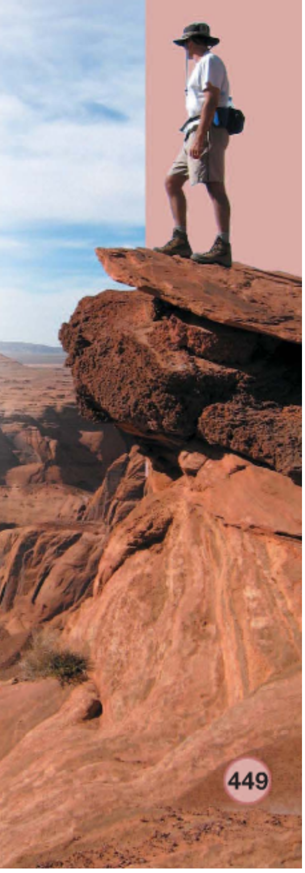
Chapter 18

Earth's History and Rocks

If you wanted to learn about people and places that existed 50 years ago, what would you do? Maybe you would read a history book or talk to your grandparents to find out what things were like a long time ago.

Fifty years is a long time for people, but not for planet Earth. Our planet is 4.6 billion years old and a lot has happened here on Earth since it formed. For example, life forms have evolved, and many—like the dinosaurs—have disappeared.

How do you think scientists learn about Earth's ancient past? For starters, they might look at the layers of rock underfoot. How a rock has been formed and shaped tells a story. Additional stories are told by fossils found inside rocks. Fortunately, there are places on Earth where layers and layers of rock are above ground for all to see and interpret. One such amazing place is the Grand Canyon. This chapter takes you back through Earth's geologic history and gives you tools to interpret that history. And because Earth's history is "written" in them, at the end of this chapter, you will learn about rocks.



Key Questions

- ✔ *How do we know Earth's age?*
- ✔ *How do scientists "read" Earth's history in rocks?*
- ✔ *What is the rock cycle?*

18.1 Geologic Time

The **geologic time scale** is a model of Earth's history. You'll find a colorful chart of the geologic time scale on the next page. What are the units of time on the geologic time scale? How do scientists use fossils to chart Earth's history? Read on to find out.

Earth's earliest history

Parts of geologic time The geologic time scale is divided into shorter and shorter lengths of time, from eons to eras to periods. This is similar to how a day is divided into hours, and hours into minutes (Figure 18.1). However, time units on the geologic time scale are much longer. The geologic time scale units are based on tracking life forms within the layers of Earth's crust. If a particular kind of fossil that has been dated is found in two locations some distances apart, this suggests that the life forms might have been deposited in the same layer.

The Precambrian The Precambrian can be divided into two eons (the Archean and the Proterozoic) and represents 88 percent of Earth's history. Early in the Precambrian, Earth's surface was molten rock. From this molten rock, the oceanic crust formed. Later, through partial melting of the oceanic crust, continental crust began to form. Earth's atmosphere formed from volcanic outgassing and water vapor. Then, cooling of the atmosphere led to rain which collected in low areas and formed the oceans. The first primitive cells appeared in these oceans. With the appearance of photosynthesis in cells, oxygen began to build up in the atmosphere, and the early ozone layer began to act as a sun shield as more complex life forms evolved. Most of the life forms of the Precambrian did not have hard body parts and so left no easily found fossils.

Paleozoic Era The Paleozoic Era and the eras that followed represent the Phanerozoic Eon. The word *Paleozoic* comes from Greek and means "ancient life." Paleozoic rocks contain fossils of the first plants and animals, such as snails, clams, corals, and trilobites, that had hard parts. Trilobites were invertebrates, meaning they had no backbones (Figure 18.2). The Paleozoic Era lasted for nearly 300 million years. At the end of this era, the continents that existed during this time period collided to form a new supercontinent, Pangaea.

