitude is distance north or south of the equator. Longitude is the distance east or west of the Prime Meridian, which runs through Greenwich, England.

1.5 Maps

- Identify and define types of maps common in Earth science.
- Use maps to find information about a location.



How much information can be put on one map?

What a confusing map! It shows the locations of a few important features in Yellowstone, including Old Faithful, trails, development, trees, streams, and hillsides. But it has all those squiggly lines! Look carefully and try to notice some features about the lines. For example, they don't cross. In some locations they are so close together they nearly form a solid and in other locations they are much farther apart. What is this map trying to tell you?

Topographic Maps

Topographic maps represent the locations of geographical features, such as hills and valleys. Topographic maps use contour lines to show different elevations. A **contour line** is a line of equal elevation. If you walk along a contour line you will not go uphill or downhill. Topographic maps are also called contour maps. The rules of topographic maps are:

- Each line connects all points of a specific elevation.

- Contour lines never cross since a single point can only have one elevation.
- Every fifth contour line is bolded and labeled.
- Adjacent contour lines are separated by a constant difference in elevation (such as 20 ft or 100 ft). The difference in elevation is the **contour interval**, which is indicated in the map legend.
- Scales indicate horizontal distance and are also found on the map legend.

FIGURE 1.19
Old Faithful erupting, Yellowstone National Park.

While the **Figure** 1.19 isn't exactly the same view as the map at the top of this concept, it is easy to see the main features. Hills, forests, development, and trees are all seen around Old Faithful.

Bathymetric Maps

A **bathymetric map** 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.

Kilauea is the youngest volcano found above sea level in Hawaii. On the flank of Kilauea is an even younger volcano called Loihi. The bathymetric map pictured in the **Figure** 1.20 shows the form of Loihi.

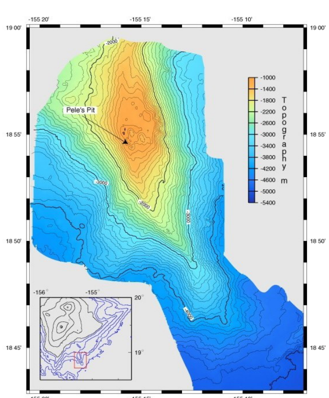


FIGURE 1.20
Loihi volcano growing on the flank of Kilauea volcano in Hawaii. Black lines in the inset show the land surface above sea level and blue lines show the topography below sea level.

Geologic Maps

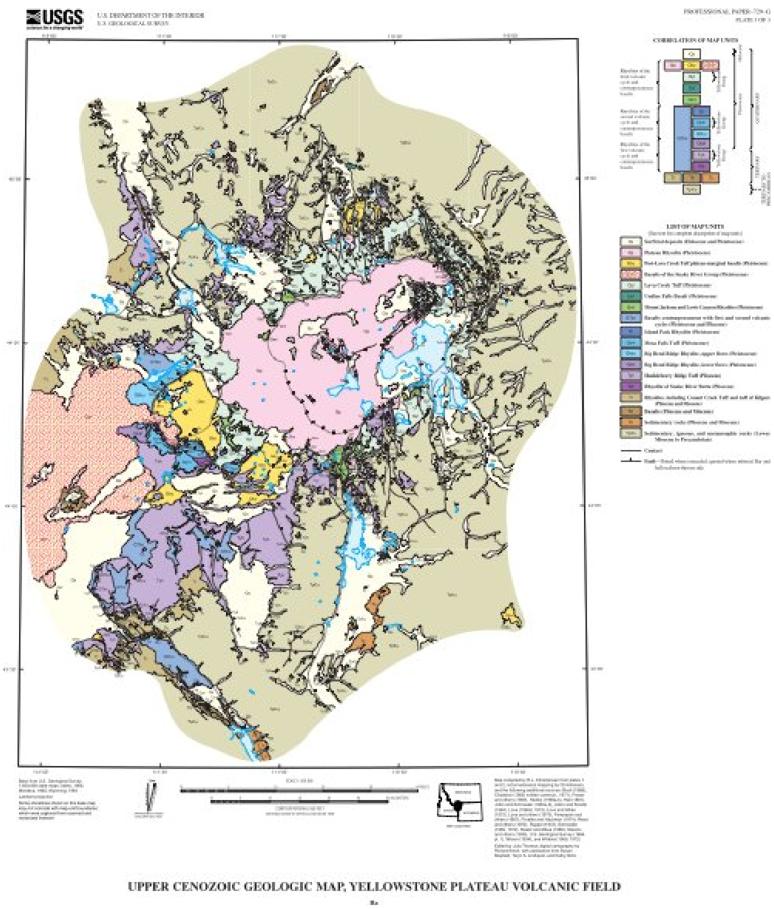


FIGURE 1.21
A geologic map of the region around Old Faithful, Yellowstone National Park.

A **geologic map** shows the geological features of a region (see **Figure** 1.21 for an example). Rock units are color-coded and identified in a key. Faults and folds are also shown on geologic maps. The geology is superimposed on a topographic map to give a more complete view of the geology of the region.

