


Earth's History

CALIFORNIA

Standards Preview

S 7.4 Evidence from rocks allows us to understand the evolution of life on Earth. As a basis for understanding this concept:

- a.** Students know Earth processes today are similar to those that occurred in the past and slow geologic processes have large cumulative effects over long periods of time.
- b.** Students know the history of life on Earth has been disrupted by major catastrophic events, such as major volcanic eruptions or the impacts of asteroids.
- c.** Students know that the rock cycle includes the formation of new sediment and rocks and that rocks are often found in layers, with the oldest generally on the bottom.
- d.** Students know that evidence from geologic layers and radioactive dating indicates Earth is approximately 4.6 billion years old and that life on this planet has existed for more than 3 billion years.
- f.** Students know how movements of Earth's continental and oceanic plates through time, with associated changes in climate and geographic connections, have affected the past and present distribution of organisms.
- g.** Students know how to explain significant developments and extinctions of plant and animal life on the *geologic time scale*.

A photograph of a man with a beard and long hair, wearing a red and white plaid shirt, leaning over a large fossilized dinosaur skeleton. The skeleton is the focus of his attention, and he appears to be examining it closely. The background is dark, suggesting a museum setting.

A paleontologist examines a fossilized dinosaur skeleton in the Denver Museum of Nature and Science.



Video Preview

Discovery Channel School

A Trip Through Geologic Time



Focus on the
BIG Idea



S 7.4.d

How does evidence from rocks help scientists understand Earth's history?

Check What You Know

While hiking, you find a rock containing a small fossil. The fossil looks like the shell of a present-day clam. When this fossilized organism was alive, what kind of environment existed in the area where you are hiking? Explain your answer.



Fossil brachiopod ▲

Build Science Vocabulary

The images shown here represent some of the key terms in this chapter. You can use this vocabulary skill to help you understand the meaning of some key terms in this chapter.

Vocabulary Skill

Use Clues to Determine Meaning

In this textbook, important new words, or key terms, first appear in dark type with a yellow highlight. The meanings, or definitions, of these words usually follow the new terms. In addition to the definitions themselves, there are often other clues that help you understand the meanings. The example below introduces the key term *relative age*.

What *relative age* means

A similar example

The **relative age** of a rock is its age compared to the ages of other rocks. You have probably used the idea of relative age when comparing your age with someone else's age, such as the age of an older brother or younger sister. The relative age of a rock does not give the exact number in years since the rock was formed.

What the term does not mean

Apply It!

1. In your own words, explain what *relative age* means.
2. What familiar example is relative age compared to?

index fossil



Chapter 8 Vocabulary

Section 1 (page 268)

geology
erosion
uniformitarianism
igneous rock
sedimentary rock
metamorphic rock
rock cycle
magma
lava

Section 2 (page 272)

relative age intrusion
absolute age fault
law of unconformity
superposition inclusion
extrusion index fossil

Section 3 (page 279)

atom
element
radioactive decay
half-life

Section 4 (page 283)

plate
theory of plate tectonics
continental drift

Section 5 (page 286)

geologic time amphibian
scale reptile
era mass extinction
period mammal
invertebrate
vertebrate



igneous rock



mass extinction

plates



mammal



**Build Science Vocabulary
Online**

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Web Code: cvj-2080

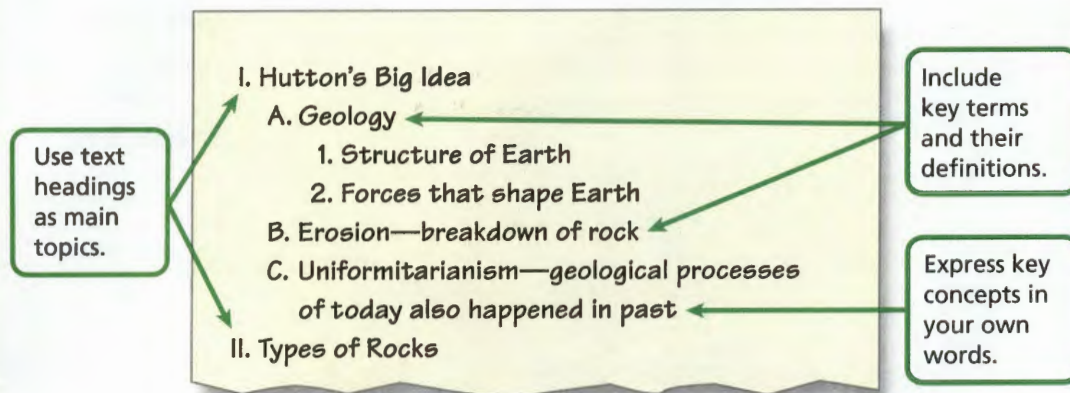
How to Read Science

Reading Skill



Create Outlines

In an outline, you show the relationship between main ideas and supporting ideas. An outline is usually set up like the example shown below. Roman numerals show the main topics. Capital letters and regular numerals show the subtopics. Use the chapter's headings, subheadings, key concepts, and key terms to help you decide what to include in your outline. Look at the sample outline for part of Section 1.



Apply It!

1. What is the first main topic in the outline above?
2. What are the three subtopics under this main topic?
3. Compare the definition of uniformitarianism in the outline to the definition in Section 1. How are they similar? How are they different?

Complete the outline above for Section 1 in this chapter. Create an outline for Section 5 in this chapter.



S 7.4.g

A Journey Through Geologic Time

This chapter will take you on a journey through geologic time. You will learn how fossils reveal the history of life on Earth. To guide you on your journey, you and your classmates will make a timeline showing the many periods of geologic time.

Your Goal

To become an expert on one geologic time period and assist in constructing a timeline

To complete this investigation, you must

- research a geologic time period of your choice
- create a travel brochure that shows what life was like in this time period
- illustrate your time period for the timeline
- follow the safety guidelines in Appendix A

Plan It!

Begin by selecting a time period you would like to investigate. Check with your teacher to be sure that all the time periods will be covered by members of your class. Then, collect information on your time period's animals, plants, and environment. Use this information to write a travel brochure about your time period. Create illustrations that depict your time period and place them on the timeline. Use the travel brochure to present your geologic time period to your classmates.



The Rock Cycle

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Standards Focus

S 7.4.a Students know Earth processes today are similar to those that occurred in the past and slow geologic processes have large cumulative effects over long periods of time.

S 7.4.c Students know that the rock cycle includes the formation of new sediment and rocks and that rocks are often found in layers, with the oldest generally on the bottom.

- What is uniformitarianism?
- What is the rock cycle?

Key Terms

- geology
- erosion
- uniformitarianism
- igneous rock
- sedimentary rock
- metamorphic rock
- rock cycle
- magma
- lava

Lab zone
Standards Warm-Up
How Does Pressure Affect Particles of Rock?

1. Place a sheet of paper over a slice of soft bread.
2. Put a stack of several heavy books on top of the paper. After 10 minutes, remove the books. Observe what happened to the bread.
3. Slice the bread so you can observe its cross section.
4. Carefully slice a piece of fresh bread and compare its cross section to that of the pressed bread.

Think It Over

Observing How did the bread change after you removed the books? Describe the texture of the bread. How does the bread feel? What can you predict about how pressure affects rocks?

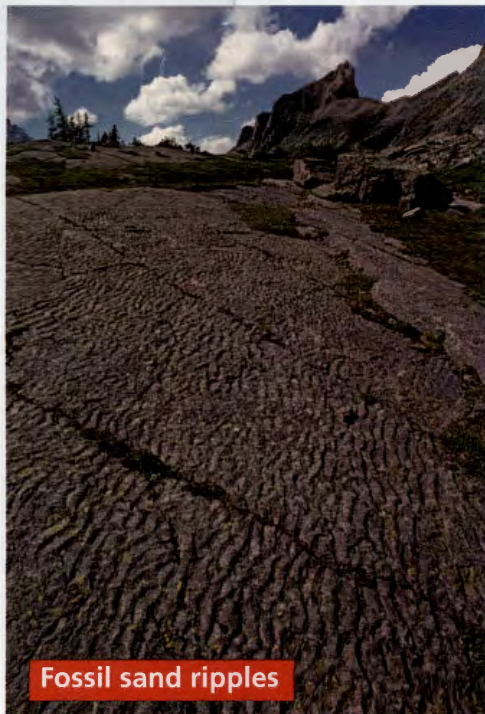
Visitors to Badlands National Park in South Dakota see some of the strangest scenery on Earth. The park contains jagged peaks, steep cliffs, and deep canyons sculpted in colorful rock that is layered like a birthday cake. The layers of this cake are red, orange, pink, yellow, or tan. These rocks formed over millions of years as particles of mud, sand, and volcanic ash were deposited in thick layers. The mud and sand slowly changed to sedimentary rock. Then, uplift of the land exposed the rocks to the forces that wear away Earth's surface.

Hutton's Big Idea

Geology is the study of the structure of planet Earth and the forces that make and shape Earth. The modern science of geology began in the late 1700s. James Hutton, a Scottish doctor and farmer, studied the rocks and landscape around him. He observed the structure of mountains and valleys. Hutton watched streams cutting through the land in the process of erosion. **Erosion** occurs when running water, ice, or wind break down rocks and carry the pieces away. After studying geologic processes in his own time, Hutton concluded that those same processes had occurred long ago.



Badlands National Park ▲



Fossil sand ripples



Modern sand ripples

Hutton's idea is called the principle of **uniformitarianism** (yoo nuh for muh TEHR ee un iz um). 🗝️ The principle of **uniformitarianism** states that the geologic processes that operate today also operated in the past. Ancient rocks can be understood by observing present-day geologic processes.

Hutton observed that most geologic processes happen very slowly. He inferred that these processes must have been at work for a very long time to produce such enormous features as mountains and deep valleys. Hutton concluded that Earth must be much older than was commonly thought in his time.



Reading
Checkpoint

Who first proposed the principle of uniformitarianism?

Types of Rocks

🗝️ Geologists classify rocks into three main groups—igneous, sedimentary, and metamorphic. **Igneous rocks** form when molten material from beneath Earth's surface cools and hardens. Igneous rock may form on or below Earth's surface.

Sedimentary rock is made of sediments that have been deposited and then pressed together to form solid rock. Most sediments are tiny pieces of rocks and minerals. Sediments may also include the remains of plants or animals, such as leaves or shells. Most fossils are found in sedimentary rocks. Through fossils, geology provides evidence that supports the theory of evolution.

Metamorphic rock forms when an existing rock is changed by heat, pressure, or chemical reactions. Most metamorphic rock forms under pressure deep underground.

FIGURE 1
Sand Ripples

Ancient, fossilized sand ripples, are similar to sand ripples that form today.

Applying Concepts What do the fossilized ripples tell you about conditions when the rocks formed?

The Rock Cycle

The **rock cycle** is a series of processes on and beneath Earth's surface that slowly change rocks from one kind to another. **Forces inside Earth and at the surface produce a rock cycle that builds, changes, and destroys rocks.** The rock cycle is a very slow process, taking place over millions of years. Figure 3 shows the rock cycle. Notice that it can follow many pathways.

Volcanic Activity One possible pathway through the rock cycle begins with **magma**—molten material beneath Earth's surface. As the magma is forced toward the surface, it may form a volcanic mountain. Some of the magma hardens underground, forming igneous rock, such as basalt or granite. Some of the magma flows onto the surface as **lava**.

Erosion Over time, erosion wears away the mountain, exposing the igneous rock core. Rain and snow fall on the rock. Oxygen and other chemicals in the air react with minerals in the rock. These conditions break the rock into tiny particles. Water, ice, and wind then carry the particles away.