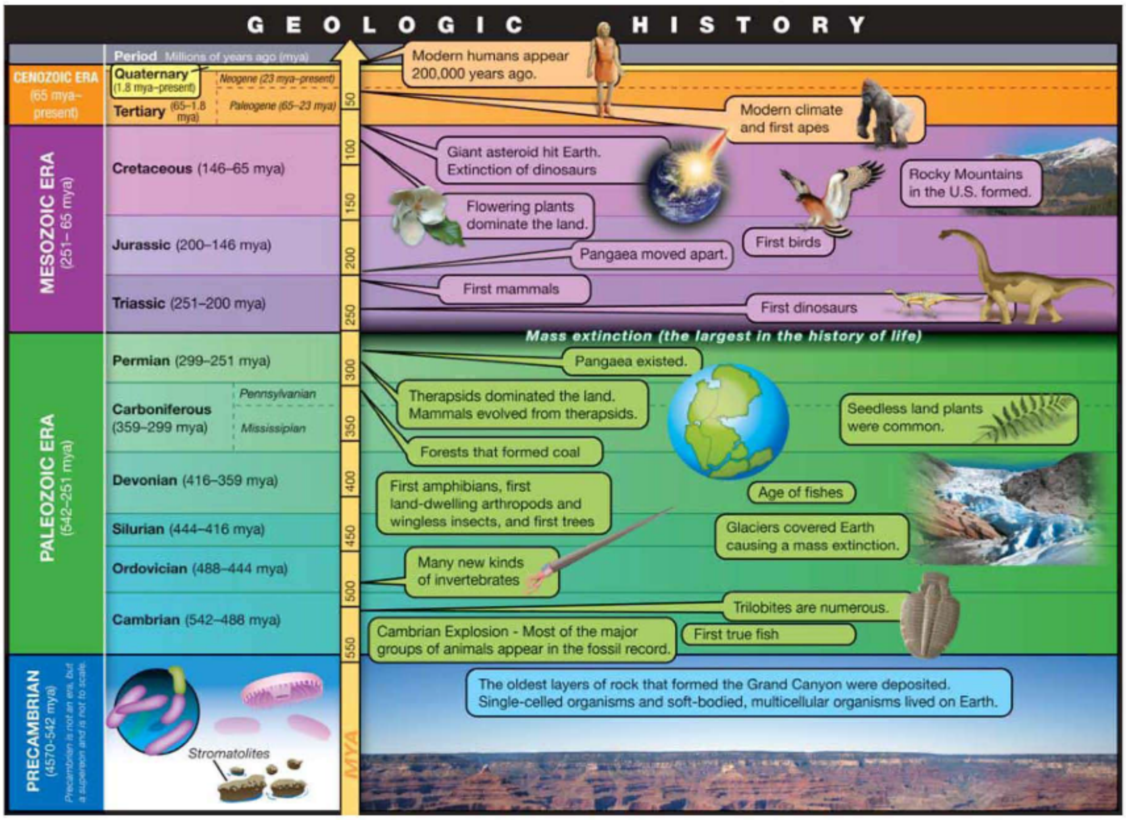
VOCABULARY

geologic time scale - a model of Earth's history.

TIME	
Units for One Day	Units for Geologic Time
One **day** is divided into... **hours** which are divided into... **minutes.**	One **eon** is divided into... **eras** which are divided into... **periods.**

Figure 18.1: *A comparison of units of time.*

Figure 18.2: *A trilobite fossil.*


GEOLOGIC HISTORY
Period Millions of years ago (mya)
CENOZOIC ERA (65 mya–present)
Quaternary (1.8 mya–present)
Neogene (23 mya–present)
Tertiary (65–1.8 mya)
Paleogene (65–23 mya)
MESOZOIC ERA (251–65 mya)
Cretaceous (146–65 mya)
Jurassic (200–146 mya)
Triassic (251–200 mya)
PALEOZOIC ERA (542–251 mya)
Permian (299–251 mya)
Carboniferous (359–299 mya)
Pennsylvanian
Mississipian
Devonian (416–359 mya)
Silurian (444–416 mya)
Ordovician (488–444 mya)
Cambrian (542–488 mya)
PRECAMBRIAN (4570–542 mya)
Precambrian is not an era, but a supereon and is not to scale.
Stromatolites
MYA
50
100
150
200
250
300
350
400
450
500
550
Modern humans appear 200,000 years ago.
Modern climate and first apes
Giant asteroid hit Earth. Extinction of dinosaurs
Rocky Mountains in the U.S. formed.
Flowering plants dominate the land.
First birds
Pangaea moved apart.
First mammals
First dinosaurs
Mass extinction (the largest in the history of life)
Pangaea existed.
Therapsids dominated the land. Mammals evolved from therapsids.
Seedless land plants were common.
Forests that formed coal
First amphibians, first land-dwelling arthropods and wingless insects, and first trees
Age of fishes
Glaciers covered Earth causing a mass extinction.
Many new kinds of invertebrates
Trilobites are numerous.
Cambrian Explosion - Most of the major groups of animals appear in the fossil record.
First true fish
The oldest layers of rock that formed the Grand Canyon were deposited. Single-celled organisms and soft-bodied, multicellular organisms lived on Earth.

The Mesozoic Era to the present

Mesozoic Era Animals with backbones began to appear during the Paleozoic Era. These new animals, called vertebrates, rose to dominance during the next era, the Mesozoic Era. The word *Mesozoic* means "middle life." The Mesozoic Era lasted for nearly 200 million years and saw the rise and disappearance of the dinosaurs. Dinosaurs gave this era its common name, the Age of Reptiles. The Mesozoic was also the time during which flowering plants evolved. The breakup of Pangaea also marked this era.