Summary

- Earth scientists regularly use topographic, bathymetric, and geologic maps.
- Topographic maps reveal the shape of a landscape. Elevations indicate height above sea level.
- Bathymetric maps are like topographic maps of features found below the water. Elevations indicate depth below sea level.
- Geologic maps show rock units and geologic features like faults and folds.

Explore More

Use this resource to answer the questions that follow. Just watch to 4:04.

https://www.youtube.com/watch?v=62Hme0-F80U

1. What do topographic maps do and how do they do it?
2. What are the meanings of the terms topographic map, contour line, contour interval and index contour?

3. If you were to walk along a contour line, what would happen to your elevation?
4. If you walk perpendicular to contour lines what are you doing?
5. What do close contour lines indicate?

Explore More Answers

1. They depict a 3-d earth on a 2-d surface by using a contour line.
2. Topographic map: Map that shows the topography of a region. Contour line: lines that connect points of equal elevation. Contour interval: The difference in elevation between contour lines. Index contour: Every 5th contour line is darker; provides a frame of reference.
3. Elevation does not change along a contour line so your elevation does not change.
4. Walking uphill or downhill.
5. A steep slope.

Review

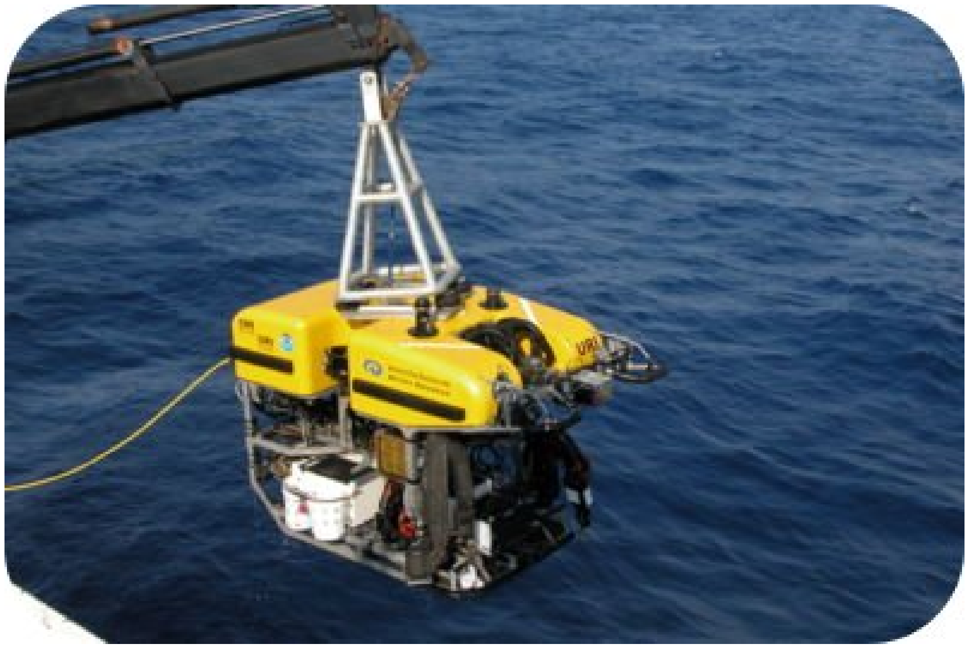
1. What will a hill look like on a topographic map? How will a basin look different from a hill?
2. How will a steep slope look different from a shallow slope?
3. What would a geologic map of the Grand Canyon look like? Remember that the Grand Canyon has many layers of rocks exposed like a layer cake.

Review Answers

1. A hill looks like a bulls-eye with the high point in the center. Most hills will not be that round. A basin will look similar but the low point will be at the center. Hatch lines point inward.
2. For a steep slope the contour lines are very close together. For a shallow slope the contour lines are very far apart.
3. A geologic map of the ground canyon has contour lines very close together where the canyon slopes are. The colors that indicate different rock layers are striped and paralleling the canyon sides.

1.6 Seafloor

- Describe ways scientists learn about the deep ocean.



Is it true that we know more about the dark side of the Moon than we do about the oceans?

It's true! Why do you think so? The oceans are deep, dark, frigid, and under extraordinarily high pressure at all but the surface. It's hard to imagine an environment that's less hospitable to human life! Yet, as you will see, we know quite a bit about the oceans and this is due mostly to technology. Rovers, like the one pictured, allow scientists to go to places that are too inhospitable or dangerous for human life.

Studying the Seafloor

Scuba divers can only dive to about 40 meters, and they cannot stay down there for very long. Although this is good for researching the organisms and ecosystems very near a coast, most oceanic research requires accessing greater depths.

