

The Geologic Time Scale

ESSENTIAL QUESTION

What is the geologic time scale?

By the end of this lesson, you should understand how geologists use the geologic time scale to divide Earth's history.

In Earth's ancient past, molten material cooled and hardened to form new land. This process continues today when lava cools and hardens on Earth's surface. It is just one of many geologic processes that have shaped Earth for billions of years.

Quick Labs

- Investigating Events in Earth's History
- Timeline of Earth's History

Engage Your Brain

1 Predict Check T or F to show whether you think each statement is true or false.

- | T | F | |
|--------------------------|--------------------------|--|
| <input type="checkbox"/> | <input type="checkbox"/> | In Earth's past, mass extinctions wiped out nearly all life in the oceans. |
| <input type="checkbox"/> | <input type="checkbox"/> | Most changes to Earth's surface happen suddenly. |
| <input type="checkbox"/> | <input type="checkbox"/> | Early humans and dinosaurs lived side by side during Earth's distant past. |
| <input type="checkbox"/> | <input type="checkbox"/> | We live in the Cenozoic Era. |

2 Compare Describe the mountains that you see in the photo. What do you think they looked like when they were much younger, more than 400 million years ago?



Active Reading

3 Synthesize You can often define an unknown word if you know the meaning of its word parts. Use the word parts and sentence below to make an educated guess about the meaning of the word *geology*.

Word part	Meaning
geo-	Earth
-logy	study of

Example sentence:

Joseph was interested in rocks and minerals, so he decided to study *geology*.

geology:

Vocabulary Terms

- geology
- geologic time scale

4 Identify As you read, place a question mark next to any words that you don't understand. When you finish reading the lesson, go back and review the text that you marked. If the information is still confusing, consult a classmate or a teacher.

Once Upon a Time

Volcanic eruptions can cause sudden, drastic changes to Earth's surface.

How have geologists described the rate of geologic change?

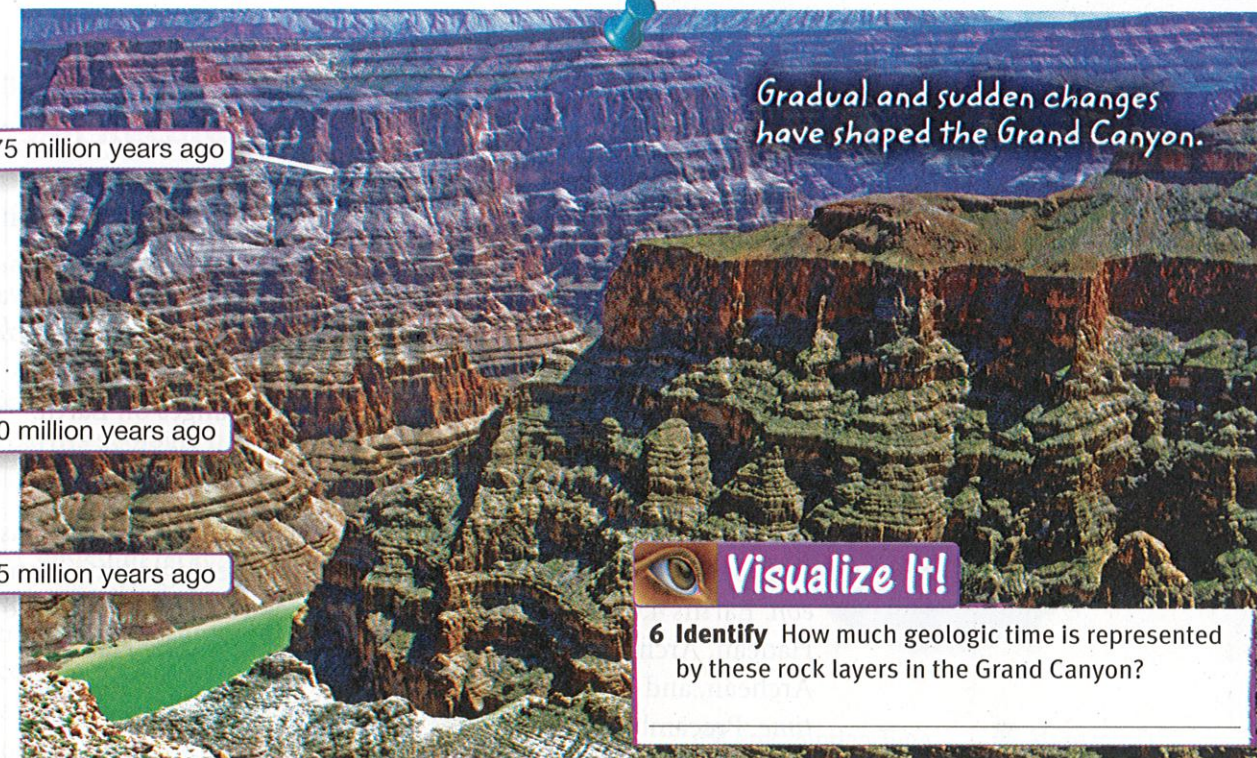
How old is Earth? How does new rock form? How do mountains form? These are the types of questions asked by scientists who study geology. **Geology** is the scientific study of the origin, history, and structure of Earth and the processes that shape it. Early geologists proposed different ideas to explain how Earth changes over time.