Deposition Streams carry the particles of rock to the ocean. There they are deposited as sediment. Over millions of years, layers of sediment pile up on the ocean floor. The weight of the layers presses the sediments together. Chemicals in the water cement the particles together. Sedimentary rock such as sandstone is formed.

Heat and Pressure As more and more sediments pile up on the sandstone, the sandstone becomes deeply buried. Pressure increases. The rock becomes hot. Heat and pressure change the rock's texture from gritty to smooth. After millions of years, the sandstone is changed into a metamorphic rock such as quartzite.

Melting The formation of metamorphic rock does not end the rock cycle. Forces inside Earth can push all three types of rock many kilometers beneath the surface. There, intense heat and pressure melt the rock. This molten material can then form new igneous rock. And so the cycle continues.



Volcanic activity can produce igneous rock.



Erosion and deposition may produce layers of sedimentary rock.



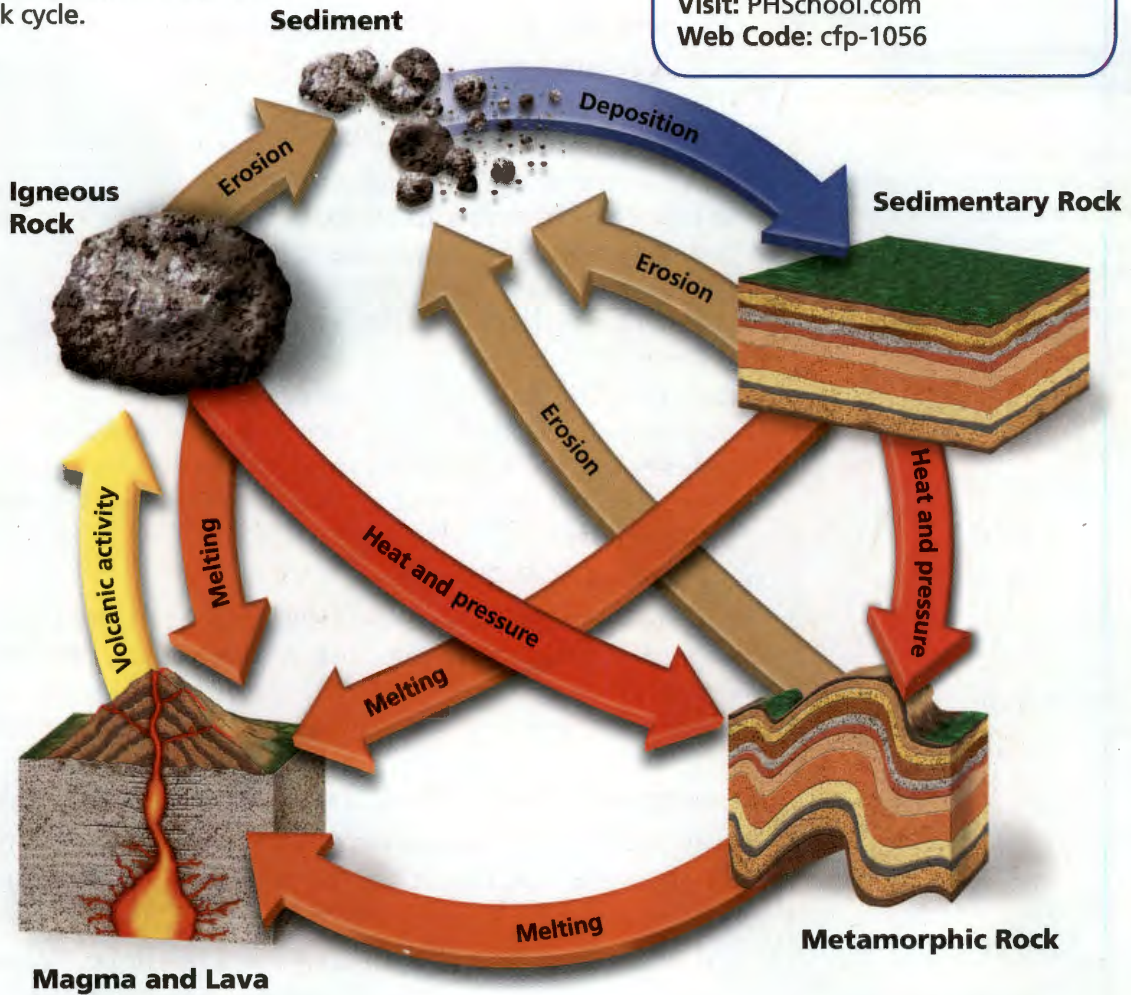
Heat and pressure can cause rocks to bend.

FIGURE 2

Processes That Change Rocks

Processes such as volcanic activity and erosion can change rock from one kind to another. **Relating Cause and Effect** What factors cause sediments to become sedimentary rock?

FIGURE 3
The Rock Cycle
 Igneous, sedimentary, and metamorphic rock change continuously through the rock cycle.



Go **Online**
active art

For: Rock Cycle activity
 Visit: PHSchool.com
 Web Code: cfp-1056

Section 1 Assessment

S 7.4.a, 7.4.c, E-LA: Writing 7.2.1, Reading 7.2.0

Target Reading Skill Create Outlines
 Complete your outline of this section. Use your outline to help answer the questions below.

c. Making Generalizations How does the rock cycle relate to the principle of uniformitarianism?

Reviewing Key Concepts

1. a. **Defining** What is uniformitarianism?
- b. **Explaining** How does uniformitarianism help geologists understand Earth's history?
- c. **Applying Concepts** Do you think that earthquakes happened millions of years ago? Explain your answer.
2. a. **Identifying** What are the three types of rock?
- b. **Explaining** What is the rock cycle?

Writing in Science

Rock Legend Pick one type of rock and write a possible "biography" of the rock as it moves through the rock cycle. Your story should state the type of rock, how the rock formed, and how it might change.

The Relative Age of Rocks

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Standards Focus

S 7.4.c Students know that the rock cycle includes the formation of new sediment and rocks and that rocks are often found in layers, with the oldest generally on the bottom.

- 🔑 What is the law of superposition?
- 🔑 How do geologists determine the relative age of rocks?
- 🔑 How are index fossils useful to geologists?

Key Terms

- relative age
- absolute age
- law of superposition
- extrusion
- intrusion
- fault
- unconformity
- inclusion
- index fossil

Lab zone

Standards Warm-Up

Which Layer Is the Oldest?

1. Make a stack of different-colored layers of clay. Each layer should be about the size and thickness of a pancake. If these flat layers are sediments, which layer of sediment was deposited first? (*Hint: This is the oldest layer.*)
2. Now form the stack into a dome by pressing it over a small rounded object, such as a small bowl. With a cheese-slicer or plastic knife, carefully cut off the top of the dome. Look at the layers that you have exposed. Which layer is the oldest?



Think It Over

Inferring If you press the stack into a small bowl and trim away the clay that sticks above the edge, where will you find the oldest layer?

As sedimentary rock forms, the remains of organisms in the sediment may become fossils. Millions of years later, if you split open the rock, you might see the petrified bones of an extinct reptile or insect.

Your first question about a new fossil might be, “What is it?” Your next question would probably be, “How old is it?” Geologists have two ways to express the age of a rock and any fossil it contains. The **relative age** of a rock is its age compared to the ages of other rocks. You have probably used the idea of relative age when comparing your age with someone else’s age. For example, if you say that you are older than your brother but younger than your sister, you are describing your relative age.

The relative age of a rock does not provide its absolute age. The **absolute age** of a rock is the number of years since the rock formed. It may be impossible to know a rock’s absolute age exactly. But sometimes geologists can determine a rock’s absolute age to within a certain number of years.

- ◀ The age of each family member could be given as relative age or absolute age.

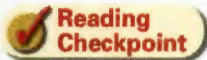


The Position of Rock Layers

Have you ever seen rock layers of different colors on a cliff beside a road? What are these layers, and how did they form? The sediment that forms sedimentary rocks is deposited in flat layers one on top of the other. Over time, the sediment hardens and changes into sedimentary rock. These rock layers provide a record of Earth's geologic history.

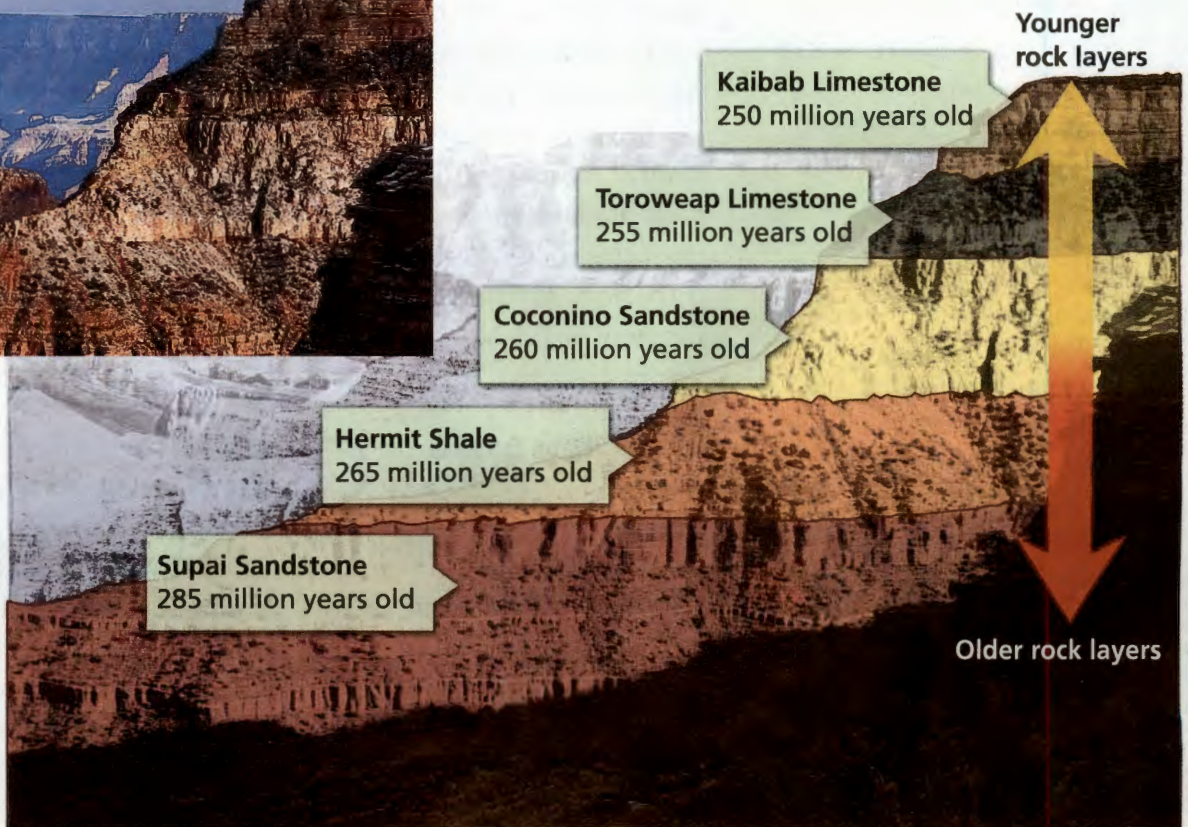
It can be difficult to determine the absolute age of a rock. So geologists use a method to find a rock's relative age. Geologists use the **law of superposition** to determine the relative ages of sedimentary rock layers. 🗨️ **According to the law of superposition, in horizontal sedimentary rock layers the oldest layer is at the bottom. Each higher layer is younger than the layers below it.** Relative dating only establishes the order in which rocks were formed. Scientists cannot use the law of superposition to determine the absolute age of rocks.

The walls of the Grand Canyon in Arizona illustrate the law of superposition. You can see some of the rock layers found in the Grand Canyon in Figure 4. The deeper down you go in the Grand Canyon, the older the rocks.