Seafloor Bathymetry

How do scientists create bathymetric maps like the one of Loihi volcano in Hawaii shown in the concept "Maps"? Early explorers mapped a small amount of the seafloor by painstakingly dropping a line over the side of a ship to measure the depth at one tiny spot at a time. Then, during World War II, battleships and submarines carried **echo sounders** to locate enemy submarines (**Figure** 1.22). Echo sounders produce sound waves that travel outward in all directions, bounce off the nearest object, and then return to the ship. By knowing the speed of sound in seawater, scientists calculate the distance to the object based on the time it takes for the wave to make a round trip.

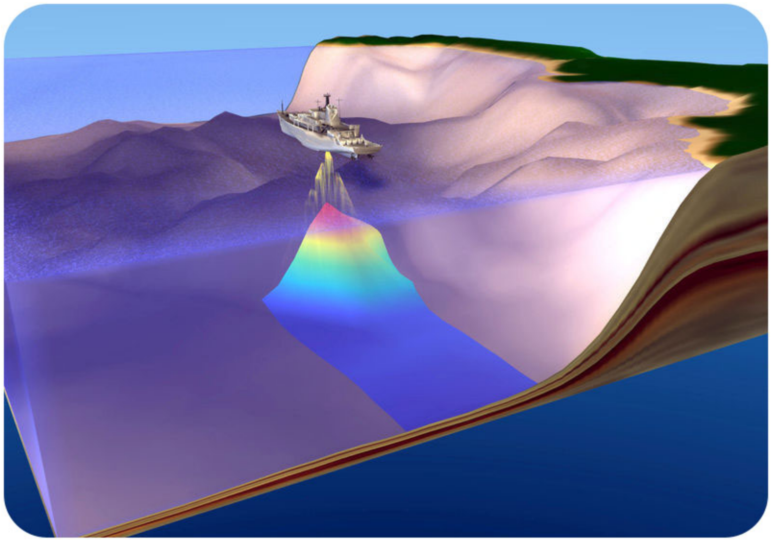


FIGURE 1.22

This echo sounder has many beams and creates a three dimensional map of the seafloor. Early echo sounders had a single beam and created a line of depth measurements.Echo sounders now have many beams to get a more detailed and more rapid picture of the seafloor.

Sampling Remotely

Samples of seawater from different depths in the water column are needed to understand ocean chemistry. To do this, bottles are placed along a cable at regular depths and closed as a weight is dropped down the cable. The water trapped in the bottle can be analyzed later in a laboratory (**Figure** 1.23).

Scientists are also interested in collecting rock and sediment samples from the seafloor. A dredge is a giant rectangular bucket that is dragged along behind a ship to collect loose rocks. Gravity corers are metal tubes that fall to the seafloor and slice into the sediments to collect a sample. The research vessel, the *Joides Resolution*, drills deep into the seafloor to collect samples of the sediment and ocean crust. Scientists analyze the samples for chemistry and paleomagnetism.

Submersibles

Samples of seawater and rocks can be collected directly by scientists in a **submersible**. These subs can take scientists down to make observations. The subs have arms for collecting samples. The human operated vehicle Alvin can dive up to 4,500 m beneath the ocean surface and has made more than 4,400 dives since 1964 (**Figure** 1.24).

Remotely Operated Vehicles

To avoid the expense, dangers, and limitations of human missions under the sea, **remotely operated vehicles**, or ROVs, allow scientists to study the ocean's depths by using small vehicles carrying cameras and scientific instruments. ROVs were used to study the *Titanic*, which would have been far too dangerous for a manned sub to enter. Scientists control ROVs electronically with sophisticated operating systems.

Footage of the NOAA *Titanic* Expedition of 2004 is visible in this video: http://www.youtube.com/watch?v=6Z7RE EnwKOQ .

Summary

- Most of the ocean is less well known than the dark side of the Moon because it is inhospitable and inaccessible.
- Echo sounders use sound waves to make bathymetric maps.

FIGURE 1.23
A Niskin bottle being deployed off the side of a research ship.

- Submersibles and ROVs allow scientists to view otherwise inhospitable regions either directly or remotely.

Explore More

Use this resource to answer the questions that follow.

http://www.ted.com/talks/robert_ballard_on_exploring_the_oceans

1. What is NOAA?
2. How did people study the ocean bottom in Ballard's early career years?
3. What was Ballard's expedition in 19xx looking for at the bottom of the ocean at the Galapagos Rift? What did they find?
4. Which natural resources are found at the mid-ocean ridge?
5. How do the giant clams found at the vents feed themselves?
6. What are some of the advantages of robotic technologies over manned submersibles for deep sea exploration?
7. Hydrogen sulfide preserves organics (without oxygen they do not degrade). What does Ballard expect to find in the Black Sea?
8. What's the purpose of the command center?
9. Why are kids the best drivers of remote vehicles?
10. Should we colonize the sea? Why or why not?

FIGURE 1.24
Alvin allows two people and a pilot to make a nine hour dive.