Cenozoic Era The first mammals began to appear during the Mesozoic Era, but they became the dominant life form during the Cenozoic Era. Not surprisingly, the common name for the Cenozoic Era is the Age of Mammals (Figure 18.3). Cenozoic gets its name, which means "recent life," from the fact that it is the most recent of the three eras. Today's continents moved into their current positions during the Cenozoic.

Patterns in the geologic time scale Do you notice any patterns in Earth's geologic history? The positions and shapes of Earth's landmasses have changed over time. Additionally, there has been a progression of life forms. Vertebrate animals have some advantages over invertebrates, and so the Age of Invertebrates gave way to the Age of Reptiles. Similarly, the Age of Reptiles gave way to the Age of Mammals because warm-blooded animals have some advantages over cold-blooded reptiles. In addition to gradual changes in life forms during Earth's history, there have been dramatic events that led to change. For example, scientists have accumulated evidence to indicate that a large asteroid crashed into Earth near Mexico's Yucatan peninsula about 65 million years ago (Figure 18.4). The resulting climate change may have caused the extinction of the majority of Mesozoic Era reptiles, including the dinosaurs.

What if? Recent findings suggest this asteroid impacted 300,000 years before the mass extinction. A new hypothesis is that ash from massive volcanic eruptions caused the extinction by blocking sunlight and causing a greenhouse effect. Scientists do not agree whether the asteroid impact, the volcanic eruptions, some other yet undiscovered factors, or some combinations of these events was the ultimate cause of the mass extinction. What do you think?

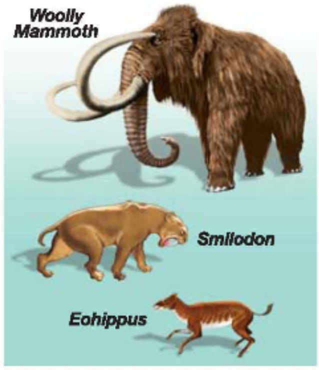


Figure 18.3: *Mammals of the Cenozoic era.*

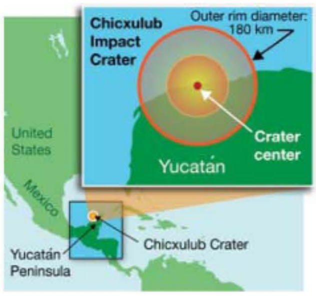


Figure 18.4: *The Chicxulub crater marks the spot where a large asteroid crashed into Earth 65 million years ago.*

Absolute dating

What is absolute dating? **Absolute dating** is any process that provides the real age of a sample in years. *Radiometric dating* is a form of absolute dating that measures the change in naturally-occurring radioactive forms of certain elements in rocks, minerals, or fossils.

Radioactive isotopes Radiometric dating relies on using *isotopes* of elements. For example, a hydrogen atom always has only one proton, but isotopes of hydrogen might have one, two, or no neutrons. Some isotopes are unstable and break down, or *decay*, over time. An isotope that decays is called a **radioactive isotope**. When such a radioactive isotope decays, it loses energy and matter. After decay, the radioactive isotope becomes a daughter isotope of a different daughter element. This daughter isotope might be stable, or it might be unstable and decay again.

Radiometric dating using uranium Uranium-238 is a radioactive isotope that has 92 protons and 146 neutrons. Through radioactive decay, slightly unstable uranium-238 changes to become another radioactive isotope, thorium-234. In 4.5 billion years, half of a sample of uranium-238 will become thorium-234. This amount of time-the time it takes for half of the unstable atoms in uranium-238 to decay -is the half-life of uranium-238. After a series of additional decays, ordinary lead is produced. Scientists can determine the rock's age by the ratio of uranium-238 to lead atoms in the sample (Figure 18.5).

Earth is approximately 4.6 billion years old Radiometric dating has been used to find the age of Earth. Interestingly, the oldest rocks on Earth have been dated with the uranium-lead system to be approximately 4 billion years old. But scientists have found moon rocks and meteorites that are approximately 4.6 billion years old. Since Earth was formed at the same time as the rest of the solar system, Earth must be approximately 4.6 billion years old too.

Why are Earth rocks only 4 billion years old? So why are the rocks found on Earth only 4 billion years old? Rocks that are as old as Earth are not found because our planet is geologically active and has been since it formed. Over time, rocks have been eroded away or buried deeply beneath other rocks. However, it is possible that rocks older than 4 billion years old exist on Earth and might one day be found.

