SECTION 1

# Evidence of the Past

*In 1995, scientist Paul Sereno found a dinosaur skull that was 1.5 m long in the Sahara, a desert in Africa. The dinosaur may have been the largest land predator that has ever existed!*

Scientists such as Paul Sereno look for clues to help them reconstruct what happened in the past. These scientists, called *paleontologists* (PAY lee uhn TAHL uh jists), use fossils to reconstruct the history of life before humans existed. Fossils show us that life on Earth has changed a great deal. They also provide us clues about how those changes happened.

## READING WARM-UP

### Objectives

- Explain how fossils can be formed and how their age can be estimated.
- Describe the geologic time scale and the way that scientists use it.
- Compare two ways that conditions for life on Earth have changed over time.

### Terms to Learn

fossil
relative dating
absolute dating
geologic time scale
extinct
plate tectonics

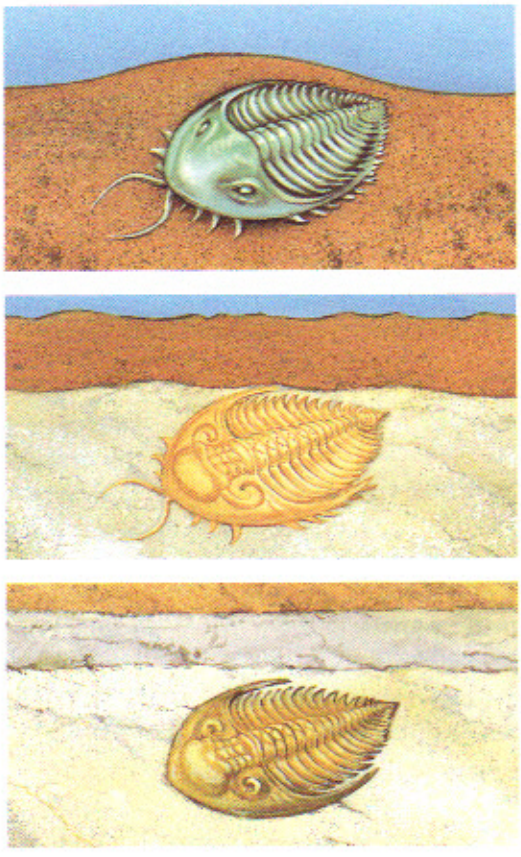
## READING STRATEGY

**Reading Organizer** As you read this section, make a concept map by using the terms above.

## Fossils

**Fossils** are traces or imprints of living things—such as animals, plants, bacteria, and fungi—that are preserved in rock. Fossils sometimes form when a dead organism is covered by a layer of sediment. The sediment may later be pressed together to form sedimentary rock. **Figure 1** shows one way that fossils can form in sedimentary rock.

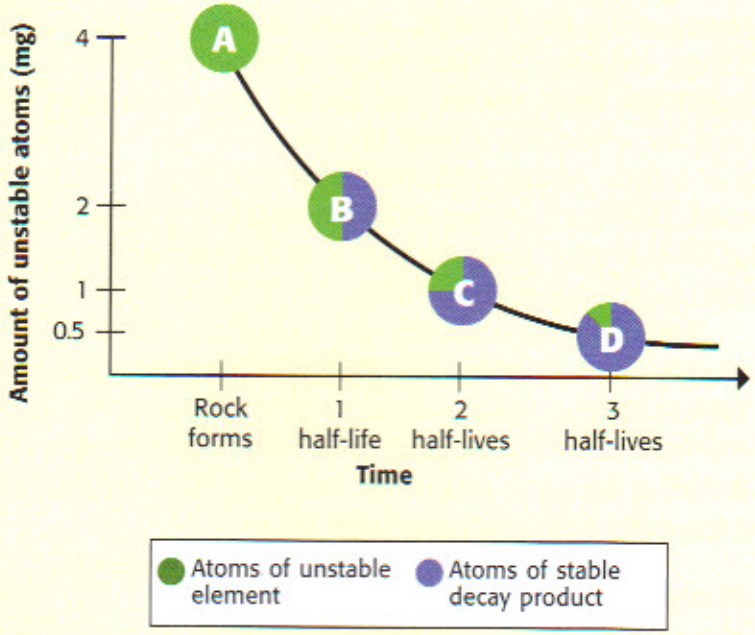
**Figure 1** One Way Fossils Can Form



1. Fossils can form in several ways. The most common way is when an organism dies and becomes buried in sediment.
2. The organism gradually decomposes and leaves a hollow impression, or *mold*, in the sediment.
3. Over time, the mold fills with sediment, which forms a *cast* of the organism.