Explore More Answers

1. The National Oceanic and Atmospheric Administration.
2. In a manned submersible.
3. The missing heat. Giant chimneys.
4. The chimneys have chemicals that have commercial grade copper, lead, silver, zinc and gold.
5. Their bodies have been taken over by bacteria that produce food by chemosynthesis.
6. The robots don't need to come back to the surface.
7. Perfectly preserved bodies and other organics.
8. To collect and disseminate data from oceanographic expeditions.
9. They have more gaming experience.
10. Answers will vary.

Review

1. How does an echo sounder work?
2. Why is an ROV better for some tasks than a submersible? Why is a submersible better for some tasks than an ROV?
3. How do marine geologists collect rock and sediment samples?

Review Answers

1. A pulse of sound is emitted from the base of the ship. The time it takes for the sound to hit the bottom and return gives the distance to the bottom, if the speed of sound in water is known.
2. ROVs are better because they are less expensive and they can do things that are too dangerous for submersibles that absolutely must return to the surface because they have passengers.
3. Marine geologists collect rocks with dredges and submersibles and sediments with gravity corers.

1.7 Telescopes

- Describe different types of telescopes and explain their relationship to electromagnetic radiation.
- Explain how scientists use telescopes of various types to understand space.

WWGD? What would Galileo do (if he could see the things we can see through a telescope)?

If you think oceans are inhospitable, try space! Humans have been to our Moon and many have orbited Earth in spacecraft, even staying for months at a time in a space station. Much of what has been learned about space since Galileo has been through a telescope. Although astronomers use very large telescopes, many of which pick up wavelengths of energy other than visible light, there is still much to be gained from looking at the planets and stars on a clear night. If you haven't ever looked at the night sky through a telescope you should try to soon!

Electromagnetic Radiation

Electromagnetic (EM) radiation is energy that is transmitted through space as a wave. Light is one type of EM wave. An EM wave has two components: an electric field and a magnetic field. Each of these components oscillates between positive and negative values. The distance between two adjacent oscillations is called a **wavelength**. Frequency measures the number of wavelengths that pass a given point every second. Wavelength and frequency are reciprocal, which means that as one increases, the other decreases.

Visible light —the light that human eyes can see —comes in a variety of colors. The color of visible light is determined by its wavelength. Visible light ranges from wavelengths of 400 nm to 700 nm, corresponding to the colors violet through red. EM radiation with wavelengths shorter than 400 nm or longer than 700 nm exists all around you —you just can't see it. The full range of electromagnetic radiation, or the **electromagnetic spectrum**, is shown in **Figure** 1.25.

Like our Sun, every star emits light at a wide range of wavelengths, all across the visible spectrum and even outside the visible spectrum. Astronomers can learn a lot from studying the details of the spectrum of light from a star.

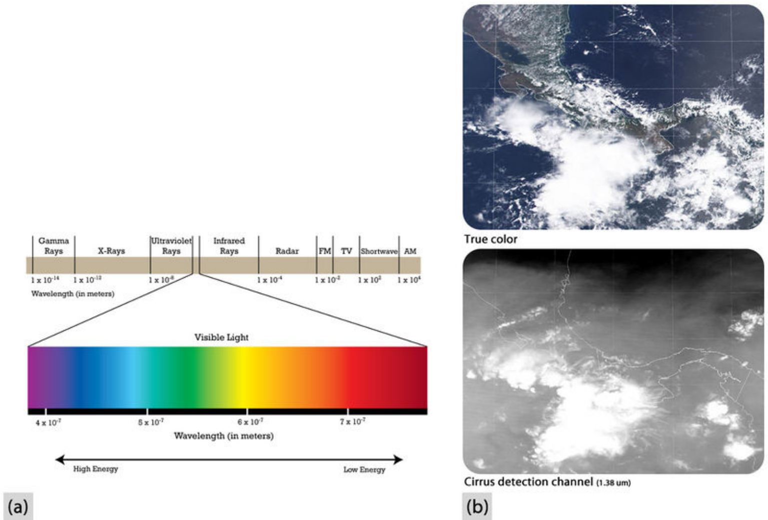


FIGURE 1.25

(a) Visible light is part of the electromagnetic spectrum, which ranges from gamma rays with very short wavelengths, to radio waves with very long wavelengths. (b) These are images of the same scene. In the top, only the wavelengths of visible light show. In the bottom, a layer of thick clouds appears in the infrared wavelengths.

Types of Telescopes

The term "telescope" was coined by the Italian scientist and mathematician Galileo Galilei (1564–1642). Galileo built the first telescope in 1608 and subsequently made many improvements to telescope design.

Optical Telescopes

Telescopes that rely on the refraction, or bending, of light by lenses are called **refracting telescopes**, or simply "refractors." Galileo's and other early telescopes were all refractors. Many of the small telescopes used by amateur astronomers today are refractors. Refractors, including this one at the Lick Observatory near San Jose, California, are particularly good for viewing details within our solar system, such as the surface of Earth's Moon or the rings around Saturn.

Around 1670, Sir Isaac Newton created the first **reflecting telescopes**, or "reflectors." The mirrors in a reflecting telescope are much lighter than the heavy glass lenses in a refractor. This is significant, because:

- To support the thick glass lenses, a refractor must be strong and heavy.
- Mirrors are easier to make precisely than it is to make glass lenses.
- Because they do not need to be as heavy to support the same size lens, reflectors can be made larger than refractors.