Reading Checkpoint

Why do sedimentary rocks have layers?



Video Field Trip
Discovery Channel School
A Trip Through
Geologic Time

FIGURE 4
The Grand Canyon
More than a dozen rock layers make up the walls of the Grand Canyon. You can see five layers clearly in the photograph.
Applying Concepts In which labeled layers would you find the oldest fossils? Explain.

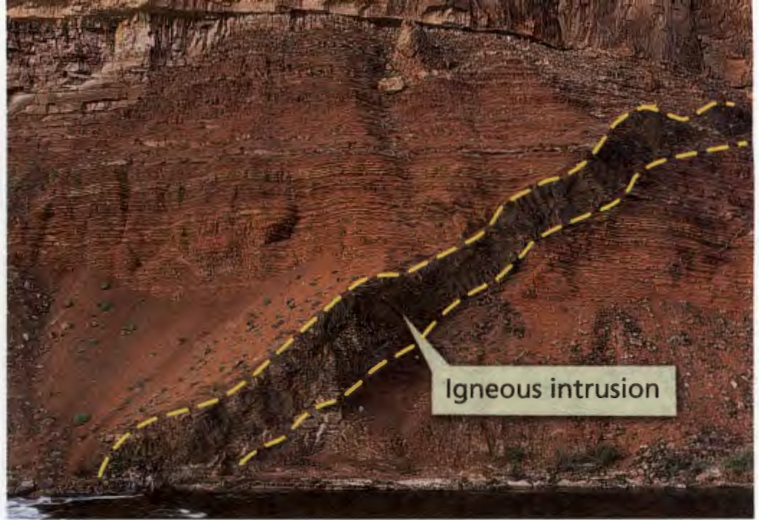


FIGURE 5
Faults and Intrusions
 Faults and intrusions give clues to the relative ages of rocks. Rock layers are broken and shifted along a fault (left). An intrusion cuts through rock layers (right).

Determining Relative Age

There are other clues besides the position of rock layers to the relative ages of rocks. 🚗 To determine relative age, geologists also study extrusions and intrusions of igneous rock, faults, gaps in the geologic record, and inclusions.

Clues From Igneous Rock Igneous rock forms when magma or lava hardens. Magma is molten material beneath Earth's surface. Magma that flows onto the surface is called lava.

Lava that hardens on the surface is called an **extrusion**. An extrusion is always younger than the rocks below it.

Beneath the surface, magma may push into bodies of rock. There, the magma cools and hardens into a mass of igneous rock called an **intrusion**. An intrusion is always younger than the rock layers around and beneath it. Figure 5 shows an intrusion. Geologists study where intrusions and extrusions formed in relation to other rock layers. This helps geologists understand the relative ages of the different types of rock.

Clues From Faults More clues come from the study of faults. A **fault** is a break in Earth's crust. Forces inside Earth cause movement of the rock on opposite sides of a fault.

A fault is always younger than the rock it cuts through. To determine the relative age of a fault, geologists find the relative age of the youngest layer cut by the fault.

Movements along faults can make it harder for geologists to determine the relative ages of rock layers. You can see in Figure 5 how the rock layers no longer line up because of movement along the fault.

Lab
zone

Try This Activity

Sampling a Sandwich

Your teacher will give you a sandwich that represents rock layers in Earth's crust.

1. Use a round, hollow, uncooked noodle as a coring tool. Push the noodle through the layers of the sandwich.
2. Pull the noodle out of the sandwich. Break the noodle gently to remove your core sample.
3. Draw a picture of what you see in each layer of the core.

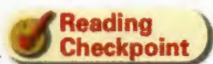
Making Models Which layer of your sandwich is the "oldest"? The "youngest"? Why do you think scientists study core samples?

Cross-Cutting Relationships When geologists use extrusions, intrusions, or faults to date rocks, they apply the principle of cross-cutting relationships. That principle states: When something cuts across a body of rock, that “something” is younger than the rock it cuts across.

To understand this principle, think of a sandwich made from a roll and a slice of cheese. The roll must be made before the cheese can be put inside. The roll is like a body of rock, and the cheese is like an intrusion. Look again at the igneous intrusion in the photo on the right in Figure 5. The igneous intrusion is something like a sandwich filling.

Gaps in the Geologic Record The geologic record of sedimentary rock layers is not always complete. Deposition slowly builds layer upon layer of sedimentary rock. But some of these layers may erode away, exposing an older rock surface. Then deposition begins again, building new rock layers.

The surface where new rock layers meet a much older rock surface beneath them is called an **unconformity**. An unconformity is a gap in the geologic record. An unconformity shows where some rock layers have been lost because of erosion. Figure 6 shows how an unconformity forms.



What is an unconformity?

Inclusions Inclusions can help date rocks when an unconformity is present. An **inclusion** is a piece of rock that is contained in another rock. Unlike an intrusion, which starts out as liquid magma, an inclusion starts as a solid rock piece that breaks off from an existing rock. Then, after a long time, the broken-off piece of rock becomes part of a second rock.

The rock containing an inclusion is younger than the rock from which the inclusion came. Look at the bottom frame of Figure 6. Notice the inclusions in the bright pink layer. They broke off from the eroded surface of the unconformity. The rock pieces later became part of sediments that were deposited on the eroded surface. These sediments, including the broken rock pieces, hardened into sedimentary rock.

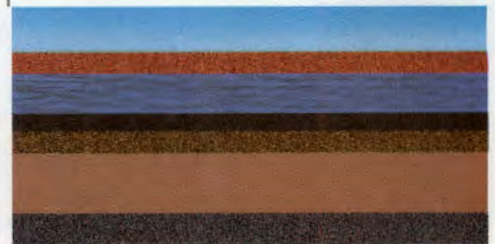


FIGURE 6

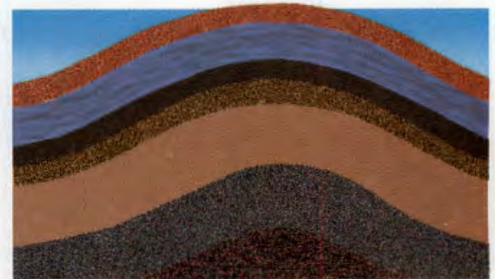
Unconformity

An unconformity occurs where erosion wears away layers of sedimentary rock. Other rock layers then form on top.

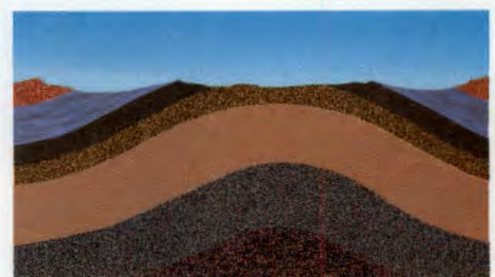
Sequencing What two processes must take place before an unconformity can occur?



1 Sedimentary rocks form in horizontal layers.



2 Folding tilts the rock layers.



3 The surface is eroded.



4 New sediment is deposited, forming rock layers above the unconformity. Notice the inclusions in the new rock.



FIGURE 7

Looking for Fossils

These scientists are removing fossils from rock layers.

Applying Concepts How can fossils help geologists match rock layers?

Using Fossils to Date Rocks

To date rock layers, geologists first give a relative age to a layer of rock at one location. Then they can give the same age to matching layers of rock at other locations.

Certain fossils, called index fossils, help geologists match rock layers. To be useful as an **index fossil**, a fossil must be widely distributed and represent a type of organism that existed only briefly. A fossil is considered widely distributed if it occurs in many different areas. Geologists look for index fossils in layers of rock. 🗺️ **Index fossils are useful because they tell the relative ages of the rock layers in which they occur.**

Geologists use particular types of organisms as index fossils—for example, certain types of ammonites. Ammonites (AM uh nyts) were a group of hard-shelled animals. Ammonites evolved in shallow seas more than 500 million years ago and became extinct about 65 million years ago.

Ammonite fossils make good index fossils for two reasons. First, they are widely distributed. Second, many different types of ammonites evolved and then became extinct after a few million years. Geologists can identify the different types of ammonites through differences in the structure of their shells. Based on these differences, geologists can identify the rock layers in which a particular type of ammonite fossil occurs.

You can use index fossils to match rock layers. Look at Figure 8, which shows rock layers from four different locations. Notice that two of the fossils are each found in only one of these rock layers. These are the index fossils.



**Reading
Checkpoint**

What characteristics must a fossil have to be useful as an index fossil?

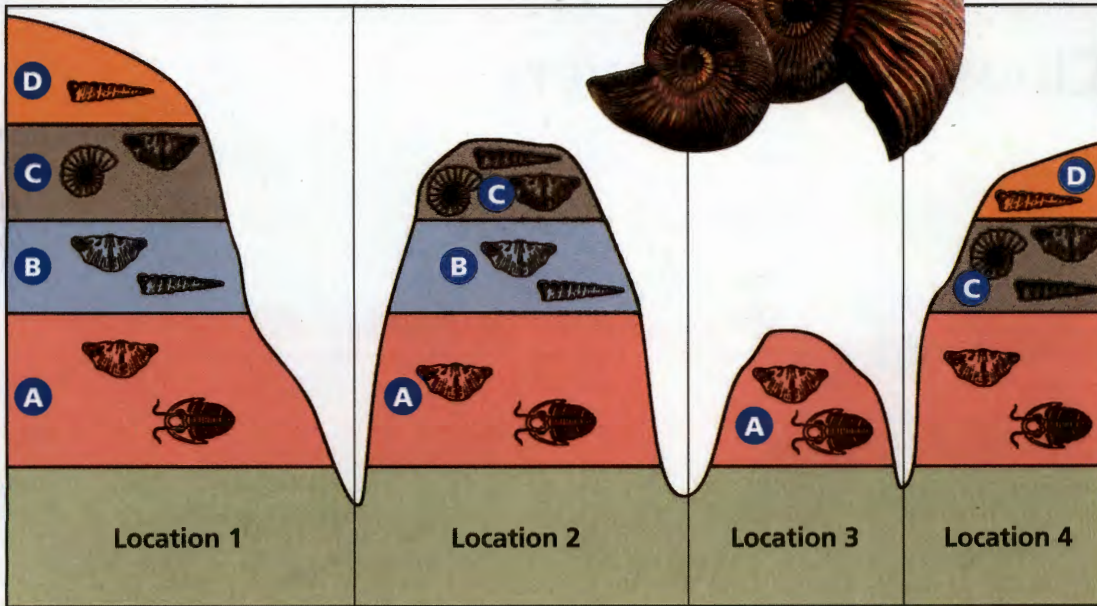


FIGURE 8
Using Index Fossils
 Scientists use index fossils to match up rock layers at locations that may be far apart. The ammonites in layer C are index fossils. **Interpreting Diagrams** Can you find another index fossil in the diagram? (Hint: Look for a fossil that occurs in only one layer, but in several different locations.)

Go **Online**
active art

For: Index Fossils activities
 Visit: PHSchool.com
 Web Code: cfp-2042

Section 2 Assessment

S 7.4.c, E-LA: Reading 7.1.3

Vocabulary Skill Use Clues to Determine Meaning Reread the definition of *extrusion*. Identify two phrases that help you understand the meaning of *extrusion*.

3. a. **Defining** What is an index fossil?
- b. **Applying Concepts** The fossil record shows that horseshoe crabs have existed with very little change for about 200 million years. Would horseshoe crabs be useful as an index fossil? Explain why or why not.

Reviewing Key Concepts

1. a. **Defining** In your own words, define the terms *relative age* and *absolute age*.
- b. **Explaining** What is the law of superposition?
- c. **Inferring** A geologist finds a cliff where the edges of several different rock layers can be seen. Which layer is the oldest? Explain.
2. a. **Reviewing** Besides the law of superposition, what are three types of clues to the relative age of rock layers?
- b. **Comparing and Contrasting** Compare and contrast extrusions and intrusions.
- c. **Sequencing** An intrusion crosses an extrusion. Which layer is the older? Explain.