**fossil** the remains or physical evidence of an organism preserved by geological processes

**Figure 2** **Using Half-Lives to Date Fossils**




**A** The unstable atoms in this sample of rock have a half-life of 1.3 billion years. The sample contained 4 mg of unstable atoms when it formed.

**B** After 1.3 billion years, (one half-life for this type of unstable atom), 2 mg of the unstable atoms have decayed to become stable atoms, and 2 mg of unstable atoms remain.

**C** After 2.6 billion years (two half-lives for this sample), the rock sample contains 3 mg of stable decay atoms and 1 mg of unstable atoms.

**D** After three half-lives, only 0.5 mg of unstable atoms remain in the rock sample. This is equal to one-eighth of the original amount.

## The Age of Fossils

Sedimentary rock has many layers. The oldest layers are usually on the bottom. The newest layers are usually on the top. The layers can tell a scientist the relative age of fossils. Fossils found in the bottom layers are usually older than the fossils in the top layers. So, scientists can determine whether a fossil is older or younger than other fossils based on its position in sedimentary rock. Estimating the age of rocks and fossils in this way is called **relative dating.**

In addition, scientists can determine the age of a fossil more precisely. **Absolute dating** is a method that measures the age of fossils or rocks in years. In one type of absolute dating, scientists examine atoms. *Atoms* are the particles that make up all matter. Atoms, in turn, are made of smaller particles. Some atoms are unstable and will decay by releasing energy, particles, or both. When an atom decays it becomes a different, and more stable, kind of atom. Each kind of unstable atom decays at its own rate. As shown in **Figure 2,** the time it takes for half of the unstable atoms in a sample to decay is the *half-life* of that type of unstable atom. By measuring the ratio of unstable atoms to stable atoms, scientists can determine the approximate age of a sample of rock.

**Reading Check** **Which type of fossil dating is more precise?**
*(See the Appendix for answers to Reading Checks.)*

**relative dating** any method of determining whether an event or object is older or younger than other events or objects

**absolute dating** any method of measuring the age of an object or event in years

MATH PRACTICE

**Fractions of Fractions**

Find the answer to each of the following problems. Be sure to show your work. You may want to draw pictures.

**1.** 1/2 × 1/2 × 1/2 × 1/2

**2.** 1/2 × 1/8

**3.** 1/4 × 1/4

## The Geologic Time Scale

Think about important events that have happened during your lifetime. You usually recall each event in terms of the day, month, or year in which it happened. These divisions of time make it easier to recall when you were born, when you kicked the winning soccer goal, or when you started the fifth grade. Scientists also use a type of calendar to divide the Earth's long history. The span of time from the formation of the Earth to now is very long. Therefore, the calendar is divided into very long units of time.

The calendar scientists use to outline the history of life on Earth is called the **geologic time scale,** shown in **Table 1.** After a fossil is dated, a paleontologist can place the fossil in chronological order with other fossils. This ordering forms a picture of the past that shows how organisms have changed over time.

### Divisions in the Geologic Time Scale

Paleontologists have divided the geologic time scale into large blocks of time. Each block may be divided into smaller blocks of time as scientists continue to find more fossil information.

The divisions known as *eras* are characterized by the type of organism that dominated the Earth at the time. For instance, the Mesozoic era—dominated by dinosaurs and other reptiles—is referred to as the *Age of Reptiles*. Eras began with a change in the type of organism that was most dominant.