Larger telescopes can collect more light and so they can study dimmer or more distant objects. The largest optical telescopes in the world today are reflectors. Several large reflecting telescopes are located at the summit of Mauna Loa volcano in Hawaii, shown in **Figure** 1.26.

Using sound and laser technology, researchers have begun to reveal the secrets of the ocean floor from the Sonoma Coast to Monterey Bay. By creating complex 3-D maps, they're hoping to learn more about waves and achieve ambitious conservation goals.

Find out more by watching this video at http://www.kqed.org/quest/television/amateur-astronomers .

MEDIA

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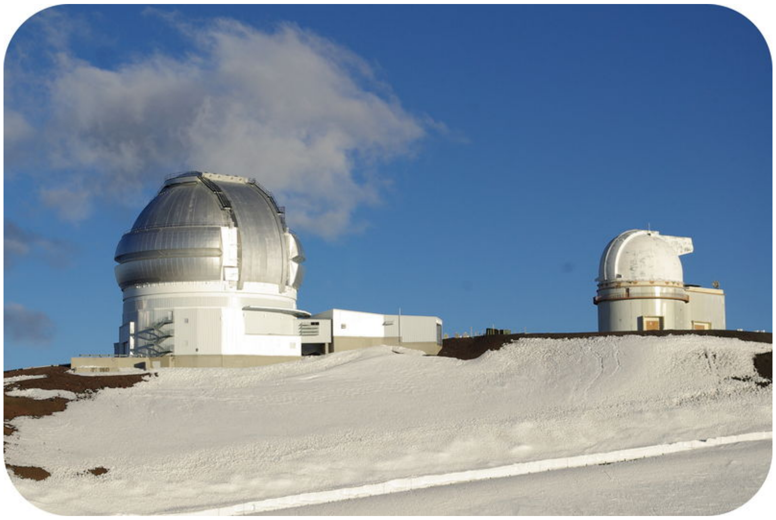

FIGURE 1.26

Telescopes on top of Mauna Kea in Hawaii.

Radio Telescopes

Even larger telescopes are built to collect light at longer wavelengths —radio waves. **Radio telescopes** collect and focus radio waves or **microwaves**, the waves with the shortest wavelength, from space.

The largest single telescope in the world is at the Arecibo Observatory in Puerto Rico (**Figure** 1.27). This telescope is located in a naturally occurring hole so that it does not collapse under its own weight. Since the telescope is set into the ground, it cannot be aimed to different parts of the sky and so can only observe the part of the sky that happens to be overhead at a given time.

A group of radio telescopes can be linked together with a computer so that they are all observing the same object (**Figure** 1.28). The computer combines the data, making the group function like one single telescope.

Scientists have upped their search for extraterrestrial intelligence with the Allen Telescope Array, a string of 350 radio telescopes, located 300 miles north of San Francisco. Find out why SETI scientists now say we might be hearing from ET sooner than you think.

See more at http://science.kqed.org/quest/video/seti-the-new-search-for-et/ .

MEDIA

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FIGURE 1.27
The radio telescope at the Arecibo Observatory has a diameter of 305 m.

FIGURE 1.28
Radio telescopes at the Very Large Array, the National Radio Observatory in New Mexico.

SETI listens for signs of other civilization's technology. Dr. Jill Tartar explains the program: What it's looking for; what the problems are; what the potential benefits are. Dr. Tartar also explains the Allen Telescope Array and its role in SETI.

See more at http://www.youtube.com/watch?v=QwEm3WHvNHI .

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Space Telescopes

Earth's atmosphere not only blocks radiation in some parts of the EM spectrum, but also distorts light. Observatories built on high mountains lessen these problems, but **space telescopes** avoid such problems completely because they orbit outside Earth's atmosphere. Space telescopes can carry instruments to observe objects emitting various types of electromagnetic radiation, such as visible, infrared, or ultraviolet light; gamma rays; or x-rays.

The Hubble Space Telescope (HST), shown in **Figure** 1.29, has orbited Earth for more than 20 years, sending back the most amazing images and helping to answer many of the biggest questions in astronomy. The James Webb Space Telescope, designed to replace the aging Hubble, is targeted for launch in 2018.

Find out more by visiting the Hubble Space Telescope website at http://hubblesite.org .