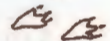
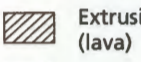

Lab zone

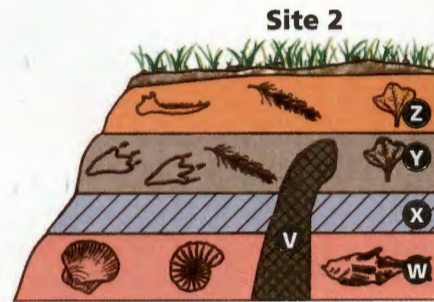
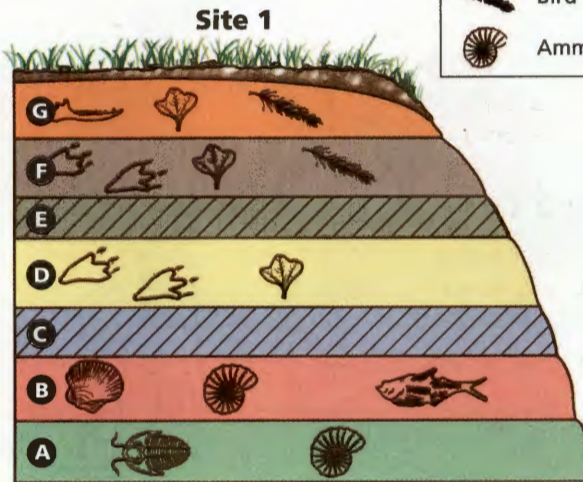
At-Home Activity

Drawer to the Past Collect ten items out of a drawer full of odds and ends such as keys, coins, receipts, photographs, and souvenirs. Have your family members put them in order from oldest to newest. What clues will you use to determine their relative ages? Do you know the absolute age of any of the items?

Finding Clues to Rock Layers

S 7.4.c, 7.7.c

Key					
	Trilobite		Fish		Plant
	Bird		Shell		Mammal
	Ammonite		Dinosaur		Extrusion (lava)
					Intrusion



Problem

How can you use fossils and geologic features to interpret the relative ages of rock layers?

Skills Focus

interpreting data, drawing conclusions

Procedure

1. Study the rock layers at Sites 1 and 2. Write down the similarities and differences between the layers at the two sites.
2. List the kinds of fossils that are found in each rock layer of Sites 1 and 2.

Analyze and Conclude

Site 1

1. **Interpreting Data** What "fossil clues" in layers A and B indicate the kind of environment that existed when these rock layers were formed? How did the environment change in layer D?
2. **Drawing Conclusions** Which layer is the oldest? How do you know?
3. **Drawing Conclusions** Which of the layers formed most recently? How do you know?

4. **Inferring** Why are there no fossils in layers C and E?
5. **Observing** What kind of fossils are found in layer F?

Site 2

6. **Inferring** Which layer at Site 1 might have formed at the same time as layer W at Site 2?
7. **Interpreting Data** What clues show an unconformity or gap in the horizontal rock layers? Which rock layers are missing? What might have happened to these rock layers?
8. **Drawing Conclusions** Which is older, intrusion V or layer Y? How do you know?
9. **Communicating** Write a journal entry describing how the environment at Site 2 changed over time. Starting with the earliest layer, describe the types of organisms, their environment, and how the environment changed.




More to Explore

Draw a sketch similar to Site 2 and include a fault that cuts across the intrusion. Have a partner then identify the relative age of the fault, the intrusion, and the layers cut by the fault.

Radioactive Dating

CALIFORNIA
Standards Focus

S 7.4.d Students know that evidence from geologic layers and radioactive dating indicates Earth is approximately 4.6 billion years old and that life on this planet has existed for more than 3 billion years.

-  What happens during radioactive decay?
-  What can be learned from radioactive dating?
-  What is the probable age of Earth?

Key Terms

- atom
- element
- radioactive decay
- half-life

Lab zone
Standards Warm-Up
How Long Till It's Gone?

1. Make a small cube—about 5 cm × 5 cm × 5 cm—from modeling clay.
2. Carefully use a knife to cut the clay in half. Put one half of the clay aside.
3. Cut the clay in half two more times. Each time you cut the clay, put one half of it aside.

Think It Over

Predicting How big will the remaining piece of clay be if you repeat the process several more times?



In Australia, scientists have found sedimentary rocks that contain some of the world's oldest fossils. These are fossils of stromatolites (stroh MAT uh lyts). Stromatolites are the remains of reefs built by organisms similar to present-day bacteria. Sediment eventually covered these reefs. As the sediment changed to rock, so did the reefs. Using absolute dating, scientists have determined that some stromatolites are more than 3 billion years old. To understand absolute dating, you need to learn more about the chemistry of rocks.



FIGURE 9

Stromatolites

Scientists think that ancient stromatolites were formed by organisms similar to blue-green bacteria (above). Modern stromatolites (right) still form reefs along the western coast of Australia.



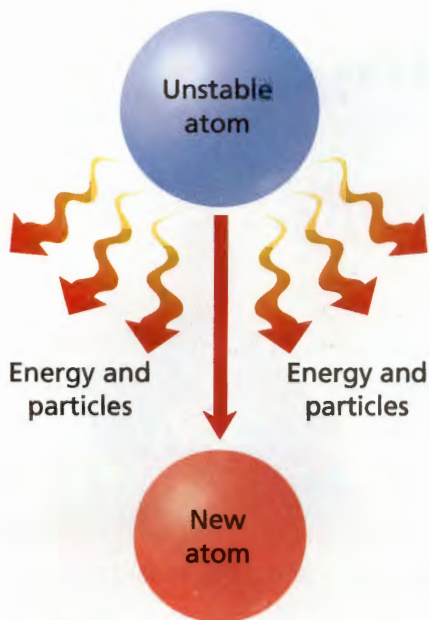


FIGURE 10
Radioactive Decay
 In the process of radioactive decay, a “parent” atom releases energy and particles as it changes to a new kind of atom, a “daughter” atom.

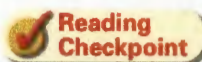
Radioactive Decay

Rocks are a form of matter. All the matter you see, including rocks, is made of tiny particles called **atoms**. When all the atoms in a particular type of matter are the same, the matter is an **element**. Carbon, oxygen, iron, lead, and potassium are just some of the more than 110 currently known elements.

Most elements are stable. They do not change under normal conditions. But some elements exist in forms that are unstable. Over time, these elements break down, or decay, by releasing particles and energy in a process called **radioactive decay**. These unstable elements are said to be radioactive. ➡ **During the process of radioactive decay, the atoms of one element break down to form atoms of another element.**

Radioactive elements occur naturally in igneous rocks. Scientists use the rate at which these elements decay to calculate the rock’s age. You calculate your age based on a specific day—your birthday. What’s the “birthday” of a rock? For an igneous rock, that “birthday” is when it first hardens to become rock. As a radioactive element within the igneous rock decays, it changes into another element. So the composition of the rock changes slowly over time. The amount of the radioactive element goes down. But the amount of the new element goes up.

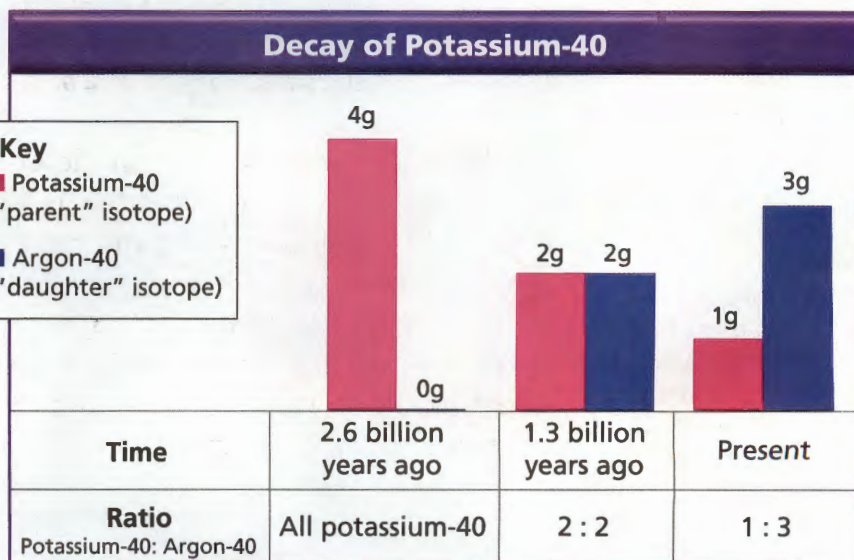
The rate of decay of each radioactive element is constant—it never changes. Scientists can measure it experimentally. This rate of decay is the element’s half-life. The **half-life** of a radioactive element is the time it takes for half of the radioactive atoms to decay. You can see in Figure 11 how a radioactive element decays over time.



Reading Checkpoint

What is the meaning of the term “half-life”?

FIGURE 11
 The half-life of a radioactive element is the amount of time it takes for half of the radioactive atoms to decay. The half-life of potassium-40 is 1.3 billion years. **Calculating** After three half-lives, how much of the radioactive element remains?



Elements Used in Radioactive Dating

Radioactive Element	Half-life (years)	Dating Range (years)
Carbon-14	5,730	500–50,000
Potassium-40	1.3 billion	50,000–4.6 billion
Rubidium-87	48.8 billion	10 million–4.6 billion
Thorium-232	14 billion	10 million–4.6 billion
Uranium-235	713 million	10 million–4.6 billion
Uranium-238	4.5 billion	10 million–4.6 billion

FIGURE 12
The half-lives of different radioactive elements vary greatly.

Determining Absolute Ages

Radioactive dating is used to determine the absolute ages of rocks. In radioactive dating, scientists first measure the amount of a radioactive element (the “parent” element) in a mineral in a rock. Then they measure the amount of the stable element into which the radioactive element decays (the “daughter” element). By calculating the ratio of the radioactive element to the stable element, scientists can determine the age of the rock.

Potassium–Argon Dating Scientists often date rocks using potassium-40. This form of potassium decays to stable argon-40 and has a half-life of 1.3 billion years. Potassium-40 is useful in dating the most ancient rocks because of its long half-life.

Carbon-14 Dating A radioactive form of carbon is carbon-14. All plants and animals contain carbon, including some carbon-14. As plants and animals grow, carbon atoms are added to their tissues. After an organism dies, no more carbon is added. But the carbon-14 in the organism’s body decays. It changes to stable nitrogen-14. To determine the age of a sample, scientists measure the amount of carbon-14 that is left in the organism’s remains. From this amount, they can determine its absolute age. Carbon-14 has been used to date fossils such as frozen mammoths, as well as pieces of wood and bone.

Carbon-14 is very useful in dating materials from plants and animals that lived up to about 50,000 years ago. Carbon-14 has a half-life of only 5,730 years. For this reason, it can’t be used to date very ancient fossils or rocks. The amount of carbon-14 left would be too small to measure accurately.

Math Skills

Percentage What percentage of a radioactive element will be left after 3 half-lives? First, multiply $\frac{1}{2}$ three times to determine what fraction of the element will remain.

$$\frac{1}{2} \times \frac{1}{2} \times \frac{1}{2} = \frac{1}{8}$$

You can convert this fraction to a percentage by setting up a proportion:

$$\frac{1}{8} = \frac{d\%}{100\%}$$

To find the value of d , begin by cross multiplying, as for any proportion:

$$1 \times 100 = 8 \times d$$

$$d = \frac{100}{8}$$

$$d = 12.5\%$$

Practice Problems What percentage of a radioactive element will remain after 5 half-lives?