Paleontologists sometimes adjust and add details to the geologic time scale. For example, the early history of the Earth has been poorly understood. There is little evidence that life existed billions of years ago. So, the earliest part of the geologic time scale is not named as an era. But more evidence of life before the Paleozoic era is being gathered. Scientists have proposed using this evidence to name new eras before the Paleozoic era.

***Table 1* Geologic Time Scale**

| Era | Period | Time* |
|---|---|---|
| Cenozoic era | Quaternary | 2 |
| | Tertiary | 65 |
| Mesozoic era | Cretaceous | 144 |
| | Jurassic | 206 |
| | Triassic | 248 |
| Paleozoic era | Permian | 290 |
| | Carboniferous | 345 |
| | Devonian | 408 |
| | Silurian | 439 |
| | Ordovician | 495 |
| | Cambrian | 543 |
| Precambrian time | | 4,600 |

**indicates how many millions of years ago the period began*

**CONNECTION TO Social Studies**

**A Place in Time** Most of the periods of the Paleozoic era were named by geologists for places where rocks from that period are found. Research the name of each period of the Paleozoic era listed in **Table 1.** On a copy of a world map, label the locations related to each name.

ACTIVITY

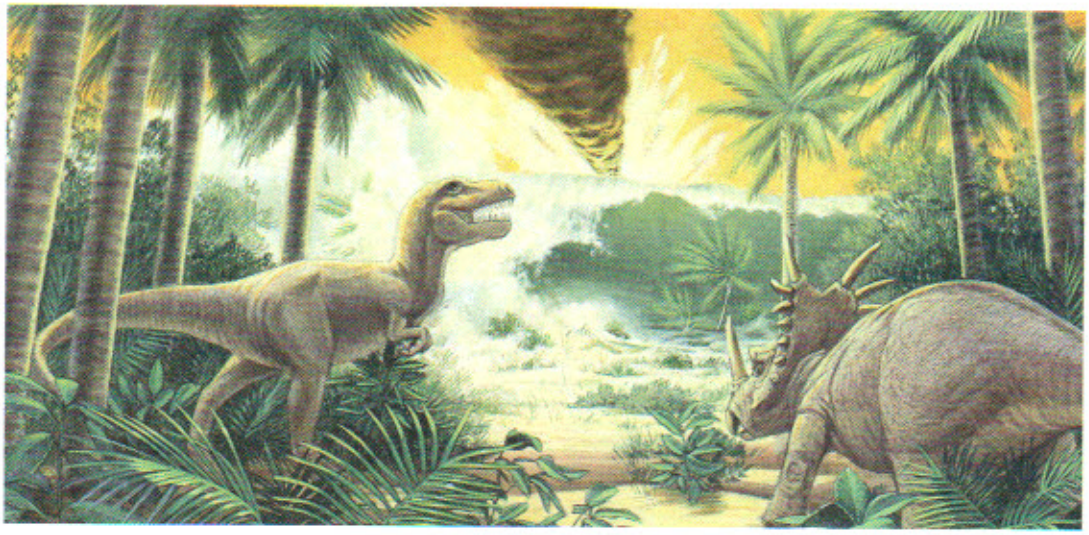


**Figure 3** *Scientists think that a meteorite hit Earth about 65 million years ago and caused major climate changes.*

## Mass Extinctions

Some of the important divisions in the geologic time scale mark times when rapid changes happened on Earth. During these times, many species died out completely, or became **extinct**. When a species is extinct, it does not reappear. At certain points in the Earth's history, a large number of species disappeared from the fossil record. These periods when many species suddenly become extinct are called *mass extinctions*.

Scientists are not sure what caused each of the mass extinctions. Most scientists think that the extinction of the dinosaurs happened because of extreme changes in the climate on Earth. These changes could have resulted from a giant meteorite hitting the Earth, as shown in **Figure 3.** Or, forces within the Earth could have caused many volcanoes and earthquakes.