Changes Occur Suddenly: Catastrophism

Some early scientists used catastrophism to explain geologic changes on Earth. *Catastrophism* (kuh•TAS•truh•fiz•uhm) is the principle that states that all geologic change occurs suddenly. Supporters of catastrophism thought that Earth's features, such as mountains and seas, formed during sudden events called *catastrophes* (kuh•TAS•truh•feez). These unpredictable events caused rapid change over large areas, sometimes even globally.

A volcanic eruption is just one example of a catastrophic event. In November 2010, the Merapi volcano in Indonesia erupted with violent explosions that could be heard 20 km away. Millions of cubic meters of ash, dust, and gases were released. Material reportedly fell in areas hundreds of kilometers from the volcano.

Active Reading 5 **Identify** What is one example of a geologic catastrophe?



6 Identify How much geologic time is represented by these rock layers in the Grand Canyon?

Changes Occur Gradually: Uniformitarianism

About 250 years ago, a Scottish farmer and scientist named James Hutton studied rock formations in Scotland. His years of observations challenged the principle of catastrophism and led to the foundation of modern geology.

Hutton believed that the key to understanding Earth's history is all around us. The processes that we observe today, such as erosion and deposition, do not change over time. They remain constant, or uniform. This principle is now called uniformitarianism (yoo•nuh•fohr•mih•TAIR•ee•uh•niz•uhm). *Uniformitarianism* is the idea that the same geologic processes that shape Earth today have been at work throughout Earth's history. The principle also states that the average rate of geologic change is slow and has remained relatively constant over time.

Changes Occur Both Catastrophically and Gradually

Today, geologists realize that neither uniformitarianism nor catastrophism accounts for all geologic change. While most geologic change is gradual and uniform, modern geologists recognize that catastrophes do cause some geologic change. For example, earthquakes, floods, volcanic eruptions, and asteroid impacts can cause sudden changes to Earth's surface.

Scientists have found huge craters caused by ancient asteroid impacts. About 65 million years ago, an asteroid hit Earth. Scientists think this led to the extinction of the dinosaurs. The impact would have thrown large amounts of debris into the atmosphere, which would have blocked the sun's rays. This likely limited photosynthesis, killing plants and causing the dinosaur food chain to collapse.

7 Contrast Compare catastrophism and uniformitarianism.

Catastrophism

Uniformitarianism

It's About Time

How do geologists use the geologic time scale?

By using radiometric dating techniques on meteorites and moon rocks, geologists estimate that the solar system, and therefore Earth, is about 4.6 billion years old. To help make sense of this vast amount of time, geologists use the geologic time scale to organize Earth's history. The **geologic time scale** divides Earth's history into intervals of time defined by major events or changes on Earth.

To Divide Earth's Long Geologic History

The geologic time scale divides Earth's geologic history into eons, eras, periods, and epochs. The largest unit of geologic time is an *eon*. Earth's 4.6-billion-year history is divided into four eons: the Hadean, Archean, Proterozoic, and Phanerozoic. The Hadean, Archean, and Proterozoic eons together are called *Precambrian time*. Precambrian time makes up almost 90 percent of Earth's history. Eons may be divided into smaller units of time called *eras*. The Phanerozoic Eon is the present eon. This eon is divided into three eras: the Paleozoic, Mesozoic, and Cenozoic. Each era is subdivided into a number of *periods*. The periods of the Cenozoic, the present era, are further divided into *epochs*.



Visualize It!

- 8 List** Use the diagram of the geologic time scale to list the different divisions of time, beginning with the largest division, the eon.

Precambrian time (4600 Ma to 542 Ma)

EONS		Hadean Eon	Archean Eon	Proterozoic Eon	Phanerozoic Eon
4600 Ma	3850 Ma				2500 Ma

Ma = million years

ERAS

PERIODS

Paleozoic Era						
Cambrian	Ordovician	Silurian	Devonian	Carboniferous	Permian	
542 Ma	488 Ma	444 Ma	416 Ma	359 Ma	299 Ma	251 Ma



At the beginning of the Paleozoic Era, life flourished in the oceans.