FIGURE 13

Rocks from the Moon

By determining the age of moon rocks, scientists have inferred that Earth is about 4.6 billion years old.

Go Online

PHSchool.com

For: More on radioactive dating
Visit: PHSchool.com
Web Code: cfd-2043

How Old Is Earth?

Scientists haven't found it easy to figure out the age of planet Earth. Earth is always changing, through erosion and other processes. Most of the matter that made up early Earth has been destroyed or changed. Radioactive dating shows that the oldest rocks ever found on Earth are about 4.0 billion years old. But scientists hypothesize that Earth formed even earlier than that.

Scientists have used moon rocks and meteorites to estimate the age of Earth. Meteorites are chunks of rocks from space that have hit Earth's surface. According to one hypothesis, Earth, meteorites, and the moon are about the same age. When Earth was very young, a large object from space collided with it. This collision threw a large amount of material from both bodies into orbit around Earth. Some of this material combined to form the moon.

In the 1970s, astronauts who visited the moon brought several moon rocks back to Earth. Scientists have used radioactive dating to determine the age of those moon rocks.

➡ Radioactive dating shows that the oldest moon rocks are about 4.6 billion years old. Scientists infer that Earth is only a little older than those moon rocks—roughly 4.6 billion years old. The oldest fossils of living things appear in geologic layers that are 3.5 billion years old.

Section 3 Assessment

S 7.4.d, E-LA: Reading 7.1.3

Vocabulary Skill Use Clues to Determine

Meaning Reread the definition of *radioactive decay*, and the text near the definition. In your own words, explain what *radioactive decay* means.

➡ Reviewing Key Concepts

- Defining** In your own words, define the term *radioactive element*.
 - Describing** How does the composition of a rock containing a radioactive element change over time?
 - Applying Concepts** How is a radioactive element's rate of decay like the ticking of a clock? Explain.
- Identifying** What method do geologists use to determine the absolute age of a rock?
 - Explaining** Why is it difficult to determine the absolute age of a sedimentary rock?

- Problem Solving** A geologist finds a fossil in a layer of sedimentary rock that lies in between two igneous extrusions. How could the geologist determine the age of the fossil?
- Reviewing** How old are the oldest rocks found on the moon?
 - Explaining** What do scientists estimate Earth's age to be?
 - Summarizing** How were scientists able to infer Earth's age?

Math

Practice

- Percentage** What percentage of a radioactive element will remain after 7 half-lives?

Movement of Earth's Plates

CALIFORNIA
Standards Focus

S 7.4.f Students know how movements of Earth's continental and oceanic plates through time, with associated changes in climate and geographic connections, have affected the past and present distribution of organisms.

How does the theory of plate tectonics explain the movement of Earth's landmasses?

How has the movement of Earth's plates affected organisms?

Key Terms

- plate
- theory of plate tectonics
- continental drift

Lab zone
Standards Warm-Up
Where Were the Fossils Found?

1. *Mesosaurus* is an animal that became extinct over 200 million years ago. Make labels by writing *Mesosaurus* on two small stick-on notes.
2. Fossils of *Mesosaurus* have been found in Africa and South America. On a globe of the world, place one *Mesosaurus* label on South America. Put the second label on Africa.
3. Observe the distances that separate these labels.

Think It Over

Inferring Would you expect fossils of the same extinct organism to be found on two different continents? Why or why not?



Have you ever noticed that Earth's landmasses resemble pieces of a giant jigsaw puzzle? It's true. The east coast of South America, for example, would fit nicely into the west coast of Africa. The Arabian Peninsula would fit fairly well with the northeastern coast of Africa. Since the 1600s, people have wondered why Earth's landmasses look as if they would fit together. After all, land can't move. Or can it?


FIGURE 14
Landmasses Fit Together

The Arabian peninsula, which looks something like a foot, fits between the continents of Africa and Asia almost like a puzzle piece.

FIGURE 15

Continental Drift

The movement of the continents is one factor affecting the distribution of organisms. **Interpreting Maps** How has Australia's location changed?



225 Million Years Ago



180–200 Million Years Ago



135 Million Years Ago



Earth Today


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Earth's Plates

Earth's outer layer consists of pieces that fit together like a jigsaw puzzle. This outer layer is made of more than a dozen major pieces called **plates**. Plate boundaries do not always lie along the edges of continents. The eastern boundary of the North American plate, for example, lies under the Atlantic Ocean.


Scientists use the concept of plates to explain how landmasses have changed over time. The **theory of plate tectonics** states that Earth's plates move slowly in various directions. The plates move, on average, about 5 centimeters per year. Some plates slowly pull away from each other, some plates push toward each other, and some plates slide past each other.

 According to the theory of plate tectonics, Earth's landmasses have changed position over time because they are part of plates that are slowly moving. About 260 million years ago, all the continents were joined together in a supercontinent called Pangaea. Then, about 225 million years ago, the different continents began to drift apart. The very slow movement of continents is called **continental drift**.



What is continental drift?

Distribution of Organisms

The movement of Earth's plates has affected the evolution of living things.  As Earth's plates moved, landmasses changed their locations. These changes affected where different kinds of organisms, past and present, are located.

Climate As the plates move, the continents may move north and south. As the continents move, their climate may change. As the climate changes, so do the kinds of organisms that live on the continent. For example, millions of years ago, the North American plate was much closer to the equator than it is now. North America's climate was warm and tropical then. Huge ferns grew in forests. Plants such as those ancient ferns could not grow in North America today, because the climate is too cool.



FIGURE 16
Marsupials in Australia
Because of continental drift, Australia became isolated. Today, most mammals in Australia, including this koala, are marsupials.

Separation of Organisms As plates pulled apart, organisms on different plates became separated from one another. Fossils of *Brachiosaurus*, a dinosaur, have been found in Europe, Africa, and North America. The locations of these fossils suggest that those continents were once joined.

Continental drift has also affected organisms that are alive today. When populations of organisms become widely separated, their genetic makeup may change in different ways. Therefore, the separated populations often evolve differently. Organisms in Australia have been isolated from all other organisms on Earth for millions of years. Unusual organisms have evolved in Australia. For example, most mammals in Australia are marsupials. Unlike other mammals, female marsupials have pouches in which their young develop after birth. In contrast, few marsupials exist on other continents.

Section 4 Assessment

S 7.4.f, E-LA: Writing 7.2.0,
Reading 7.1.3

Vocabulary Skill Use Clues to Determine Meaning How does Figure 15 help you understand the meaning of *continental drift*?

Reviewing Key Concepts

- a. Identifying** Name the theory that explains the movement of pieces of Earth's surface.

b. Explaining Explain why the continent of North America is not where it was 225 million years ago.

c. Predicting In 250 million years, would you expect North America to be where it is now? Explain your answer.
- a. Reviewing** What is continental drift?

b. Describing Describe how continental drift has affected mammals in Australia.

c. Predicting Suppose that, millions of years from now, Australia moves so that it connects to South America. Would Australia still have the same kinds of mammals? Explain your answer.

Writing in Science

Description Look at Figure 15. Then draw your own labeled diagram to show how India moved between 135 million years ago and today. Write a caption that explains how India moved.




The Geologic Time Scale

CALIFORNIA

Standards Focus

S 7.4.b Students know the history of life on Earth has been disrupted by major catastrophic events, such as major volcanic eruptions or the impacts of asteroids.

S 7.4.g Students know how to explain significant developments and extinctions of plant and animal life on the geologic time scale.

-  Why is the geologic time scale used to show Earth's history?
-  What were early Precambrian organisms like?
-  What were the major events of the Paleozoic, Mesozoic, and Cenozoic Eras?

Key Terms

- geologic time scale
- era
- period
- invertebrate
- vertebrate
- amphibian
- reptile
- mass extinction
- mammal

Lab zone

Standards Warm-Up

Your Time Scale


1. Make a list of about 10 to 15 important events that you remember in your life.
2. On a sheet of paper, draw a timeline to represent your life. Use a scale of 3.0 cm to 1 year.
3. Write each event in the correct year along the timeline.
4. Now divide the timeline into parts that describe major periods in your life, such as preschool years, elementary school years, and middle school years.

Think It Over

Making Models Along which part of your timeline are most of the events located? Which period of your life does this part of the timeline represent? Why do you think this is so?

Imagine squeezing Earth's 4.6-billion-year history into a 24-hour day. Earth forms at midnight. About seven hours later, the earliest one-celled organisms appear. Over the next 14 hours, simple, soft-bodied organisms such as jellyfish and worms develop. A little after 9:00 P.M.—21 hours later—larger, more complex organisms evolve in the oceans. Reptiles and insects first appear about an hour after that. Dinosaurs arrive just before 11:00 P.M., but are extinct by 11:30 P.M. Modern humans don't appear until less than a second before midnight!

The Geologic Time Scale

Months, years, or even centuries aren't very helpful for thinking about Earth's long history.  **Because the time span of Earth's past is so great, geologists use the geologic time scale to show Earth's history.** The **geologic time scale** is a record of the life forms and geologic events in Earth's history.

You can see in Figure 17 that the geologic time scale begins with Precambrian Time (pree KAM bree un). Precambrian Time covers about 88 percent of Earth's history. After Precambrian Time, the basic units of the geologic time scale are eras and periods. **Eras** are the three long units between Precambrian Time and the present. Eras are subdivided into **periods**.

FIGURE 17

The Geologic Time Scale

The eras and periods of the geologic time scale are used to date the events in Earth's long history.

Interpreting Diagrams How long ago did the Paleozoic Era end?

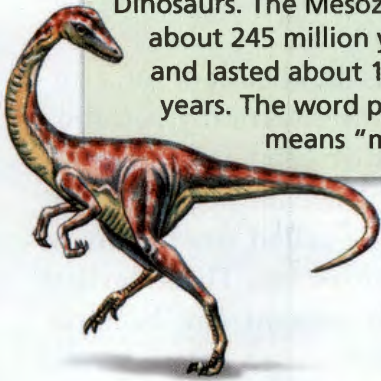


Cenozoic Era

The Cenozoic (sen uh ZOH ik) began about 66 million years ago and continues to the present. The word part *ceno-* means "recent," and *-zoic* means "life." Mammals became common during this time.

Mesozoic Era

People often call the Mesozoic (mez uh ZOH ik) the Age of Dinosaurs. The Mesozoic began about 245 million years ago and lasted about 180 million years. The word part *meso-* means "middle."



Paleozoic Era

The Paleozoic (pay lee uh ZOH ik) began about 544 million years ago and lasted for 300 million years. The word part *paleo-* means "ancient or early."

Geologic Time Scale			
Era	Period	Millions of Years Ago	Duration (millions of years)
Cenozoic	Quaternary	1.6	1.6 to present
	Tertiary		65
Mesozoic	Cretaceous	66.4	78
	Jurassic	144	64
	Triassic	208	37
Paleozoic	Permian	245	41
	Carboniferous	286	74
	Devonian	360	48
	Silurian	408	30
	Ordovician	438	67
	Cambrian	505	39
		544	
Precambrian			544 million years ago– 4.6 billion years ago



FIGURE 18


Early Earth

This artist's illustration shows Earth shortly after the moon formed. Notice the rocky objects from space striking Earth, and the molten rock flowing over the surface.

Early Earth

Precambrian Time begins when the Earth formed, about 4.6 billion years ago. Scientists hypothesize that early Earth was very hot. Over time, however, the outer layers cooled and became solid. Less than 500 million years after Earth's formation, rock on the surface formed continents.

At this time, the atmosphere, which is the blanket of gases surrounding Earth, was made up mostly of the gases nitrogen, carbon dioxide, and water vapor. There was little oxygen.

