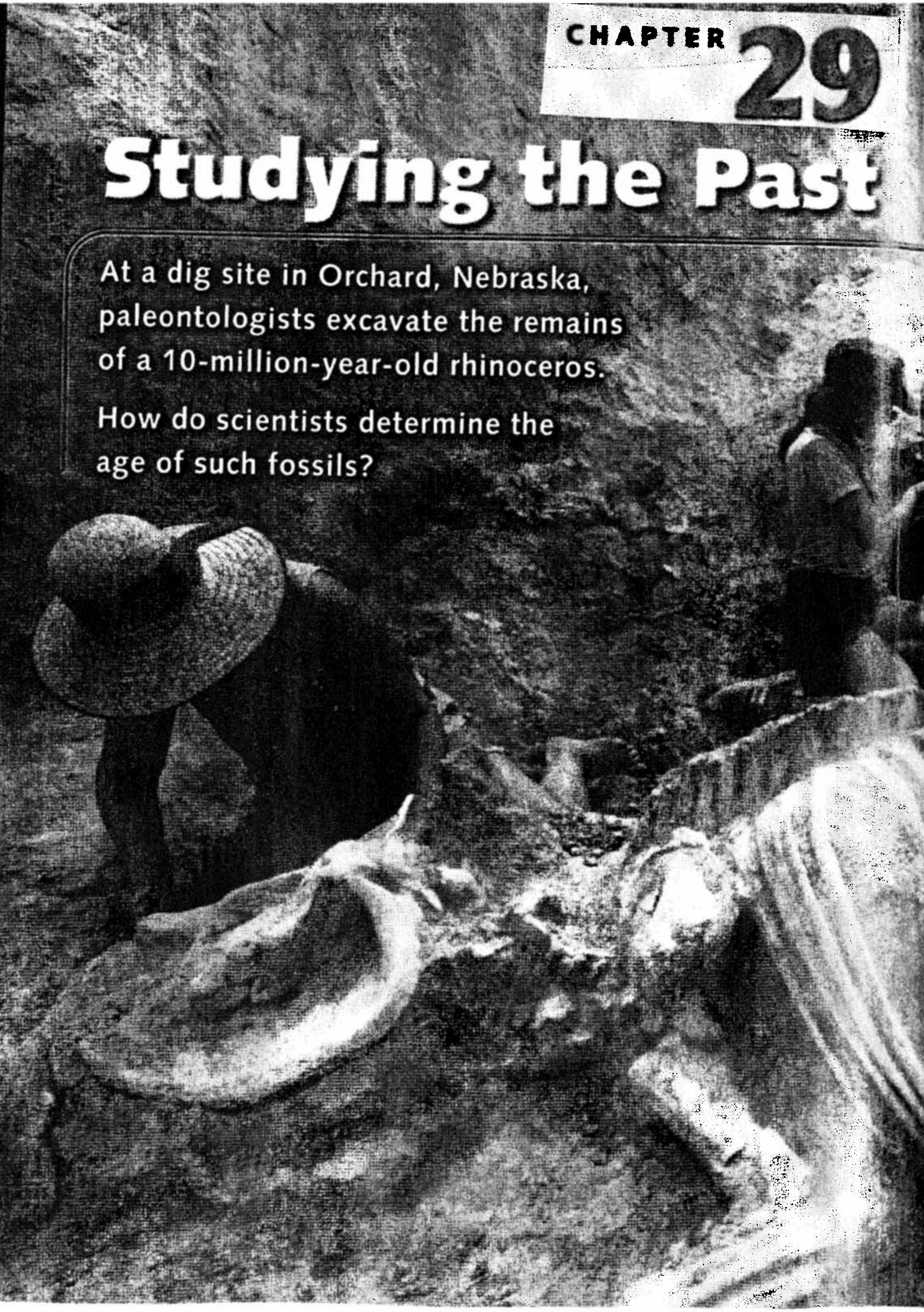
CHAPTER 29

Studying the Past

At a dig site in Orchard, Nebraska, paleontologists excavate the remains of a 10-million-year-old rhinoceros.

How do scientists determine the age of such fossils?



CHAPTER

PREVIEW

▶ FOCUS QUESTIONS In this chapter you will stu
and learn more about the key questions below.

Section 1 What is a fossil and what does it reveal abou

Section 2 What is relative dating, and how is it used to
events?

Section 3 What is absolute time and how is it measur

▶ REVIEW TOPICS As you investigate how sci
Earth's past, you will need to use information fro
chapters.

- elements and isotopes (pp. 90–93)
- igneous intrusions (p. 125)
- features of sedimentary rocks (pp. 130–131)
- stress and folds (pp. 238–239)
- weathering (pp. 258–263)

▶ READING STRATEGY

QUESTION

Before you begin Chapter 29, read the chapter
the chapter contents, and read the key idea for
In your science notebook, write questions abou
for which you want to find answers in the chap

INTERNET RESOURCES
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At our Web site, you will find the following Inte
for this chapter.

DATA CENTER

EARTH NEWS

VISUALIZATIONS
- Fossil Formation
- Unconformity Formation

LOCAL RESOU

INVESTIGATI
- What Stories
- How Do Trees
- How Did the
Grand Canyo

29.1

KEY IDEAS

Fossils form in several ways. Fossils are recognizable remains or traces of organisms that lived in former geologic ages.

KEY VOCABULARY

- paleontology
- mold
- cast
- trace fossil

Fossils

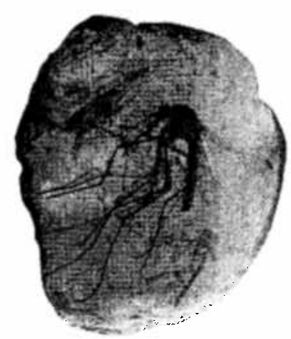
As you learned in Chapter 6, a fossil is any evidence of earlier life preserved in rock. By analyzing fossils, scientists have been able to describe Earth's past. The study of the life that existed in prehistoric times is called **paleontology.** Traces of ancient life, fossils are both the basis for the geologic time scale and an important part of the rock record.

Formation of Fossils

Fossils include shells, bones, petrified trees, footprints, impressions made by leaves, or even burrows made by worms. Fossils may form in several ways, from original remains or from replaced remains, by being preserved in molds or casts, as trace fossils, or in carbonaceous film.