To Mark Major Changes in the Fossil Record

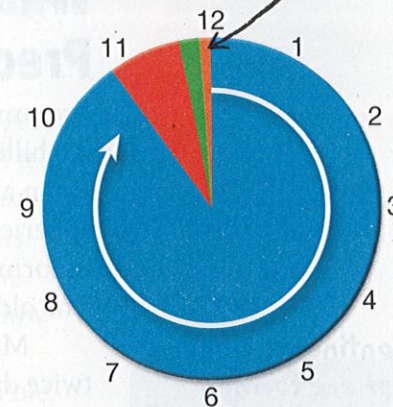
Active Reading 9 Identify As you read, underline the factors used to determine the divisions of geologic time.

Unlike divisions of time such as days or minutes, the divisions of the geologic time scale have no fixed lengths. Many divisions are based on events in Earth's geologic history. Some divisions are based entirely on the fossil record.

At least five divisions of geologic time have ended in large mass extinction events. In mass extinction events, a larger than expected number of organisms "disappear" from the fossil record in rock layers worldwide. For example, the Paleozoic Era ended about 250 million years ago with the largest extinction event known. More than 90% of marine species and 70% of land species are thought to have become extinct. The Mesozoic Era ended with the extinction of dinosaurs and many other organisms about 65 million years ago. Causes of mass extinctions are varied. Movement of the continents, lowering of global sea level, rapid climate change, and asteroid impacts are all thought to be causes.

Geologic Time Clock

The Cenozoic Era is only a tiny fraction of Earth's history.



Precambrian Time
Paleozoic Era
Mesozoic Era
Cenozoic Era

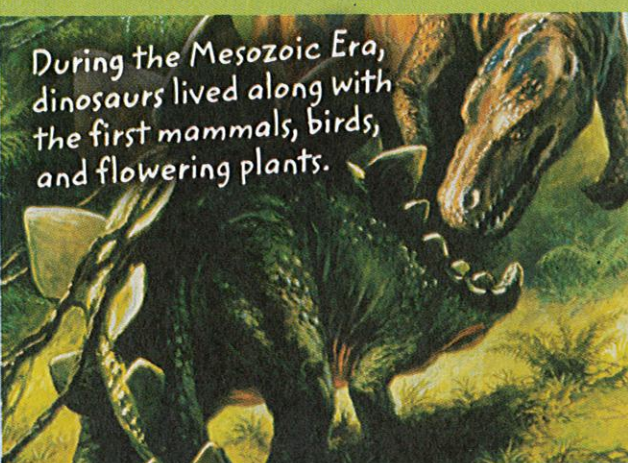
Visualize It!

- 10 Analyze** If all of Earth's history were squeezed into one 12-hour period, how long ago did Precambrian time end? How long ago did the Cenozoic Era begin?

Proterozoic Eon

Phanerozoic Eon

Mesozoic Era			
Triassic	Jurassic	Cretaceous	
251 Ma	199.6 Ma	145.5 Ma	65.5 Ma



During the Mesozoic Era, dinosaurs lived along with the first mammals, birds, and flowering plants.

Cenozoic Era

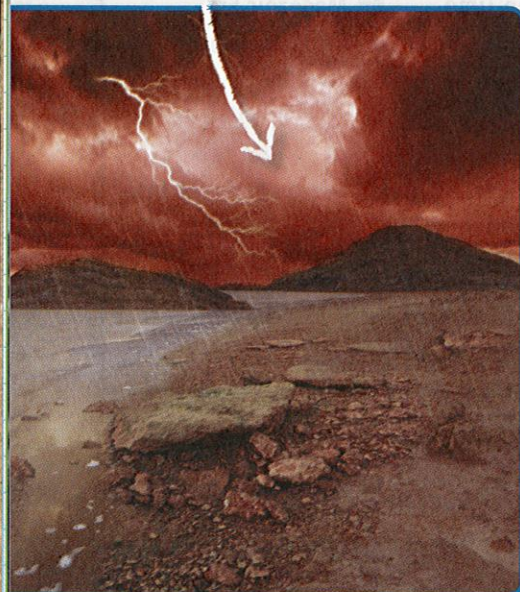
Tertiary Period					Quaternary Period
Paleocene	Eocene	Oligocene	Miocene	Pliocene	Pleistocene
65.5 Ma	55.8 Ma	33.9 Ma	23 Ma	5.3 Ma	2.6 Ma
					0.01 Ma

Time After Time...