Scientists cannot pinpoint when or where life began.  **But scientists have found fossils of single-celled organisms in rocks that formed about 3.5 billion years ago. These earliest life forms were probably similar to present-day bacteria.** Unlike most organisms today, these single-celled organisms did not need oxygen. Scientists hypothesize that all other forms of life on Earth arose from these simple organisms.

About 2.5 billion years ago, many organisms began using energy from the sun to make their own food. This process is called photosynthesis. Among these early photosynthetic organisms were cyanobacteria. These bacteria, which were once called blue-green algae, have been extremely successful. They are still alive today, and they have changed very little.

One product of photosynthesis is oxygen. Organisms released oxygen into the atmosphere. The amount of oxygen in the air slowly increased. Processes in the atmosphere changed some of this oxygen into a form called ozone. The ozone layer blocked out some of the ultraviolet rays of the sun. Shielded from the ultraviolet rays, organisms could live on land.

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Web Code: scn-0745

The Paleozoic Era

You have traveled in a time machine to the beginning of the Paleozoic Era. The time machine is now moving forward, toward the present. You are about to see a period of rapid change.

The Cambrian Explosion In the Cambrian Period, life took a big leap forward. 🚪 **At the beginning of the Paleozoic Era, many different kinds of organisms evolved.** Paleontologists call this event the Cambrian Explosion because so many new life forms appeared within a relatively short time (approximately 30 million years). For the first time, many organisms had hard parts, including shells and outer skeletons. Many animals, such as sponges, jellyfish, and worms, were invertebrates. **Invertebrates** are animals without backbones.

Scientists infer that at this time, all animals lived in the sea. Fossils provide evidence of a watery environment. That is because many Cambrian fossils are similar to modern sea animals. For example, brachiopods were small animals with two shells. Brachiopods looked like modern clams. Therefore, like clams, brachiopods probably lived in water.

Vertebrates Arise During the Ordovician (awr duh VISH ee un) and Silurian (sih LOOR ee un) periods, invertebrates shared the seas with a new type of organism. 🚪 **Jawless fishes evolved. Jawless fishes were the first vertebrates.** A **vertebrate** is an animal that has a backbone. These early fishes had sucker-like mouths.



FIGURE 19

The Cambrian Explosion

During the early Cambrian period, Earth's oceans were home to many strange organisms unlike any animals that are alive today.



FIGURE 20

Devonian Armored Fish

Paleontologists have found fossils of huge armored fish, like this *Dunkleosteus*, that lived during the Devonian Period.

Life Reaches Land Until the Silurian Period, only one-celled organisms lived on the land. But during the Silurian Period, plants became abundant. These first, simple plants grew low to the ground in damp areas. By the Devonian Period (dih VOH nee un), plants that could grow in drier areas had evolved. Among these plants were the earliest ferns. The first insects also appeared during the Silurian Period.

Both invertebrates and vertebrates lived in the Devonian seas. Even though the invertebrates were more numerous, the Devonian Period is often called the Age of Fishes. Every main group of fishes was present in the oceans at this time. Most fishes now had jaws, bony skeletons, and scales on their bodies. Some fishes, like the one in Figure 20, were huge. Sharks appeared in the late Devonian Period.

➡ **During the Devonian Period, vertebrates began to invade the land.** The first vertebrates to crawl onto land were lungfish with strong, muscular fins. The first amphibians evolved from these lungfish. An **amphibian** (am FIB ee un) is an animal that lives part of its life on land and part of its life in water.

FIGURE 21

The Coal Forest

Forests of the Carboniferous Period later formed coal deposits. **Predicting** What types of fossils would you expect to find from the Carboniferous Period?

The Carboniferous Period Throughout the rest of the Paleozoic, life expanded over Earth's continents. Other vertebrates evolved from the amphibians. For example, small reptiles developed during the Carboniferous Period. **Reptiles** have scaly skin and lay eggs with tough, leathery shells. Some types of reptiles became very large during the later Paleozoic.



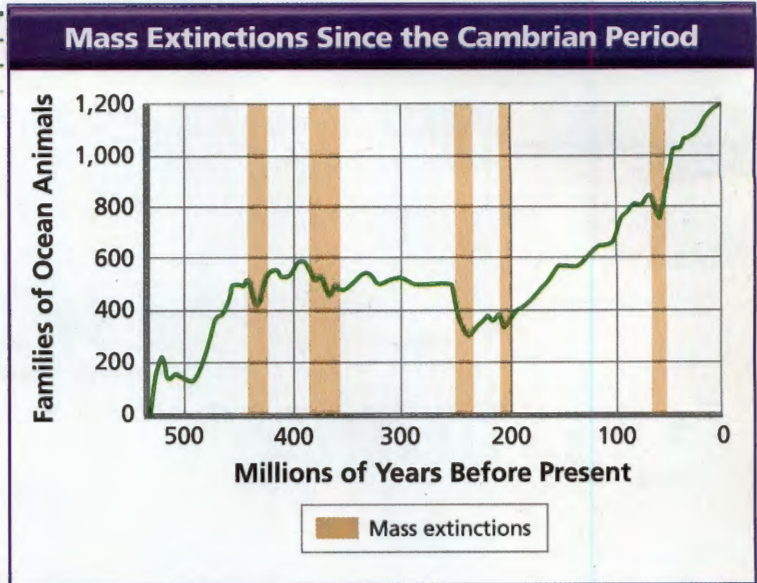
Math

Analyzing Data

Mass Extinctions

The graph shows how the number of families of animals in Earth's oceans has changed.

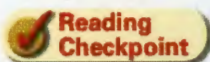
- 1. Reading Graphs** What variable is shown on the x-axis? On the y-axis of the graph?
- 2. Interpreting Data** How long ago did the most recent mass extinction occur?
- 3. Interpreting Data** Which mass extinction produced the greatest drop in the number of families of ocean animals?
- 4. Relating Cause and Effect** In general, how did the number of families change between mass extinctions?



During the Carboniferous Period, winged insects evolved into many forms, including huge dragonflies. Giant ferns and cone-bearing plants formed vast swampy forests called “coal forests.” The remains of these plants formed thick deposits of sediment that changed into coal over millions of years.

Mass Extinction Ends the Paleozoic At the end of the Paleozoic Era, many kinds of organisms died out. This was a **mass extinction**, in which many types of living things became extinct at the same time. 🏠 **The mass extinction, known as the Permian extinction, affected both plants and animals on land and in the seas.** Scientists do not know what catastrophic event caused the mass extinction, but many kinds of organisms suddenly became extinct. As much as 90 percent of marine species may have died out.

The Supercontinent Pangaea Scientists hypothesize that climate change resulting from continental drift may have caused the mass extinction at the end of the Paleozoic. 🏠 **During the Permian Period, about 260 million years ago, Earth's continents moved together to form a great landmass, or supercontinent, called Pangaea** (pan JEE uh). The formation of Pangaea caused deserts to expand in the tropics. At the same time, sheets of ice covered land closer to the South Pole. Many organisms could not survive the new climate. After Pangaea formed, it broke apart again.



Reading Checkpoint

What was Pangaea?

Go Online
active art

For: Continental Drift activity
 Visit: PHSchool.com
 Web Code: cfp-1015

FIGURE 22

The Geologic Time Scale

Sequencing Events Which organisms appear first—amphibians or fishes?

Precambrian Time

4.6 billion–544 million years ago



Precambrian Time begins with the formation of Earth. The first living things — bacteria — appeared in seas 3.5 billion years ago. Algae and fungi evolved 1 billion years ago. Animals first appeared 600 million years ago.

Paleozoic Era

544–245 million years ago

Cambrian	Ordovician	Silurian	Devonian	Carboniferous
544–505 million years ago	505–438 million years ago	438–408 million years ago	408–360 million years ago	360–286 million years ago
Pikaia Sponges Trilobite Clam Dinomischus	Brachiopod Jawless fish Crinoid Cephalopod	Jawed fish Arachnid Eurypterid Land plant	Devonian forest Shark Lung fish Bony fish	Cockroach Dragonfly Coal forest Amphibian
Invertebrate sea animals such as sponges, snails, clams, and worms evolve.	The earliest fishes evolve. Although many new species of animals arise, many become extinct by the end of the period.	Land plants and animals evolve. The plants are similar to present-day mosses.	Many types of fishes live in the seas. Early amphibians evolve. They are fishlike animals that have legs and can breathe air. Ferns and cone-bearing plants appear on land.	Tropical forests become widespread. Many different insects and amphibians evolve. The earliest reptiles appear.

Mesozoic Era

245–66 million years ago

Cenozoic Era

66 million years ago to the present






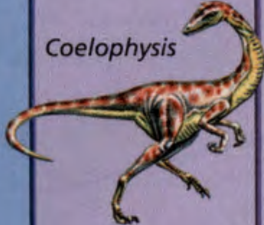

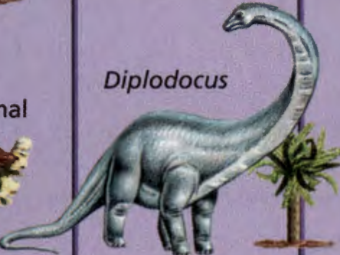











Permian	Triassic	Jurassic	Cretaceous	Tertiary	Quaternary
286–245 million years ago	245–208 million years ago	208–144 million years ago	144–66 million years ago	66–1.8 million years ago	1.8 million years ago to the present
 Conifer  Dimetrodon  Dicynodon	 Cycad Early mammal  Coelophysis 	 Morganucodon Diplodocus  Archaeopteryx 	Triceratops  Magnolia  Tyrannosaurus rex  Creodont 	 Uintatherium  Plesiadapis Hyacotherium 	Saber-toothed cat   Megatherium  Homo sapiens
Seed plants, insects, and reptiles become common. Reptile-like mammals appear. At the end of the period, most sea animals and amphibians become extinct.	The first dinosaurs evolve. First turtles and crocodiles appear. Mammals first appear. Cone-bearing trees and palmlike trees dominate forests.	Large dinosaurs roam the world. The first birds appear. Mammals become more common and varied.	The first flowering plants appear. At the end of the period, a mass extinction causes the disappearance of many organisms, including the dinosaurs.	New groups of animals, including the first monkeys and apes, appear. Flowering plants become the most common kinds of plants. First grasses appear.	Mammals, flowering plants, and insects dominate land. Humans appear. Later in the period, many large mammals, including mammoths, become extinct.



FIGURE 23

Flying Reptile

Dimorphodon was a flying reptile that lived during the Jurassic Period. Like dinosaurs, flying reptiles became extinct at the end of the Cretaceous period.

Comparing and Contrasting

How is *Dimorphodon* similar to the bird in Figure 24?

The Mesozoic Era

Millions of years flash by as your time machine travels. Watch out—there’s a dinosaur! You’re observing an era that you’ve read about in books and seen in movies.

The Triassic Period Some living things survived the Permian mass extinction. These organisms became the main forms of life early in the Triassic Period (try AS ik). Plants and animals that survived included fish, insects, reptiles, and cone-bearing plants called conifers. 🐢 **Reptiles were so successful during the Mesozoic Era that this time is sometimes called the Age of Reptiles.** About 225 million years ago, the first dinosaurs appeared. Mammals also first appeared during the Triassic Period. A **mammal** is a warm-blooded vertebrate that feeds its young milk. Mammals probably evolved from warm-blooded reptiles. The mammals of the Triassic Period were very small.

The Jurassic Period During the Jurassic Period (joo RAS ik), dinosaurs became the dominant animals on land. Scientists have identified several hundred different kinds of dinosaurs. Some were plant eaters, while others were meat eaters. Dinosaurs “ruled” Earth for about 150 million years.

One of the first birds, called *Archaeopteryx*, appeared during the Jurassic Period. The name *Archaeopteryx* means “ancient winged thing.” Many paleontologists now think that birds evolved from dinosaurs.