Original Remains

Fossils are rarely the original unchanged remains of plants or animals. Most often, the original remains decay or decompose before rock forms around them. In rare cases, an organism is preserved in its entirety. Large woolly mammoths found frozen in permafrost in Siberia and Alaska are examples of original remains. Also, some prehistoric insects that were trapped in resin—a sticky sap that oozes from trees—were preserved intact when the resin hardened into amber. Original remains can be altered, as minerals in surrounding sediments are deposited into the porous areas of an animal's hard parts after the soft parts have decayed. This happens with shells as well as some dinosaur bones and teeth.



AMBER This insect is an example of original remains preserved in amber.

Replaced Remains

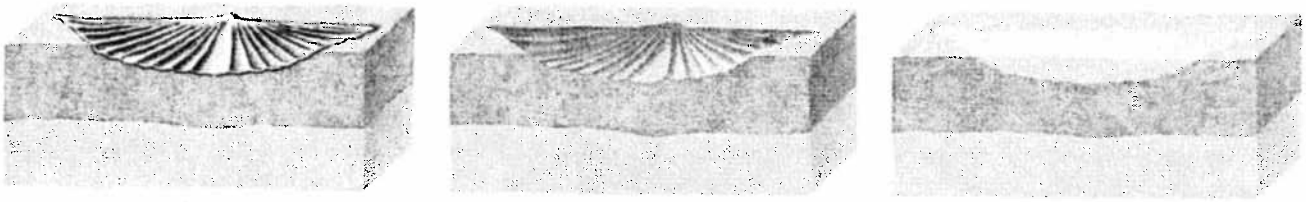
Some fossils form as remains are slowly replaced, molecule by molecule, by rock-forming minerals. This is the case with many fossil bones, teeth, and shells. The hard parts are replaced after the soft parts have decayed. Sometimes, circulating groundwater removes the original organic material of the soft parts of an organism, completely replacing them with minerals. The result is a copy of the original organism. Petrified wood is a good example of this.

Molds and Casts

Fossils may also be preserved as molds and casts. After an organism, or part of an organism, such as a plant, leaf, or insect, is buried in mud or other sediments, its hard body parts become a fossil as the sediments become rock. If the fossil later dissolves out of the rock, a hollow depression in the rock, called a **mold,** results. The mold shows the original shape and surface of the fossil. Minerals may then seep into the mold and fill it, forming a **cast,** or copy, of the original fossil. Molds and casts of shellfish are common fossils. In the rock layers of some areas, there are molds of ferns, leaves, and fish.

PETRIFIED LOGS These fossilized remains are in the Petrified Forest National Park, Arizona.

Mold and Cast Formation



1. A brachiopod has died and fallen into soft sediments. The hard shell remains after the soft body parts decay.
2. The sediments become rock. The shell decays, leaving a mold of the shell.
3. Minerals fill the mold, creating a cast of the original shell.

Trace Fossils

Often, no part of a skeleton or plant survives as a fossil. However, other, more indirect evidence of life may be preserved as a **trace fossil.** Trace fossils include any impressions left in rock by an animal, such as trails, footprints, tracks, burrows, and even bite marks on fossils of trilobites. Scientists infer the existence of many animals from trace fossils. For example, scientists can learn about dinosaurs that lived in a particular area from footprints the animals left behind.

VISUALIZATIONS
CLASSZONE.COM
Observe how fossils can form.
Keycode: ES2901

Carbonaceous Films

Sometimes the only fossil trace is a thin carbon film resembling a silhouette. The remains of plants or animals in sediments are affected by high temperature and pressure as additional sediments are deposited. These conditions cause the carbon compounds making up the tissues of animals and plants to undergo chemical changes. This carbonizing process results in a thin film of carbon that details the remains.

FOSSIL BRACHIOPODS You can see examples of both molds and casts in this photograph. The molds are hollowed, the "reverse" of the original shells.

29.1 *Section Review*

1. Identify two ways in which remains may be preserved as fossils.
2. Describe trace fossils and how paleontologists use them to make inferences about the past.
3. **COMPARE AND CONTRAST** Explain how original remains, replaced remains, molds, and casts are similar and how they are different.
4. **PAIRED ACTIVITY** Work with a partner to complete the table with examples of each type of fossil.

Original	Replaced	Molds	Casts

29.2

KEY IDEA

Scientists use a number of principles and methods to determine the order of past geologic events.

KEY VOCABULARY

- relative dating
- strata
- unconformity
- correlation
- index fossils
- key bed

VOCABULARY STRATEGY

The word *superposition* comes from the Latin words *super* and *pōnere,* which mean, respectively, "above" and "to place." *Superposition* means "the state of being placed above."

Relative Time

Prior to the late 1700s, scientists estimated the age of Earth to be only about 6000 years. However, evidence showing geologic processes, such as erosion and sedimentation, occur over extremely long time spans led to the realization that Earth must be much older. Scientists then tried to determine Earth's age; by examining layers of rock, they were able to get a better idea of geologic history. Because paleontologists cannot always identify the exact age of a specimen or the exact time of an event, they often use a process called relative dating.

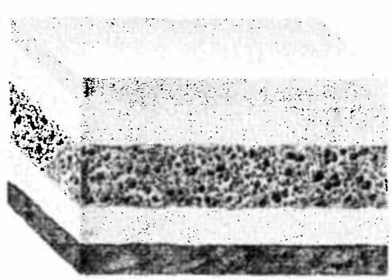
Relative Dating

Relative dating is the process of placing events in the sequence in which they occurred. Relative dating does not identify the actual dates on which the events occurred. For example, suppose your family took a trip several years ago. You cannot remember the exact date of the trip, but you know that it took place before you entered fifth grade. In recalling the trip in this way, you are using relative dating. Scientists use relative dating to help them determine the relative ages of Earth's rocks. Relative dating is based on certain principles, or rules, for telling relative time.