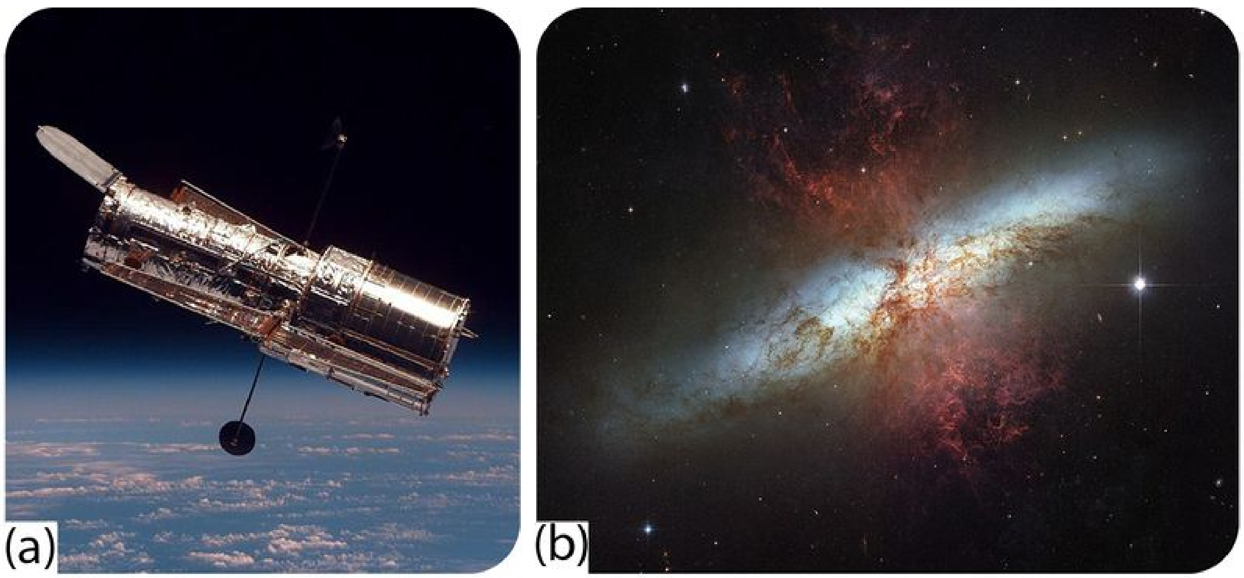

FIGURE 1.29
(a) The Hubble Space Telescope orbits Earth at an altitude of 589 km (366 mi). It collects data in visible, infrared, and ultraviolet wavelengths. (b) This starburst cluster is one of the many fantastic images taken by the HST over the past two decades.

Summary

- Electromagnetic radiation is energy transmitted as waves with different wavelengths, which appear in the electromagnetic spectrum.
- Refracting and reflecting telescopes are optical telescopes that use lenses to gather light.
- Radio telescopes collect radio waves and are sometimes used in large arrays.
- Space telescopes can see much more than Earth-bound telescopes since the atmosphere doesn't affect their information.

Explore More

Use this resource to answer the questions that follow.

- **Introduction to Telescopes** at

https://www.youtube.com/watch?v=Fz0gBULEDMc

1. Why do we need telescopes?
2. What type of telescopes do modern astronomers use and where do they view the information?
3. Describe the three powers of a telescope.
4. What is refraction? What does the light eventually reach? Why does this happen?
5. What is caused by dispersion?
6. Why do stars twinkle?
7. How does a refractor work?

Explore More Answers

1. Celestial bodies are too far away to collect samples; they can collect radiation.
2. They use reflecting telescopes that have data on a computer.
3. Collecting: bigger collects more light; focusing: mirrors or lenses bend light to create images; resolving: picking out the details of an image.
4. Light moving at an angle from one material to another it will bend. The focal point. The speed of light is different in different materials.
5. Dispersion causes different colors to travel at different speeds through the same material.
6. Starlight is bent in the atmosphere and wind moves pockets of slightly cooler air across your line of sight.
7. Lens employs refraction to bend the light.

Review

1. Describe each of the types of telescopes discussed here: reflecting, refracting, radio, and space.
2. What are the limitations of each type of telescope discussed here?
3. Look at the electromagnetic spectrum. Do you think other types of telescopes could get other types of information if they gathered different wavelengths?

Review Answers

1. Reflecting telescopes use mirrors to collect and focus light. Refracting telescopes use convex lenses to collect and focus light. Radio telescopes collect radio waves or microwaves. Space telescopes orbit above most of the atmosphere so they get less interference from the atmosphere.
2. Refracting telescopes have limitations because they use lenses to bend light and lenses are hard to make and are heavy. These telescopes can't be too big. Reflecting telescopes use mirrors, which is much better than lenses. Their limitations are mostly from the interference from the atmosphere
3. Yes different types of electromagnetic waves can be picked up by different types of telescopes. They all supply information on the solar system and space.

1.8 Satellites, Shuttles, and Space Stations

- Describe tools astronomers use to study space.

Function over fashion?

Why do astronauts need to wear such a funny suit? What would happen if they didn't? Just like space telescopes see more when they're outside Earth's atmosphere, astronauts can see and learn more from space, too. And to do that they need to surround themselves in a habitable environment. Despite a few setbacks, some of them tragic, the space program has made tremendous advances in our understanding of what lies beyond our planet. Space programs also advance technologies here on Earth.