Reading
Checkpoint

What is a mammal?



FIGURE 24
Early Bird

The artist of the illustration (left) has given *Archaeopteryx* colorful feathers. From a fossil (right), paleontologists can tell that *Archaeopteryx* was about 30 centimeters long, had feathers and teeth, and also had claws on its wings.

The Cretaceous Period Reptiles, including dinosaurs, were still the dominant vertebrates throughout the Cretaceous Period (krih TAY shus). Flying reptiles and birds competed for places in the sky. The hollow bones and feathers of birds made them better adapted to their environment than the flying reptiles, which became extinct during the Cretaceous Period. The Cretaceous Period also brought new forms of life. Flowering plants like the ones you see today evolved. Unlike the conifers, flowering plants produce seeds that are inside a fruit. The fruit helps the seeds disperse.

Another Mass Extinction Catastrophic, or destructive, events have changed the history of life on Earth. Catastrophic happenings can include volcanoes erupting or objects from space hitting Earth. 🚗 **At the close of the Cretaceous Period, about 65 million years ago, another mass extinction occurred. Some scientists hypothesize that this mass extinction, known as the Cretaceous-Tertiary (K-T) extinction, occurred when an object from space struck Earth.** This object may have been an asteroid. Asteroids are rocky masses that orbit the sun between Mars and Jupiter.

When the asteroid hit Earth, the impact threw huge amounts of dust and water vapor into the atmosphere. Many organisms on land and in the oceans died immediately. Dust and heavy clouds blocked sunlight around the world for years. Without sunlight, organisms' habitats changed. Plants died, and plant-eating animals starved. This mass extinction wiped out over half of all plant and animal groups. No dinosaurs survived.

Not all scientists agree that an asteroid impact alone caused the mass extinction. Some scientists think that climate changes caused by increased volcanic activity were partly responsible.

FIGURE 25

The End of the Dinosaurs

Many scientists hypothesize that during the Cretaceous an asteroid hit Earth near the present-day Yucatán Peninsula, in southeastern Mexico.



Lab zone Try This Activity

Life and Times

1. Place these events in their correct order: continental glaciers retreat; first fish appear; oldest fossils form; human ancestors appear; invertebrate "explosion" occurs; dinosaurs become extinct; Pangaea forms.

2. Draw a timeline and graph these dates:

- 3.5 billion years ago
- 544 million years ago
- 400 million years ago
- 260 million years ago
- 65 million years ago
- 3.5 million years ago
- 20,000 years ago

Choose a scale so the oldest date fits on the paper.

Interpreting Data Match each event with the correct date on your timeline. How does the time since the dinosaurs became extinct compare with the time since the oldest fossil formed?

The Cenozoic Era

Your voyage through time continues on through the Cenozoic Era—often called the Age of Mammals. During the Mesozoic Era, mammals had a hard time competing with dinosaurs for food and places to live. 🐞 **The extinction of dinosaurs created an opportunity for mammals. During the Cenozoic Era, mammals evolved to live in many different environments—on land, in water, and even in the air.**

The Tertiary Period During the Tertiary Period, Earth's climates were generally warm. In the oceans, marine mammals such as whales evolved. On land, flowering plants, insects, and mammals flourished. When grasses evolved, they provided food for grazing mammals. These were the ancestors of today's cattle, deer, sheep, and other grass-eating mammals. Some mammals and birds became very large.

The Quaternary Period The mammals that had evolved during the Tertiary Period eventually faced a changing environment. 🐞 **Earth's climate cooled, causing a series of ice ages during the Quaternary Period.** Thick continental glaciers advanced and retreated over parts of Europe and North America. Then, about 20,000 years ago, Earth's climate began to warm. Over thousands of years, the continental glaciers melted, except in Greenland and Antarctica.

FIGURE 26

Ice-Age Environment

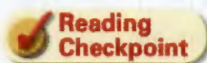
Large mammals roamed the ice-free parts of North America during the Ice Ages of the Quaternary Period.



In the oceans, algae, coral, mollusks, fish, and mammals thrived. Insects and birds shared the skies. On land, flowering plants and mammals such as bats, cats, dogs, cattle, and humans—just to name a few—became common.

The fossil record suggests that modern humans, or *Homo sapiens*, may have evolved as early as 100,000 years ago. By about 12,000 to 15,000 years ago, humans had migrated around the world to every continent except Antarctica.

Your time machine has now arrived back in the present. You and all organisms on Earth are living in the Quaternary Period of the Cenozoic Era. Is this the end of evolution and the changing of Earth's surface? No, these processes will continue as long as Earth exists. But you'll have to take your time machine into the future to see just what happens!



**Reading
Checkpoint**

How did Earth's climate change during the Quaternary Period?



FIGURE 27

Ice Age Art

An early ancestor of modern humans painted these beautiful images of animals in a cave in France more than 15,000 years ago.

Section 5 Assessment

S 7.4.b, 7.4.g, E-LA: Writing 7.2.1, Reading 7.2.0

Target Reading Skill Create Outlines Use your outline of this section to help answer the questions below.

Reviewing Key Concepts

- a. **Defining** What is the geologic time scale?

b. **Inferring** What information did geologists use to develop the geologic time scale?
- a. **Reviewing** When did the earliest organisms appear on Earth?

b. **Relating Cause and Effect** How did early photosynthetic organisms change Earth's atmosphere?
- a. **Listing** List the periods of the Paleozoic.

b. **Describing** How did organisms change during the first period of the Paleozoic?

c. **Relating Cause and Effect** What event do scientists think may have caused the mass extinction at the end of the Paleozoic?
- a. **Reviewing** Which group of animals was dominant during the Mesozoic Era?

b. **Inferring** How was their small size helpful to the mammals of the Mesozoic?

- c. **Developing Hypotheses** Many scientists think that the asteroid impact at the end of the Cretaceous prevented plant growth for many years. Although many dinosaurs were plant eaters, some were meat eaters. Develop a hypothesis to explain why all dinosaurs became extinct.
- a. **Identifying** What term do scientists apply to the Cenozoic Era?

b. **Inferring** What conditions allowed so many different kinds of mammals to evolve during the Cenozoic Era?

Writing in Science

Description Suppose that you are going on a tour of Earth during one era of geologic time. Write a paragraph describing the organisms and environments that you see on the tour. Your tour should include at least one stop in each geologic period of the era.

As Time Goes By



S 7.4.g, 7.7.d

Problem

How can you make a scale model of geologic time?

Skills

measuring, calculating, making models

Materials

- worksheet with 2,000 asterisks
- one ream of paper

Procedure

PART 1 Table A

1. Copy Table A into your lab notebook. Figure how long ago these historic events happened and write the answers on your chart.
2. Obtain a worksheet with 2,000 asterisks printed on it. Each asterisk represents one year. The first asterisk at the top represents one year ago.



3. Starting from this asterisk, circle the asterisk that represents how many years ago each event in Table A occurred.
4. Label each circled asterisk to indicate the event.
5. Obtain a ream of copy paper. There are 500 sheets in a ream. If each sheet had 2,000 asterisks on it, there would be a total of 1 million asterisks. Therefore, each ream would represent 1 million years.

Table A: Historic Events

Event	Date	Number of Years Ago
You are born.		
One of your parents is born.		
First space shuttle sent into space.	1981	
Neil Armstrong first walks on the moon.	1969	
World War I ends.	1918	
Civil War ends.	1865	
Declaration of Independence is signed.	1776	
Columbus crosses Atlantic Ocean.	1492	
Leif Ericson visits North America.	1000	

Table B: Geologic Events

Event	Number of Years Ago	Reams or Sheets of Paper	Thickness of Paper
Last ice age ends.	10,000		
Whales evolve.	50 million		
Pangaea begins to break up.	225 million		
First vertebrates develop.	530 million		
Multicellular organisms (algae) develop.	1 billion		
Single-celled organisms develop.	3.5 billion		
Oldest known rocks form.	4.0 billion		
Earth forms.	4.6 billion		

PART 2 Table B

6. Copy Table B into your lab notebook. Determine how much paper in reams or sheets would be needed to represent the events in geologic time found in Table B. (*Hint:* Recall that each ream represents 1 million years.)
7. Measure the thickness of a ream of paper. Use this thickness to calculate how thick a stack of paper would need to be to represent how long ago each geologic event occurred. (*Hint:* Use a calculator to multiply the thickness of the ream of paper by the number of reams.) Enter your results in Table B.

Analyze and Conclude

1. **Measuring** Measure the height of your classroom. How many reams of paper would you need to reach the ceiling? How many years would the height of the ceiling represent? Which geologic events listed in Table B would fall on a ream of paper inside your classroom?
2. **Calculating** At this scale, how many classrooms would have to be stacked on top of each other to represent the age of Earth? The time when vertebrates appeared?

3. **Calculating** How many times higher would the thickness of the stack be for the age of Earth than for the breakup of Pangaea?
4. **Making Models** On your model, how could you distinguish one era or period from another? How could you show when particular organisms evolved and when they became extinct?
5. **Communicating** Is the scale of your model practical? What would be the advantages and disadvantages of a model that fit geologic time on a timeline 1 meter long?

More to Explore

This model represents geologic time as a straight line. Can you think of other ways of representing geologic time graphically? Using colored pencils, draw your own version of the geologic time scale so that it fits on a single sheet of typing paper. (*Hint:* You could represent geologic time as a wheel, a ribbon, or a spiral.)

The **BIG Idea**

Evidence from rocks shows that life has existed for billions of years and how Earth has changed over time.

1 The Rock Cycle**Key Concepts**

S 7.4.a, 7.4.c

- The principle of uniformitarianism states that the geologic processes that operate today also operated in the past.
- Rocks are classified into three groups—igneous, sedimentary, and metamorphic.
- Internal and surface forces produce a rock cycle that builds, destroys, and changes rocks.

Key Terms

- geology • erosion • uniformitarianism
- igneous rock • sedimentary rock
- metamorphic rock • rock cycle
- magma • lava

2 The Relative Age of Rocks**Key Concepts**

S 7.4.c

- According to the law of superposition, in horizontal sedimentary rock layers, each higher layer is younger than the layers below it.
- To determine relative age, geologists also study extrusions, intrusions, faults, gaps in the geologic record, and inclusions.
- Index fossils indicate the relative ages of the rock layers in which they occur.

Key Terms

- relative age • absolute age
- law of superposition • extrusion • intrusion
- fault • unconformity • inclusion • index fossil

3 Radioactive Dating**Key Concepts**

S 7.4.d

- During radioactive decay, the atoms of one element break down to form atoms of another.
- Radioactive dating is used to determine the absolute age of rocks.
- Radioactive dating indicates that Earth is roughly 4.6 billion years old.

Key Terms

- atom • element • radioactive decay • half-life

4 Movement of Earth's Plates**Key Concepts**

S 7.4.f

- According to the theory of plate tectonics, Earth's landmasses have changed position over time because they are part of plates that are slowly moving.
- As Earth's plates moved, landmasses changed their locations. These changes have affected where different kinds of organisms, past and present, are located.

Key Terms

- plate • theory of plate tectonics
- continental drift

5 The Geologic Time Scale**Key Concepts**

S 7.4.b, 7.4.g

- Scientists have found fossils of single-celled organisms in rocks that formed about 3.5 billion years ago. These earliest life forms were probably similar to present-day bacteria.
- Geologists use the geologic time scale to show the time span of Earth's history.
- At the beginning of the Paleozoic Era, many different kinds of organisms evolved.
- At the close of the Mesozoic Era, about 65 million years ago, a mass extinction occurred. Scientists hypothesize that this mass extinction occurred when an object from space struck Earth.
- During the Cenozoic Era, mammals evolved to live in many environments.