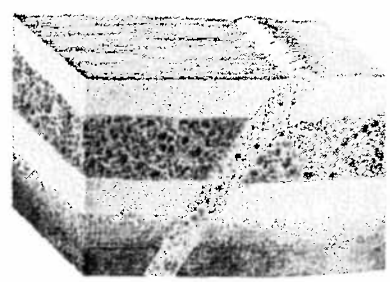
The Principle of Superposition

Sedimentary rock forms after particles settle out of a fluid and, over time, are compressed into layers, or **strata.** The principle of superposition states that in an undisturbed sequence of sedimentary strata, the oldest rock layer will be at the bottom and the youngest will be at the top. The principle of superposition is the basis for all relative dating and is a fundamental concept in studying Earth's history.

Remember that most layers of sediment are deposited in a horizontal position. You can see that the strata shown in step 1, below, have not been disturbed. Thus, you can infer that they are in their original horizontal positions.



1 According to the principle of superposition, the oldest layer is at the bottom. The youngest layer of sediment, the last deposited, is at the top.



2 The intrusion that cuts across all layers is the youngest (principle of cross-cutting relationships). The embedded fragments of the next-to-last layer indicate an earlier, horizontal intrusion.

The Principle of Cross-Cutting Relationships

Step 2 on page 650 shows a magma intrusion cutting across the horizontal strata. The principle of cross-cutting relationships states that an igneous intrusion is always younger than the rock it has intruded, or cut across. Therefore, an intrusion is always younger than the surrounding layers.

VISUALIZATIONS
CLASSZONE.COM
Observe an animation showing the formation of an unconformity.
Keycode: ES2902

Embedded Fragments

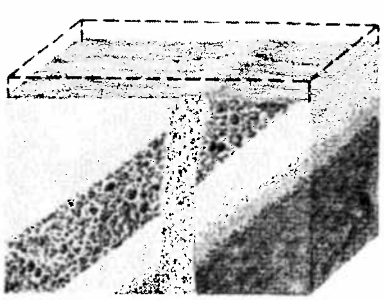
Rocks that are embedded in another rock must be older than the rock in which they are found. For example, the pebbles in a conglomerate must have existed before the conglomerate formed, and so they are older than the conglomerate. In step 2 on page 650, the next-to-last horizontal layer has intruded upon pre-existing sedimentary layers. The embedded fragments within this igneous intrusion come from the sedimentary layers above and below.

Gaps in Relative Time

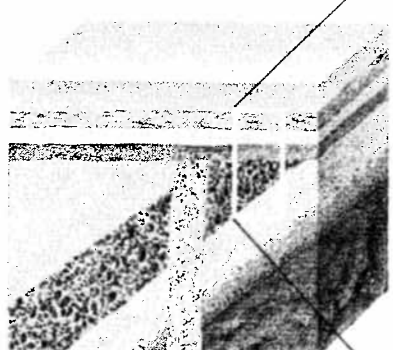
Another way of reading the rock record involves the examination of unconformities. An **unconformity** indicates where layers of rock are missing in the strata sequence. For example, in step 3 below erosion has removed a portion of the rock layers. The processes that bring about such unconformities all require huge expanses of time and represent large gaps in geologic time. Strata may be missing because they were never deposited. More likely, as when pages are missing from a book, the rock layers may have been deposited and later removed.

Angular Unconformity

Original horizontal sediments are sometimes tilted during uplift. Over time the exposed surface is worn down. An angular unconformity results when younger, flat strata are deposited on top of the older strata, as in step 4.

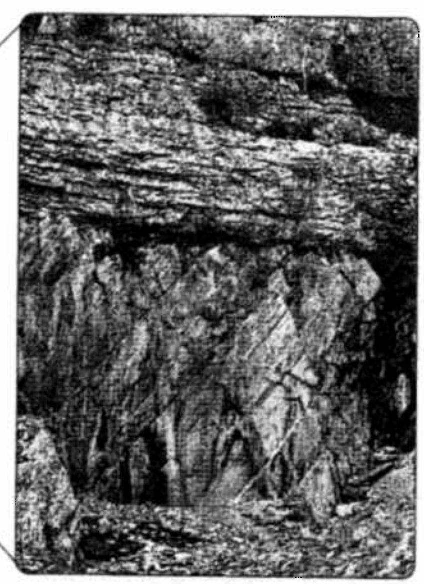


3 Over time, rock layers may tilt and erode. Such changes can cause gaps in the rock record.



4 An angular unconformity has formed after new sediments were deposited on tilted rock layers.

UNCONFORMITY The horizontal layers at the top of this photograph of an unconformity are younger than the tilted rock layers below them.



INVESTIGATIONS
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What Stories Do Rocks Tell? Read rock layers to interpret the geologic story of a place. Check your predictions by watching an animated sequences.
Keycode: ES2903

Disconformity

Sometimes original horizontal sediments are lifted up and the top layers eroded. When they are resubmerged beneath a freshwater or saltwater sea, new sediments are deposited. The result is called a disconformity: even though the layers are still horizontal, some layers are missing. It may be hard to identify a disconformity because no folding or tilting has occurred. Nevertheless, a disconformity results in a gap in the rock record.

Nonconformity

A nonconformity results when sedimentary layers have been deposited on igneous or metamorphic rock. If a crystalline rock such as granite is lifted up from deep within Earth's interior, it begins to erode on the surface. If the granite is then submerged under a body of water, sediments are deposited on top of the eroded granite. The resulting boundary is a nonconformity.

Rock Layer Correlation

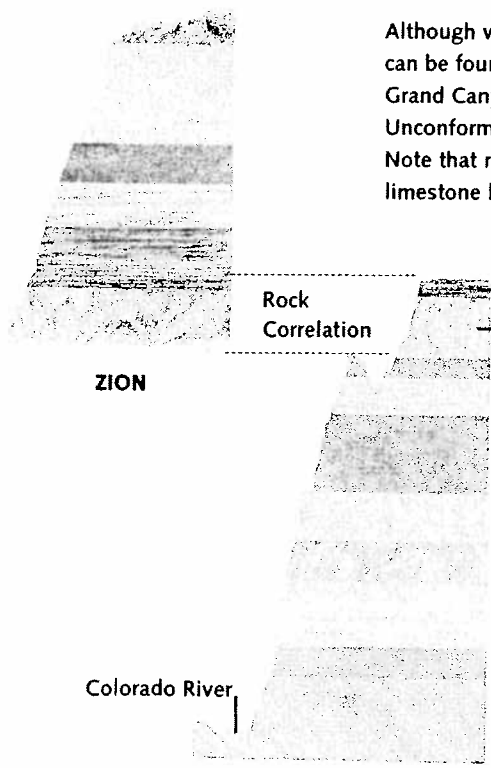
Correlation is the matching of rock layers from one area to another. In the illustration below, for example, you can see the strata from two locations. A geologist might wish to know if a layer of limestone in Zion National Park is the same limestone layer as one in Grand Canyon National Park. Geologists use several methods to match, or correlate, rock layers.