Rockets

A **rocket** is propelled into space by particles flying out of one end at high speed (see **Figure** 1.30). A rocket in space moves like a skater holding the fire extinguisher. Fuel is ignited in a chamber, which causes an explosion of gases.

The explosion creates pressure that forces the gases out of the rocket. As these gases rush out the end, the rocket moves in the opposite direction, as predicted by Newton's Third Law of Motion. The reaction force of the gases on the rocket pushes the rocket forward. The force pushing the rocket is called thrust. Nothing would get into space without being thrust upward by a rocket.

FIGURE 1.30
The space shuttle Atlantis being launched into orbit by a rocket on Cape Canaveral, Florida.

Satellites

One of the first uses of rockets in space was to launch satellites. A **satellite** is an object that orbits a larger object. An **orbit** is a circular or elliptical path around an object. The Moon was Earth's first satellite, but now many human-made "artificial satellites" orbit the planet. Thousands of artificial satellites have been put into orbit around Earth (**Figure** 1.31). We have even put satellites into orbit around the Moon, the Sun, Venus, Mars, Jupiter, and Saturn.

There are four main types of satellites.

- Imaging satellites take pictures of Earth's surface for military or scientific purposes. Imaging satellites study the Moon and other planets.
- Communications satellites receive and send signals for telephone, television, or other types of communications.
- Navigational satellites are used for navigation systems, such as the Global Positioning System (GPS).
- The International Space Station, the largest artificial satellite, is designed for humans to live in space while conducting scientific research.

Space Stations

Humans have a presence in space at the International Space Station (ISS) (pictured in **Figure** 1.32). Modern space stations are constructed piece by piece to create a modular system. The primary purpose of the ISS is scientific research, especially in medicine, biology, and physics.

Space Shuttles

Craft designed for human spaceflight, like the Apollo missions, were very successful, but were also very expensive, could not carry much cargo, and could be used only once. To outfit the ISS, NASA needed a space vehicle that was reusable and able to carry large pieces of equipment, such as satellites, space telescopes, or sections of a space station. The resulting spacecraft was a **space shuttle**, shown in (**Figure** 1.33).

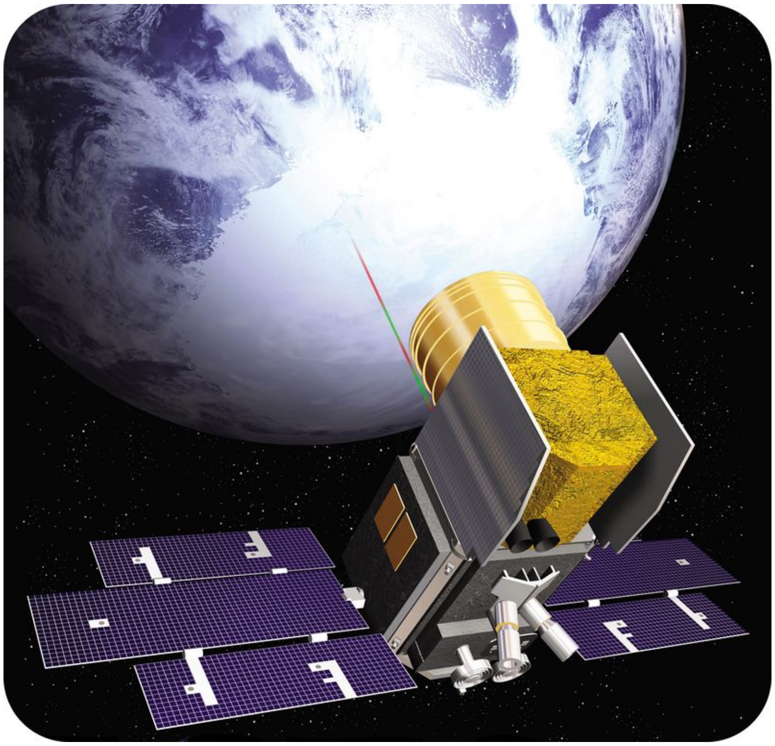

FIGURE 1.31
Satellites operate with solar panels for energy.

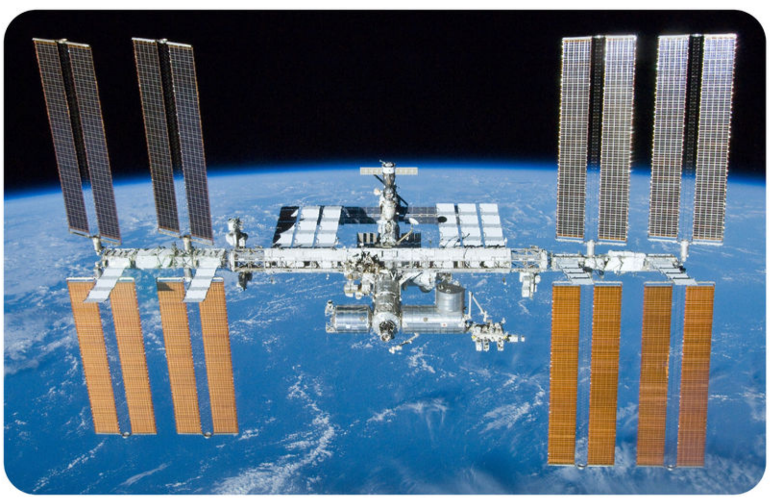

FIGURE 1.32
A photograph of the International Space Station was taken from the space shuttle Atlantis in June 2007. Construction of the station was completed in 2011, but new pieces and experiments continue to be added.