**geologic time scale** the standard method used to divide the Earth's long natural history into manageable parts

**extinct** describes a species that has died out completely

**Reading Check** What are mass extinctions?


### Making a Geologic Timeline

1. Use a **metric ruler** to mark 10 cm sections on a **strip of paper** that is 46 cm long.
2. Label each 10 cm section in order from top to bottom as follows: 1 bya (billion years ago), 2 bya, etc. The timeline begins at 4.6 bya.
3. Divide each 10 cm section into 10 equal subsections. Divide the top 1 cm into 10 subsections. Calculate the number of years that are represented by 1 mm on this scale.
4. On your timeline, label the following events:
   a. Earth forms. (4.6 billion years ago)
   b. First animals appear. (600 million years ago)
   c. Dinosaurs appear. (251 million years ago)
   d. Dinosaurs are extinct. (65 million years ago)
   e. Humans appear. (160,000 years ago)
5. Label other events from the chapter.
6. Describe what most of the timeline looks like.
7. Compare the length of time dinosaurs existed with the length of time humans have existed.

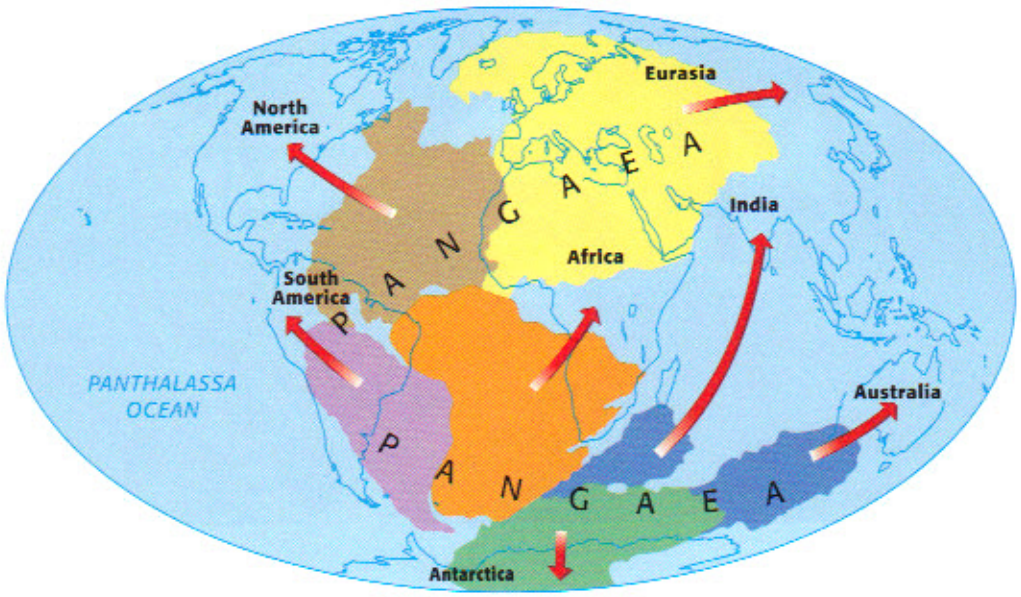



**Figure 4** *The continents have been slowly moving throughout the history of Earth. The colored areas show the location of the continents 245 million years ago, and blue outlines show where the continents are today.*

## The Changing Earth

Did you know that fossils of tropical plants have been found in Antarctica? Antarctica, now frozen, must have once had a warm climate to support these plants. The fossils provide evidence that Antarctica was once located near the equator!

**plate tectonics** the theory that explains how large pieces of the Earth's outermost layer, called *tectonic plates,* move and change shape

### Pangaea

Have you ever noticed that the continents look like pieces of a puzzle? German scientist Alfred Wegener had a similar thought in the early 1900s. He proposed that long ago the continents formed one landmass surrounded by a gigantic ocean. Wegener called that single landmass *Pangaea* (pan JEE uh), which means "all Earth." **Figure 4** shows how the continents may have formed from Pangaea.