Correlation of Rock Layers


ZION NATIONAL PARK, UTAH


GRAND CANYON NATIONAL PARK, EAST RIM, ARIZONA

Although widely separated, the same rock layers can be found at Zion National Park, Utah, and at Grand Canyon National Park, Arizona. Unconformities make the correlation incomplete. Note that rock layers below Zion's Kaibab limestone have not been exposed.



Walking the Outcrop

A simple and direct method of correlation is "walking the outcrop." An outcrop is the part of a rock layer that can be seen at Earth's surface. Walking along outcrops is an easy way of finding out whether two rock layers are the same. Walking can be difficult, however, in areas where the outcrop is covered by thick soil or heavy vegetation or where extensive erosion has occurred. Also, this method is not practical when comparing outcrops that are far apart.

Matching Rock Characteristics

In this method, rocks are matched by characteristics such as appearance, color, and composition. For example, a rock that weathers with a distinctive rust color would be easy to recognize and therefore usable for correlation.

Using Index Fossils

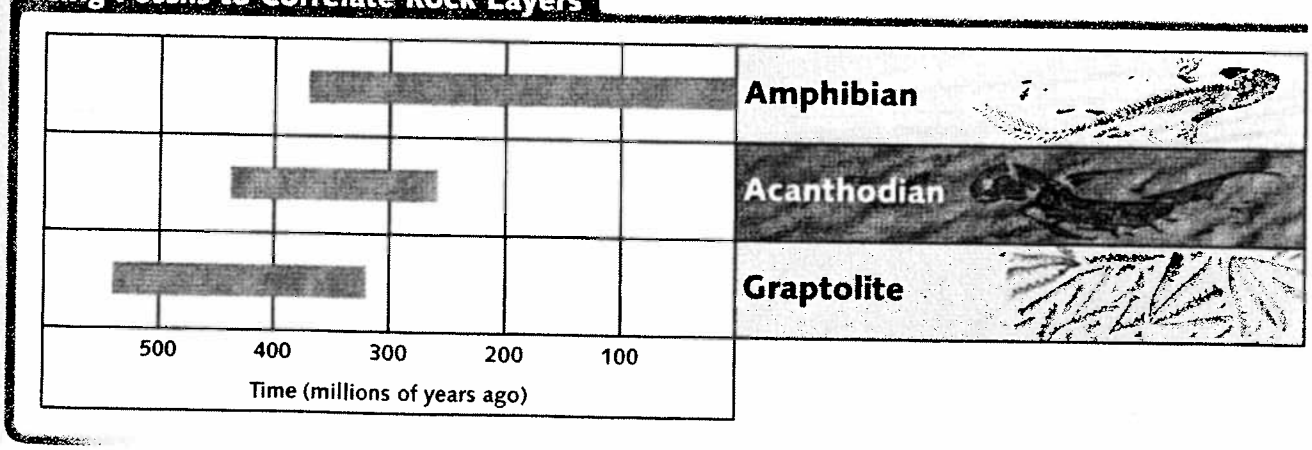
One of the best methods of correlating rock layers over long distances is the use of index, or guide, fossils. **Index fossils** are the remains of organisms that lived and died within a particular time segment of Earth's history. After death, their bodies were deposited in sediments. Most of the organisms then became extinct. Therefore, each layer contains fossils unlike those in the layer above or below it. Geologists can use these distinctive fossils to correlate layers of rock from different areas.

Index fossils have four characteristics. First, the fossils are easily recognizable. That is, they are unique in some way that enables scientists to easily distinguish them from other, similar fossils. Second, index fossils are abundant. Third, the fossils are widespread in occurrence. That is, they are found over a broad geographical area. This makes it possible to use them to match rock layers of a particular age over wide areas. Fourth, index fossils are the remains of organisms that existed for only a brief period, so the fossils occur in only a few rock layers. Index fossils found in rock layers in different parts of the world indicate that the layers were formed at the same time.

Scientific Thinking

INTERPRET HISTORY
Using correlation, scientists have determined the relative ages of most of the rocks on Earth's surface. They have worked out a timetable that divides geologic time into units. Refer to this timetable on pages 668–669. Based on the rock correlation chart of Zion and the Grand Canyon, find the relative ages of the area of correlation. Hint: Kaibab is Permian limestone, and the Moenkopi formation is largely Triassic sandstone. Based on information in the timetable, infer what North America may have been like. What life forms were in existence? What geologic forces were present?

Using Fossils to Correlate Rock Layers



INDEX FOSSILS are used by paleontologists to correlate rock layers. Fossil amphibians, acanthodians, and graptolites are used in this way.

Fossils as Environmental Indicators

In addition to determining relative time and correlating rock layers, fossils are important as indicators of past climate. For example, coral reefs today form only in shallow, warm water between approximately 30° N and 30° S latitudes. A rock containing fossil coral is evidence that the particular area was once covered with shallow, warm water.

Matching Key Beds

A single rock layer that, like an index fossil, is unique, easily recognizable, and widespread is called a **key bed.** Large volcanic eruptions are an excellent source of material for key beds. Volcanic ash and debris are spread over a large area. This material eventually becomes a clay, called bentonite, in sedimentary rock layers. In some areas, beds of bentonite have been used to correlate rock layers. Similarly, dust and debris from the impacts of large meteorites on Earth's surface create key beds. The layer that results from such events represents a single instant in time but is unique and widespread.