VOCABULARY

absolute dating - any process that provides the real age of a sample in years.

radioactive isotope - an unstable isotope that loses energy and matter over time.

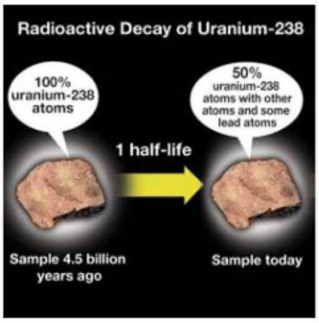


Figure 18.5: *The radioactive decay of uranium to lead. Radioactive decay is measured in half-lives. After one half-life, 50 percent of the uranium-238 atoms have decayed.*

Trees and absolute dating

What trees can tell us You have just learned about radiometric dating as a way for gauging the absolute age of something. Tree-ring dating or *dendrochronology* is another absolute dating method that dates trees by studying tree rings.

One tree ring equals one year You have seen tree rings if you have ever looked at the cross-section of a log. The concentric circular layers are formed as the tree grows. One tree ring represents one year of growth. Often, a tree ring includes two bands—one light and one dark (Figure 18.6). Counting tree rings can tell you a tree's age while the pattern of rings provides a record of the tree's growth in varying environmental conditions.

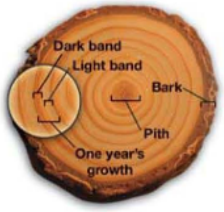


Figure 18.6: *A cross-section of a tree shows tree rings. The oldest rings are at the center of the tree and the youngest rings are around the edge.*

Tree coring Tree coring is a technique for finding the age of a tree without having to cut it down. To get a tree core, a scientist uses a thin metal tube, called a borer, to drill to the center of the tree. When the scientist pulls the borer back out of the tree, a pencil-sized tree core is inside the tube. It looks like this.

Tree-ring dating Dendrochronology was founded and named by Andrew Douglass (1867–1962), an American astronomer. Realizing that trees can be very old and being curious about Earth's past climate, he hypothesized that trees might be excellent recorders of climate changes. He began to test his hypothesis by studying and recording tree ring patterns. By 1914, he had published his findings that trees within a similar area had matching tree ring patterns. He showed that wide tree rings indicated a year with a lot of rain and narrow rings indicated a dry year.

Trees live a long time Trees are good record-keepers because they tend to live a long time. The oldest tree that we know about, a bristlecone pine called "Methuselah," is over 4,800 years old. This bristlecone pine and others live in California (Figure 18.7). Redwood trees, one of the world's tallest species at about 300 feet tall, are also found in California and live as long as 2,000 years.

Figure 18.7: *A bristlecone pine growing in California.*

Section 18.1 Review

1. Explain how Earth's history is divided in the geologic time scale.
2. Which answer is correct? During the Precambrian:
   a. human beings lived and thrived.
   b. dinosaurs became extinct.
   c. single-celled and soft-bodied organisms appeared.
   d. flowering plants evolved.
3. Compare and contrast the Paleozoic and Mesozoic Eras in terms of the length of each era, landmasses, and the life forms that evolved in each. What is interesting or surprising to you in each era?
4. Look at the chart of Earth's geologic history on page 411. Were humans around when the supercontinent Pangaea broke up?
5. Compare and contrast the two methods of absolute dating you read about.
6. How much uranium-238 isotope is left in a pure sample after one half-life?
7. How have scientists determined the age of Earth? How old is Earth?
8. The half-life of uranium-238 is 4.5 billion years. The half-life of carbon-14, another radioactive element, is 5,730 years. You want to use absolute dating to determine the age of a rock that was about as old as Earth. Would you measure the radioactive decay of carbon-14 or uranium-238? Explain your answer.
9. If a tree has 25 rings, how old is it?
10. Figure 18.8 shows cross-sections from two trees that grew in different areas.
    a. The trees were the same age when they were cut. How old are these trees?
    b. Make a drawing of what a tree core would look like for each tree cross-section.
    c. Write a fictional history that explains the wet and dry conditions for each tree during each year of its lifetime.

CHALLENGE

Learn more about Earth's geologic history by doing one of the following projects.

(1) Create a time line for one era.

(2) Create a colorful poster that illustrates the events in one period.

(3) Write a short story about one period. Your story should include one or more major events that happened during that period.

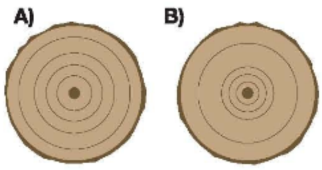


Figure 18.8: *Question 10. Note: When counting rings, do not count the very center (called the pith).*