A space shuttle has three main parts. The part you are probably most familiar with is the **orbiter**, with wings like an airplane. When a space shuttle launches, the orbiter is attached to a huge fuel tank that contains liquid fuel. On the sides of the fuel tank are two large "booster rockets." All of this is needed to get the orbiter out of Earth's atmosphere. Once in space, the orbiter can be used to release equipment (such as a satellite or supplies for the International Space Station), to repair existing equipment such as the Hubble Space Telescope, or to do experiments directly on board the orbiter.

When the mission is complete, the orbiter re-enters Earth's atmosphere and flies back to Earth more like a glider than an airplane. The Space Shuttle program did 135 missions between 1981 and 2011, when the remaining shuttles were retired. The ISS is now serviced by Russian Soyuz spacecraft.

FIGURE 1.33
Atlantis on the launch pad in 2006. Since 1981, the space shuttle has been the United States' primary vehicle for carrying people and large equipment into space.

FIGURE 1.34
The space shuttle orbiter Atlantis touches down at the Kennedy Space Center in Florida.

Summary

- Rockets are propelled into space by particles flying out one end at high speed. Nothing would get into space without them.
- Thousands of artificial satellites orbit Earth. Satellites are used for imaging, communications, navigation, and human habitation.
- Space stations are continuously inhabited by humans and are used for scientific research.

Explore More

Use these resources to answer the questions that follow.

MEDIA

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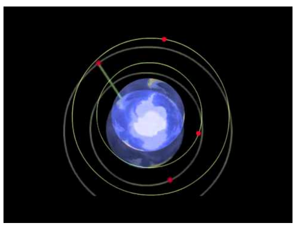
1. What are satellites used for?
2. Explain how geostationary orbit works.
3. How far are geostationary orbits above the earth?
4. What is orbital position?
5. What determines satellite life?



MEDIA

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6. What is a geostationary satellite and what are its characteristics?
7. What is a polar satellite and what are its characteristics

MEDIA

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URL: http://gamma.ck12.org/flx/render/embeddedobject/1642

8. How do astronauts get to the ISS?
9. List your observations about the ISS.
10. Does it look like fun to be on the ISS?

Explore More Answers

1. Broadcasting, entertainment, broadband data, communications.
2. A body stays in orbit when gravitational forces are balanced by centrifugal forces.
3. 36,000 km above equator, 1/10 of way to move. A satellite will stay in the same position.
4. A box in which satellites are parked.
5. Satellite life is determined by amount of fuel it carries and how to maximize its efficiency.
6. Geostationary orbit is around the equator; the satellite rotates in same direction as earth, its speed matches Earth's rotation and so it stays over exactly the same point; these satellites are essential for communication and GPS.
7. Polar orbiting satellites orbit pole to pole. They are at low altitudes and each orbit about 1.5 hours. They examine changes on earth's surface in 24 hours.

8. They travel to and from ISS on some type of space shuttle.
9. People are weightless; lots of gear and computers; packaged food; nothing alive but people; there are many more possibilities.
10. Answers will vary.

Review

1. How does a rocket work?
2. Why are there so many satellites orbiting Earth at this time?
3. Would you like to spend months in the International Space Station? If so, what would you be interested in studying? If not, why not?

Review Answers

1. For every action there is an equal and opposite reaction, even in space. Gases in the rocket chamber explode out one side causing the rocket to thrust in the opposite direction.
2. Satellites do all sorts of things these days; they are used for communication, observing, location position, etc.
3. Answers will vary. Reasons to go up would be to see Earth from above, to experience weightlessness, to engage in scientific research.

Summary

In *Principles of Science* you learned what science is and how science is different from other ways of viewing the world. In this chapter, you will learn about what Earth Science encompasses and how it is done. Earth scientists learn about the world by using a lot of amazing tools and scientific principles. To understand things that are small or far away, a microscope or a telescope is necessary. To learn about things on the ground, a good map is useful. Rocks and other earth materials are analyzed chemically. As technology has advanced we've learned more about the oceans and space. One of the most important principles - and the most important for understanding Earth history - is "the present is the key to the past." By understanding the present, we can try to piece together Earth's magnificent 4.6 billion year history.

1.9 References

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2. Walter Siegmund. Carbon dioxide released into the atmosphere by this factory is causing the global climate to change. CC BY 2.5
3. Courtesy of NASA. The Hubble Space Telescope. Public Domain
4. Courtesy of Jacques Descloitres, MODIS Land Rapid Response Team, NASA/GSFC. Map of major geographic features of California. Public Domain
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