Stratigraphic Matching

Suppose you have followed an outcrop of limestone around a canyon wall. You then travel a short distance to a second location, in a small valley, and notice what appears to be the same layer of limestone. You remember that the limestone layer in the canyon was sandwiched between two layers of conglomerate rocks. The limestone in the valley is also sandwiched between conglomerate layers. You can conclude that the two limestone layers represent two outcrops of the same stratum. You have matched not just the outcrop of limestone, but the sequence of the three layers—conglomerate, limestone, conglomerate—from the two locations. This correlating of strata sequences is called stratigraphic matching.

29.2 Section Review

1. Can the principles of relative dating be used to determine the date a rock layer was deposited? Explain your reasoning.
2. How do unconformities represent gaps in geologic time?
3. Describe three methods you could use to correlate rock layers in two distant locations.
4. CRITICAL THINKING Would you expect to find dinosaur fossils above or below human fossils in an undisturbed strata sequence? Explain your reasoning.
5. MATHEMATICS CONNECTION Use scientific notation to express the dates given on the table on page 653.

SCIENCE & Technology

Ancient Rocks Provide Clues

A group of geologists working in western Australia dug tiny zircon crystals from ordinary-looking sedimentary rocks. When they measured the ratios of uranium to lead, they found the crystals to be 4.4 billion years old. That's about 130 million years older than any previously discovered Earth crystals!

What is the significance of this information?

Radiometric dating has led to the discovery of Earth materials so ancient that scientists are scratching their heads about what it means. What's more, further tests on the zircon crystals gave evidence that they formed on a solid crust in the presence of water.

Until this discovery, most geologists thought Earth at that time was a molten blob, still millions of years away from forming a crust! If the ancient crystals formed on a crust, geologists may have to change their picture of early Earth.

If water existed that early on Earth, life, too, might have been present far earlier than had been previously thought. At that time, asteroids and meteorites were still slamming into Earth on a regular basis. Some

ZIRCON CRYSTALS that date back 4.4 billion years have forced scientists to reconsider their ideas about Earth's history.

scientists are now wondering if forms of life may have started during a lull in the bombardments. Could more impacts have led to a mass extinction, with all the fossil records having been obliterated? Consider the result of the impact of a single asteroid on the dinosaur population only 65 million years ago.

The zircon crystals found in Australia were tiny fragments of bigger rocks eroded away millennia ago. Radiometric dating of rocks in northwestern Canada has recently revealed a staggering age—around 4.03 billion years old. These ancient metamorphic rocks provide additional clues about the formation of Earth's crust and the continents. ■

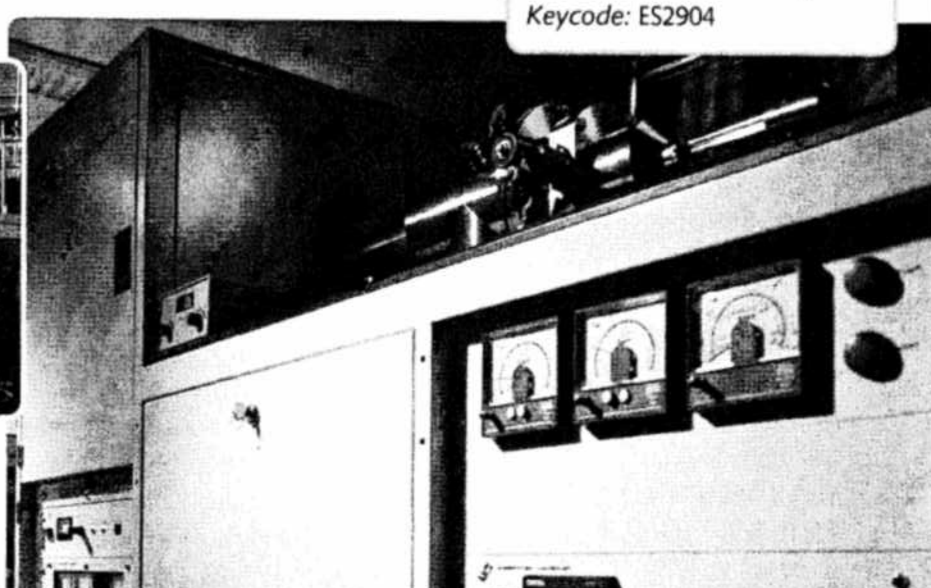
Extension

SCIENCE NOTEBOOK

Certain areas of Earth, such as mountains and valleys beneath the sea, have not been dated. Explain how radiometric dating could be used to explore these areas of Earth.

DATA CENTER
CLASSZONE.COM

Learn more about current methods of scientific dating.
Keycode: ES2904



SPECTROMETER Lab workers can use a spectrometer to analyze the chemical composition of rocks and crystals.

29.3

KEY IDEA

Scientists use radioactive-dating methods to measure absolute time.

KEY VOCABULARY

- absolute time
- varve
- radioactive decay
- parent isotope
- daughter isotope
- half-life
- radiometric dating

TREE SAMPLES By studying tree rings, scientists can determine a tree's age and the environmental conditions in which it grew, including rainfall and temperature. Somewhat like rock layers, tree rings can be correlated.

INVESTIGATIONS CLASSZONE.COM

How Do Trees Record Time?
Analyze patterns in tree rings to find out how trees tell absolute time.
Keycode: ES2905

Absolute Time

Relative dating principles help scientists place events in a sequence. However other methods must be used to determine the actual dates of events—the **absolute time.**

Historical Methods

Before the 20th century, scientists had only a few, limited means of measuring absolute time. One method involved estimating rates of erosion and sedimentation. Unfortunately, such rates are not constant, especially over time periods greater than thousands of years. Therefore only the ages of young geologic features could be accurately measured.

Another method used to measure absolute time was counting tree rings—a method still used today. As you can see on the left, a stump or limb has concentric rings of various widths. Each ring usually represents a single year. The width of a ring depends upon the temperature and the amount of rainfall that year. Each ring in a tree differs from other rings in that tree, yet is similar to the rings formed during that same year in other trees. Therefore, the pattern of rings in one tree can be correlated with that in another tree. By applying this technique to wood in Native American ruins in the southwestern United States, scientists have determined dates back to almost 2000 B.C.