**Reading Check** What idea did Alfred Wegener propose?

### Do the Continents Move?

In the mid-1960s, J. Tuzo Wilson of Canada came up with the idea that the continents were not moving by themselves. Wilson thought that huge pieces of the Earth's crust were pushed around by forces within the planet. Each huge piece of crust is called a *tectonic plate.* Wilson's theory of how these huge pieces of crust move around the Earth is called **plate tectonics.**

According to Wilson, the outer crust of the Earth is broken into seven large, rigid plates and several smaller ones. The continents and oceans ride on top of these plates. The motion of the plates causes the continents to move. For example, the plates that carry South America and Africa are slowly moving apart, as shown in **Figure 5.**

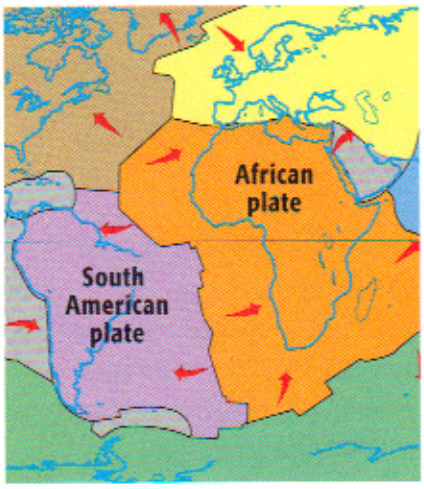



**Figure 5** *The continents ride on tectonic plates, outlined here in black. The plates are still moving about 1 to 10 cm per year.*

## Adaptation to Slow Changes

When conditions on the Earth change, organisms may become extinct. A rapid change, such as a meteorite impact, may cause a mass extinction. But slow changes, such as moving continents, allow time for adaptation.

Anywhere on Earth, you are able to see living things that are well adapted to the location where they live. Yet in the same location, you may find evidence of organisms that lived there in the past that were very different. For example, the animals currently living in Antarctica are able to survive very cold temperatures. But under the frozen surface of Antarctica are the remains of tropical forests. Conditions on Earth have changed many times in history, and life has changed, too.

**CONNECTION TO Geology**

**Mid-Atlantic Ridge** In 1947, scientists examined rock from a ridge that runs down the middle of the Atlantic Ocean, between Africa and the Americas. They found that this rock was much younger than the rock on the continents. Explain what this finding indicates about the tectonic plates.

# SECTION Review

## Summary

- Fossils are formed most often in sedimentary rock. The age of a fossil can be determined using relative dating and absolute dating.
- The geologic time scale is a timeline that is used by scientists to outline the history of Earth and life on Earth.
- Conditions for life on Earth have changed many times. Rapid changes, such as a meteorite impact, might have caused mass extinctions. But many groups of organisms have adapted to changes such as the movement of tectonic plates.

### Using Key Terms

1. Use the following terms in the same sentence: *fossil* and *extinct*.
2. In your own words, write a definition for the term *plate tectonics*.

### Understanding Key Ideas

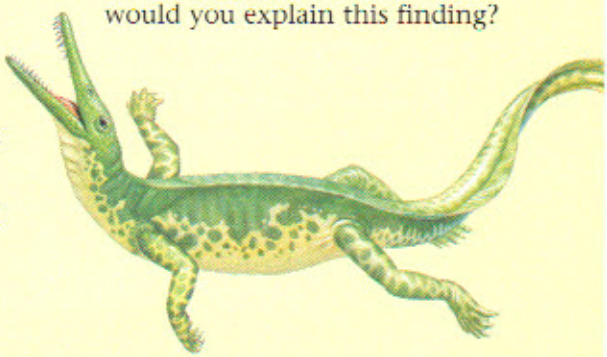
3. Explain how a fossil forms in sedimentary rock.
4. What kind of information does the geologic time scale show?
5. About how many years of Earth's history was Precambrian time?
6. What are two possible causes of mass extinctions?

### Math Skills

7. The Earth formed 4.6 billion years ago. Modern humans have existed for about 160,000 years. Simple worms have existed for at least 500 million years. For what fraction of the history of Earth have humans existed? have worms existed?

### Critical Thinking

8. **Identifying Relationships** Why are both absolute dating and relative dating used to determine the age of fossils?
9. **Making Inferences** Fossils of *Mesosaurus*, the small aquatic reptile shown below, have been found only in Africa and South America. Using what you know about plate tectonics, how would you explain this finding?



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