Key Terms

- geologic time scale • era • period
- invertebrate • vertebrate • amphibian
- reptile • mass extinction • mammal



Target Reading Skill

Outlining To help you review Section 4, copy the incomplete outline at the right. Complete the outline by adding subtopics and details. Be sure to include key concepts and key terms.

- I. Earth's Plates

- II. Plate Movement and Organisms
 - A. Climate

 - B. Separation of Organisms

Reviewing Key Terms

Choose the letter of the best answer.

1. The type of rock that forms when an existing rock is changed by pressure or other factors is
 - a. radioactive rock.
 - b. sedimentary rock.
 - c. metamorphic rock.
 - d. igneous rock.
2. A gap in the geologic record formed when sedimentary rocks cover an eroded surface is called a(n)
 - a. intrusion.
 - b. unconformity.
 - c. fault.
 - d. extrusion.
3. The time it takes for half of a radioactive element's atoms to decay is a(n)
 - a. era.
 - b. half-life.
 - c. relative age.
 - d. absolute age.
4. Earth's outer layer consists of pieces called
 - a. extrusions.
 - b. eras.
 - c. plates.
 - d. faults.
5. The geologic time scale is subdivided into
 - a. relative ages.
 - b. absolute ages.
 - c. unconformities.
 - d. eras and periods.

Complete the following sentences so that your answers clearly explain the key terms.

6. The principle of **uniformitarianism** states that _____.
7. Unlike absolute age, the **relative age** of a rock indicates only _____.
8. **Radioactive decay** is the process in which _____.
9. The **theory of plate tectonics** states that _____.
10. A **mass extinction** is a catastrophic event because _____.

Writing in Science

Field Guide Write a field guide for visitors to the Grand Canyon. In your guide, explain how geologists have learned about Earth's past by studying the canyon walls and the fossils they contain.

Video Assessment

Discovery Channel School

A Trip Through Geologic Time

Review and Assessment

Checking Concepts

- How does igneous rock form?
- Describe a process that could cause an unconformity.
- How would a scientist determine the absolute age of a fossil?
- Use the theory of plate tectonics to explain why fossils of *Brachiosaurus* have been found on several different continents.
- What was Earth's early atmosphere like?
- How did Earth's environments change from the Tertiary Period to the Quaternary Period? Explain.

Thinking Critically

- Applying Concepts** Trilobites are index fossils. Paleontologists find a trilobite fossil in a rock layer at the top of a hill in South America. Then they find the same kind of fossil in a rock layer at the bottom of a cliff in Africa. What could the paleontologists conclude about the two rock layers?
- Problem Solving** Which of the elements in the table below would be better to use in dating a fossil from Precambrian time? Explain.

Radioactive Elements	
Element	Half-life (years)
Carbon-14	5,730
Uranium-235	713 million

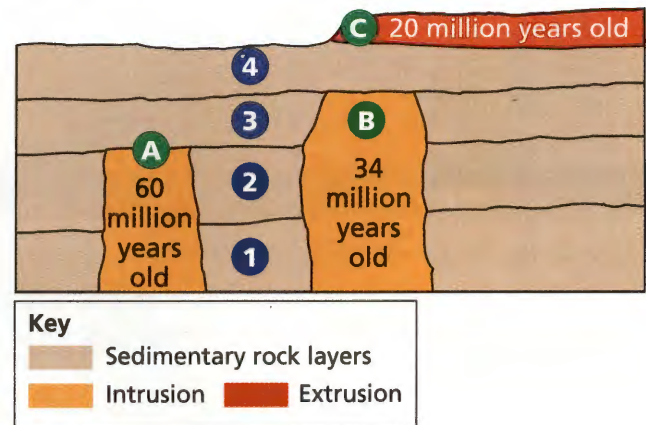
- Relating Cause and Effect** When Pangaea formed, the climate on Earth became drier. How was this climate change more favorable to reptiles than amphibians?
- Making Judgments** If you see a movie in which early humans fight giant dinosaurs, how would you judge the scientific accuracy of that movie? Give reasons for your judgment.

Math Practice

- Percentage** What percentage of a radioactive element will remain after 9 half-lives?

Applying Skills

Use the diagram of rock layers below to answer Questions 22–25.



- Inferring** According to the Law of Superposition, which is the oldest layer of sedimentary rock? Which is the youngest? How do you know?
- Measuring** What method did a scientist use to determine the age of the intrusion and extrusion?
- Interpreting Data** What is the relative age of layer 3? (*Hint: With what absolute ages can you compare it?*)
- Interpreting Data** What is the relative age of layer 4?

Lab zone

Standards Investigation

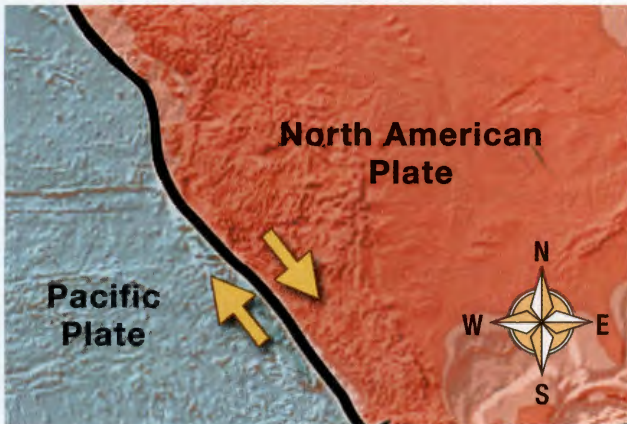
Performance Assessment You have completed your illustrations for the timeline and travel brochure. Now you are ready to present the story of the geologic time period you researched. Be sure to include the awesome sights people will see when they travel to this time period. Don't forget to warn them of any dangers that await them. In your journal, reflect on what you have learned about Earth's history.

Choose the letter of the best answer.

- Which of the following best shows that slow geologic processes can have a major impact on Earth?
 - A extrusions
 - B continental drift
 - C unconformities
 - D index fossils

S 7.4.a

Use the diagram below and your knowledge of science to answer Question 2.

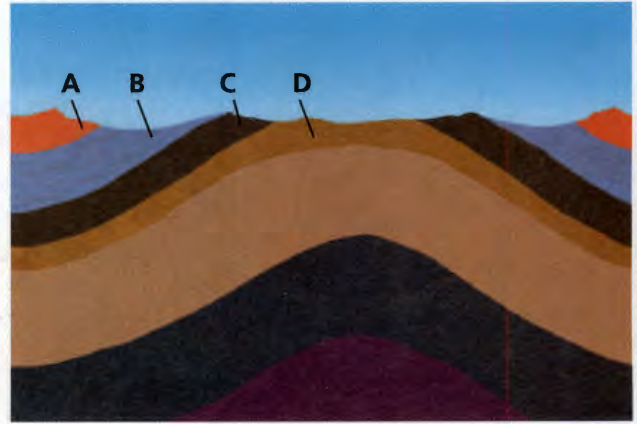


- The diagram shows part of the boundary between the Pacific plate and the North American plate. The arrows show the plates' direction of movement. In 100 years, how is the North American plate likely to have moved along this boundary?
 - A far to the northwest of the Pacific plate
 - B slightly to the northwest of the Pacific plate
 - C far to the southeast of the Pacific plate
 - D slightly to the southeast of the Pacific plate
- A geologist finds identical index fossils in a rock layer in the Grand Canyon in Arizona and in a rock layer in northern Utah, more than 675 kilometers away. What inference can she make about the ages of the two rock layers?
 - A The rock layer in the Grand Canyon is older.
 - B The rock layer in Utah is older.
 - C The two rock layers are about the same age.
 - D no inferences

S 7.4.f

S 7.4.c

Use the diagram below and your knowledge of science to answer Question 4.



- According to the law of superposition, the youngest layer of rock in this diagram is
 - A Layer A.
 - B Layer B.
 - C Layer C.
 - D Layer D.
- What should you use so that the geologic time scale covering Earth's 4.6-billion-year history can be drawn as a straight line on a poster board one meter high?
 - A 1 cm = 1 million years
 - B 1 cm = 10,000 years
 - C 1 cm = 100,000 years
 - D 1 cm = 50,000,000 years
- Dinosaurs most likely became extinct because
 - A disease killed most of the dinosaurs.
 - B large mammals preyed on them and reduced dinosaur populations.
 - C the dinosaurs couldn't obtain enough water to survive.
 - D an asteroid hit Earth, causing severe climate change.

S 7.4.c

S 7.4.g

S 7.4.b

Apply the BIG Idea

- Describe two methods geologists use to determine the age of a rock. In your answer, be sure to mention igneous rock, sedimentary rock, the law of superposition, index fossils, radioactive decay, and half-life.

S 7.4.d

Genetics and Evolution

Unit 2 Review



Chapter 5

Genetics: The Science of Heredity

The BIG Idea

Organisms produced by sexual reproduction inherit half their DNA from each parent. The new combination of DNA determines an organism's traits.

- ➡ What controls the inheritance of traits in organisms?
- ➡ What is probability, and how does it help explain the results of genetic crosses?
- ➡ What role do chromosomes play in inheritance?
- ➡ What forms the genetic code?



Chapter 6

Modern Genetics

The BIG Idea

A person's traits depend on which alleles are inherited from each parent, how those alleles work together, and environmental factors.

- ➡ What are some patterns of inheritance in humans?
- ➡ How do geneticists trace the inheritance of traits?
- ➡ What are three ways of producing organisms with desired traits?



Chapter 7

Changes Over Time

The BIG Idea

Genetic variation and environmental factors have together resulted in the evolution of species.

- ➡ How does natural selection lead to evolution?
- ➡ What evidence supports the theory of evolution?
- ➡ What factors have contributed to the diversity of species?
- ➡ How does a branching tree diagram show evolutionary relationships?



Chapter 8

Earth's History

The BIG Idea

Evidence from rocks shows that life has existed for billions of years and how Earth has changed over time.

- ➡ How do geologists determine the relative age of rocks?
- ➡ How does the theory of plate tectonics explain the movement of Earth's landmasses?
- ➡ What were the major events of the Paleozoic, Mesozoic, and Cenozoic Eras?

Unit 2 Assessment



Connecting the **BIG Ideas**

In northern Alaska and Siberia, part of the ground remains frozen all year round. This frozen layer is called permafrost. Scientists have drilled into the permafrost and found the remains of plants and animals, including woolly mammoths, giant bison, and other large animals that became extinct around 10,000 years ago. Scientists have been able to take DNA samples from these remains and compare the results to other living and extinct organisms. Evidence from this DNA may help scientists determine how changes in climate and the environment may have led to the extinction of these large mammals.

Scientists can use carbon-14 dating to determine when some organisms lived in the past. These data help scientists learn whether or not the organisms lived in a region at the same time.



1. What is the function of DNA? (*Chapter 5*)
 - a. carrying genetic information from parents to offspring
 - b. converting genetic instructions into proteins
 - c. controlling the process of meiosis
 - d. producing chains of amino acids
2. What technique allows scientists to see if two individuals are related? (*Chapter 6*)
 - a. genetic engineering
 - b. selective breeding
 - c. DNA fingerprinting
 - d. Punnett squares
3. How would climate change most likely lead to the extinction of a species? (*Chapter 7*)
 - a. Colder temperatures cause all organisms in an area to freeze.
 - b. The species cannot adapt to the new climate.
 - c. Predators kill more prey in order to survive in the changed climate.
 - d. The species becomes geographically isolated due to the climate change.
4. What process makes carbon-14 useful for dating objects? (*Chapter 8*)
 - a. sedimentation
 - b. superposition
 - c. radioactive decay
 - d. plate tectonics
5. **Summary** Summarize how scientists determine the genetic and evolutionary relationships between individuals and between species. What types of evidence do they use to support their conclusions?