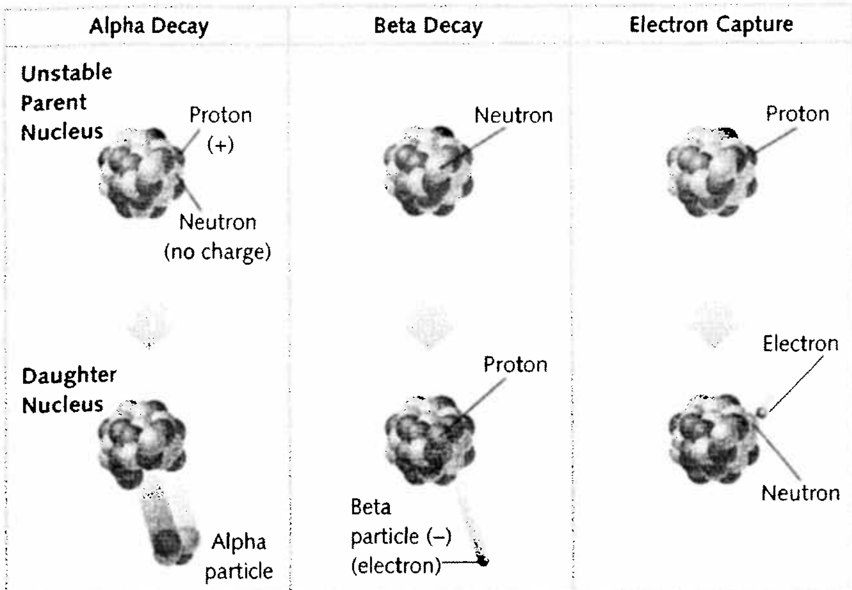
A third method of measuring absolute time is by counting varves. A **varve** is any sediment that is deposited on a yearly cycle. While varves can form in any body of water, they are clearest in glacial lakes formed during an ice age. In these lakes, two distinct layers of sediment were deposited each year—a thick, light-colored sandy layer in summer and a thin, dark-colored clay layer in winter. Like an annual tree ring, each annual varve is distinctive. As a result, the varves of one lake can be correlated with the varves of other lakes. By matching deposits, scientists have determined dates back to 15,000 years ago.

Radioactivity

In the mid-1900s, scientists began using a new tool to measure absolute time—radioactive isotopes. You learned about isotopes in Chapter 5. Radioactive isotopes emit or capture tiny particles in a process called **radioactive decay.** The diagram on page 657 shows the three main types of decay: alpha decay, beta decay, and electron capture. In alpha decay, an alpha particle (two protons and two neutrons) is emitted. In beta decay, a neutron disintegrates into a proton and an electron (or beta particle), and the electron is emitted. In electron capture, a proton captures an electron and becomes a neutron.

Each time a particle is emitted or captured, the isotope's atomic number changes and it becomes an isotope of a different element. If this new isotope is radioactive, decay continues. Radiation is released until a stable isotope—that is, one that is not radioactive—forms. The original element is called the **parent isotope,** and the product of the decay is called the **daughter isotope.**

Radioactive Decay



	Alpha Decay	Beta Decay	Electron Capture
Atomic Number	2 fewer	1 more	1 fewer
Atomic Mass	4 fewer	no change	no change

An example of this process is the decay of the radioactive isotope uranium-238 to lead-206. When the parent isotope U-238 gives off an alpha particle, it becomes thorium-234, which is also radioactive. Decay continues, with alpha and beta decay and electron capture, until finally a stable isotope is formed that is not radioactive—the daughter isotope Pb-206.

Half-Life

Radioactive elements decay at characteristic constant rates that are not affected by the passage of time or changes in temperature or pressure. At the moment an igneous rock crystallizes, radioactive elements in the rock begin to decay. The ratio of the amount of radioactive element left in the rock to the amount of stable product can be used to determine the absolute age of the rock.

The rate at which a radioactive element decays is called its half-life. **Half-life** is the time it takes for half the radioactive atoms in a sample to decay to a stable product. Refer to the graph of half-life in the Appendix, page 705. The graph shows how half-life can be used to date material.

After one half-life, half of the atoms of a radioactive element will have decayed to a stable product and half will remain unchanged. During the next half-life, half of the remaining radioactive atoms will decay.

During each half-life, half of the radioactive material in a sample, no matter how small the amount, will decay to a stable product. Half-lives range from a fraction of a second to billions of years. For example, the isotope protactinium-234 has a half-life of about one minute, whereas the isotope uranium-238 has a half-life of 4.5 billion years.

25-Minute
Mini LAB

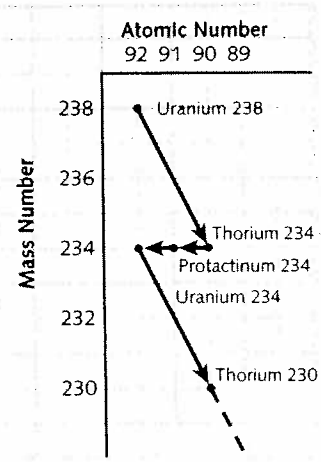
A Decay Path

Materials

- periodic table of elements
- graph paper

Procedure

1. Before becoming Pb-206, U-238 decays to Th-230, as shown below (1 alpha, 2 beta, and 1 alpha decay). Copy this graph on the top half of a sheet of graph paper.



2. The decay events from Th-230 to Pb-206 are 4 alpha, 2 beta, 1 alpha, 2 beta, and 1 alpha decay. Complete your graph. Label each point.

Analysis

Why does the atomic number increase after beta decay? Explain why there might be a pattern to a decay path.

Radiometric Dating

Scientists use radioactivity and half-lives of elements to measure absolute time through a technique called radiometric dating. In **radiometric dating,** scientists measure the amounts of a parent and a daughter isotope within a rock or mineral and use the ratio of the two to find the age of the rock. A version of radiometric dating used on organic material, such as preserved remains, can determine the time of an organism's death. Carbon-14 is used to date organic material. Uranium-lead, rubidium-strontium, and potassium-argon are used to date rocks and minerals.

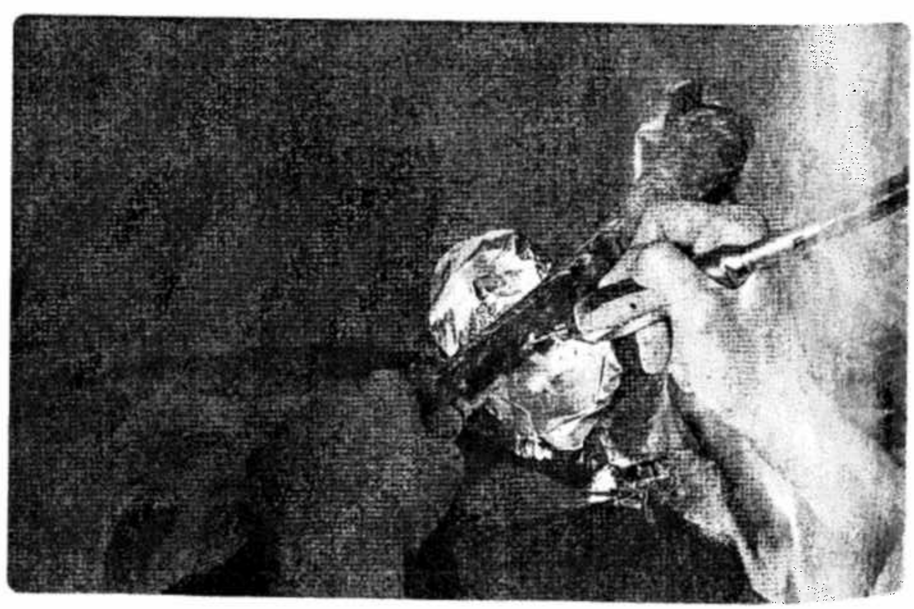
Radiocarbon Dating

All living things continually take in from their environments both radioactive carbon-14 and nonradioactive carbon-12. These amounts remain constant as long as the organism is living. When an organism dies, however, the amount of carbon-14 in its tissues decreases. The amount of carbon-12 remains the same. Thus the ratio of carbon-12 to carbon-14 can be used to tell when a plant or animal died.

Radiocarbon dating has two limitations. First, the method can only be used to date objects from organisms that once lived, such as logs and bones. Second, because the half-life of carbon-14 (5730 years) is relatively short, the method is limited to dating items that are about 70,000 years old or younger. Radiocarbon is invaluable, though, for dating such items as the wooden tools and skeletons of prehistoric people, and plant and animal remains preserved in deposits from the Ice Age.

Uranium-Lead Dating

The radioactive isotope uranium-238 decays to the isotope lead-206, the stable end product. The half-life of U-238 is 4.5 billion years. This long half-life makes it possible to use this method to date the oldest rocks of Earth's crust. Although uranium is common throughout the world, it occurs only in trace amounts in a mineral called zircon, which is found in some igneous rocks. It is rarely found in sedimentary or metamorphic rocks.



RADIOCARBON DATING Shavings of fossilized reindeer bone will be tested using the radioactive isotope carbon-14.

Isotopes Used in Radiometric Dating

Parent Isotope	Decay System	Daughter Isotope	Half-life (years)	Effective Range (years)	Possible Materials for Dating
Carbon-14	Beta decay	Nitrogen-14	5730	100–70,000	Once-living matter (wood, charcoal, bone)
Uranium-238	Alpha decay, Beta decay	Lead-206	4.5 billion	>10 million	Uranium-bearing minerals (zircon)
Rubidium-87	Beta decay	Strontium-87	47 billion	>10 million	Micas, feldspars, metamorphic rocks
Potassium-40	Beta capture	Argon-40	1.3 billion	>50,000	Micas, amphiboles, feldspars, volcanic rocks

Also, because of the long half-life of U-238, the uranium-lead method does not give reliable results for rocks that are younger than 10 million years old. In rocks that are younger, too little of the U-238 will have decayed to measure accurately.

Rubidium-Strontium Dating

A second method of dating rocks involves the decay of rubidium-87 to strontium-87. The half-life of rubidium-87 is about 47 billion years—more than ten times Earth's age! Because of this long half-life, the rubidium-strontium method is best for dating extremely old rocks. Rubidium occurs in common minerals such as feldspars and micas and thus can be used to date almost all igneous rocks. If both rubidium-87 and uranium-238 occur in the same rock, both the uranium-lead and rubidium-strontium methods can be used, and the values obtained can be checked against each other.

Potassium-Argon Dating

Potassium-40, with a half-life of about 1.3 billion years, decays to the element argon-40. Potassium, a very common element, is found in feldspars, micas, and amphiboles. Minerals that can be dated by the potassium-argon method are found in metamorphic and sedimentary rocks as well as in igneous rocks. In some cases, this method can date rocks as young as 50,000 years. Therefore, the method is used to date many rocks that cannot be dated by uranium or rubidium.

29.3 *Section Review*

1. What are the similarities between tree rings and varves?
2. Describe the three main types of radioactive decay.
3. What is the half-life of carbon-14? In what way does this half-life limit what can be dated by the radiocarbon method?
4. If an igneous rock is more than 3 billion years old, what are the two best methods you could use to find the exact age of the rock?
5. **APPLICATION** If you were to date a piece of petrified wood, would you use carbon-14 or potassium-argon dating? Why?

CHAPTER 29 LAB Activity

Deciphering Tree Rings

SKILLS AND OBJECTIVES

- ***Plot*** tree-ring growth data.
- ***Analyze*** the effect of different environmental factors on growth.
- ***Correlate*** the relationship between these factors.

MATERIALS

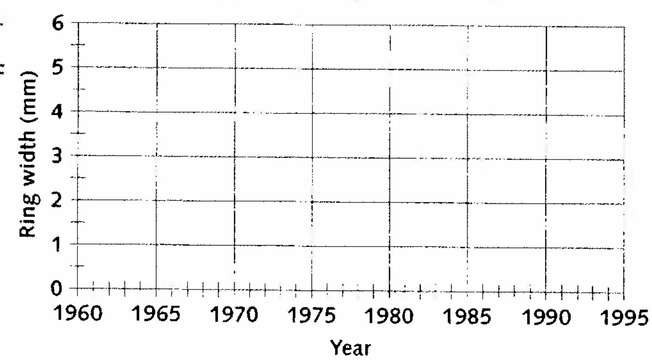
- Appendix A, datatable, page 707
- colored pencils
- graph paper
- tracing paper
- ruler

The study of dating past events and environmental changes by analyzing tree rings is called dendrochronology. Before sophisticated technology and dating tools were available, scientists could study tree-ring samples to make inferences about climate change and weather conditions, including events such as volcanic eruptions, fires, floods, or droughts.

To reconstruct past conditions based on tree rings, scientists carefully analyze data. For example, tree-growth data can be compared to weather data to find possible relationships. When data from one data set has a trend similar to another, this is called a positive correlation. When the data from two sets have opposite trends, this is called negative correlation. When the data from different sets do not seem to follow any pattern, the sets are uncorrelated. In this activity, you will investigate the relationship between tree rings and past conditions. The data were taken from five trees in a region of Alaska in the years from 1950 to 1994.

Tree-Ring Growth and Weather

Year	Tree 1 Growth	Tree 2 Growth	Tree 3 Growth	Tree 4 Growth	Tree 5 Growth	Average Growth	Average Temperature	Total Precipitation
1994	2.54	1.73	3.51	2.39	3.66		−1.39	27.13
1993	2.58	1.59	4.05	3.25	4.15		−1.19	34.77
1992	2.67	2.38						28.68
1991	2.21	2.35						31.83



Procedure

Part A: Calculating Average Tree Growth

1. Using the data in the table on page 707, calculate the average growth for each year.

2. Draw a graph similar to the graph shown. Label the x-axis "Year" and the y-axis "Ring width (millimeters)." Choose a colored pencil and plot the data from Step 1 on your graph. Connect your data points to create a line graph. For each axis, choose appropriate limits and scales.

Part B: Correlating Growth and Precipitation

❸ Lay a sheet of tracing paper over the graph from Part A. With the aid of a ruler, trace the outline of the graph setup but not the data from Part A. Copy the *x*-axis labels, but not the *y*-axis labels. Label the sheet "Growth and Precipitation."

❹ Label the *y*-axis of your traced graph "Total precipitation (cm)." Choose a different colored pencil. Using the grid of the graph from Part A as a guide, plot the precipitation for each year on the traced graph. Be sure to choose an appropriate scale and limits. Connect the data points.

Part C: Correlating Growth and Temperature

❺ Place the graph from Part B aside. Repeat Step 3, but this time label the sheet "Growth and Temperature." Again, copy only the *x*-axis labels.

❻ Label the *y*-axis of your traced graph "Average temperature (°C)." Choose an appropriate scale and limits. Using a different colored pencil, plot the temperature data for each year. Connect the data points.

Analysis and Conclusions

1. Overlay the Growth and Temperature graph on top of the original Growth graph. Are these data related? If so, how? Use the terms *positive correlation, negative correlation,* or *uncorrelated* in your answer.
2. Based on your answers to Question 1, predict tree growth during a warm year, a cold year, and a very cold year.
3. Overlay the Growth and Precipitation graph on top of the other two graphs so that all three are aligned. Is there a relationship between all three sets of data? If so, how are they related?
4. What observations can you make based on all three graphs? Which years had best growth? What were the temperature and precipitation trends during these years? What about the years of poorest growth?
5. What recent trends can you observe? Do you notice trends that show changes in the rate of growth?
6. Based on these trends, can you predict tree growth for 2010? 2050?
7. Based on the experimental data given, is there evidence for global warming or a global warming trend? Explain your reasoning.

DATA CENTER
CLASSZONE.COM
Find out more about dendrochronology.
Keycode: ES2907

Critical Thinking

12. Infer A series of rock layers, from bottom to top, is sandstone, shale, limestone, basalt. What can you infer about the rock layer at the bottom? the top? about geologic events in the area?

13. Evaluate A fossil being considered for use as an index fossil has been found in large numbers in many parts of the world and seems to be limited to rock layers from the Ordovician period. It closely resembles a Cambrian trilobite. Would this fossil be a good index fossil? Explain.

14. Communicate Use diagrams as well as words to prepare a presentation that explains how a parent isotope of uranium becomes the daughter isotope lead via the process of radioactive decay.

15. Hypothesize A particular mammal fossil is discovered in identical rock strata in eastern South America and in western Africa. Form a hypothesis that explains how fossils of the same organism, dating from the same time, can be found in such wide-ranging places.

16. Apply A table leg was made from the center of a tree that contains all its growth rings. Based on what you have learned about tree-ring dating, can you determine the age of the table? Of the tree at the time it was cut? Explain.

Internet Extension

INVESTIGATIONS
CLASSZONE.COM

How Did the Layers of the Grand Canyon Form?
Tell the geological story of the Grand Canyon.
Keycode: ES2906

Writing About the Earth System

SCIENCE NOTEBOOK Rock layers, tree rings, and varves are like pages holding the record of the Earth system's story. Review information about those in your book, the Data Center, and other resources. Then describe in your science notebook how each one records events. Consider cataclysmic events, such as a volcanic eruption, as well as less dramatic events, such as the passage of time. Of rocks, trees, and varves, which one do you think best tells the story of Earth's four spheres—geosphere, hydrosphere, biosphere, and atmosphere? Explain your answer.

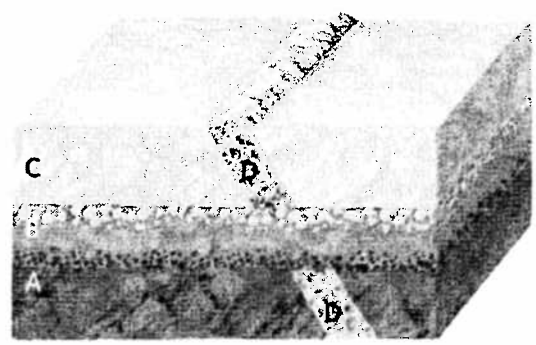
Interpreting Illustrations

The illustration shows a series of rock strata. Review what you know about sediment deposition, igneous intrusions, the principle of superposition, and cross-cutting relationships. Examine the illustration carefully, then answer the questions.

17. Which of these layers can you most easily identify as igneous rock? Explain.

18. Considering your answer to question 17, which strata are most likely *not* igneous rock? What types of rock could they be?

19. Would this stratification be possible if all the layers shown were sedimentary rock? Explain.



20. Based on your answers to questions 17–19, list the letters of the rock layers in order from oldest to youngest. Explain your answer.