What were some defining events of Precambrian time?

Precambrian time began with the formation of Earth about 4.6 billion years ago. Many changes occurred during this time. From about 4.5 to 3.8 billion years ago, early Earth formed into a spherical planet, and its molten rocks cooled. Continents began to form, and tectonic activity occurred along continental margins. The oldest fossils, life forms in the oceans, date from this time.

The first continents, oceans, and atmosphere formed during Precambrian time.



Massive supercontinents formed and broke up at least twice during Precambrian time. Earth's early atmosphere was made mainly of gases released by volcanic eruptions. During the Archean Eon, water vapor was added to the atmosphere by almost constant volcanic activity. This water fell as rain and collected in basins to form the first oceans. The atmosphere had no free oxygen until the Proterozoic Eon, when cyanobacteria released oxygen into the air during the process of photosynthesis.

Toward the end of Precambrian time, much of Earth's land surfaces were located near the poles and covered in ice. Land on Earth was largely frozen and lifeless.

Active Reading 11 Identify What was the first source of oxygen for Earth's atmosphere?

Precambrian Earth

Earth looked very different during Precambrian time.



...After Time

What were some defining events of the Paleozoic Era?

The Paleozoic Era began about 540 million years ago as the global supercontinent Pannotia was breaking up. Sea level rose and fell, at times covering much of the continents in shallow seas. Vast mountain ranges built up along the margins of the continents.

The formation of a new supercontinent, Pangaea, began during the Paleozoic. Sea level slowly dropped, and the shallow inland seas retreated. The climate during the late Paleozoic varied as Pangaea drifted toward and away from the South Pole. Conditions were warmer and drier farther from the pole.

At the start of the Paleozoic, all life was found in the ocean. Life diversified quickly and dramatically during the Cambrian Explosion, during which most major groups of organisms first evolved. The era ended about 250 million years ago with a huge mass extinction event. Between 90 and 95 percent of marine species and approximately 70 percent of land species disappeared.

Visualize It!

12 Analyze Compare the two maps. What changes do you notice in the Paleozoic map?

Paleozoic Earth

Life began to flourish in the seas and on land during the Paleozoic Era.



During the Cambrian Period, new species evolved rapidly in Earth's shallow seas.

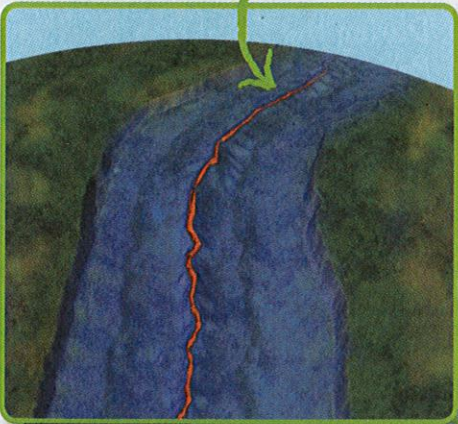


What were some defining events of the Mesozoic Era?

Active Reading

13 Identify As you read this section, underline events related to the formation of North America.

As Pangaea broke apart, the ocean basin and the Mid-Atlantic Ridge formed.



The Mesozoic Era began about 250 million years ago after the Permian mass extinction. The geologic history of this era was dominated by the breakup of Pangaea, which at one point covered nearly one-fourth of Earth's surface. The Atlantic Ocean began to open up, separating North America and Africa. During this process, the Mid-Atlantic Ridge formed, causing sea level to rise. Once again, shallow seas covered much of the land. Along the western edge of North America, tectonic activity began to fold Earth's crust, forming mountains.

The climate during the Mesozoic Era was likely warm. Periods of heavy volcanism added carbon dioxide to the atmosphere. Carbon dioxide is one of the gases that absorbs heat from Earth's surface and reradiates it back to Earth. Life during the Mesozoic was dominated by dinosaurs. The few mammals were very small. A mass extinction event about 65 million years ago marks the end of the era—and of dinosaurs. This extinction is thought to have been caused by an asteroid impact.

Mesozoic Earth



The supercontinent Pangaea split apart during the Mesozoic.

Visualize It!

14 Distinguish Look carefully at the illustration above. What two continents are separating in the highlighted area?

What have been some defining events of the Cenozoic Era?

The Cenozoic Era began about 65 million years ago with the Cretaceous mass extinction and continues to the present. During the Cenozoic, Greenland split apart from North America and Europe, marking the final breakup of Pangaea. The continents assumed their current positions. Tectonic activity continued. The Indian subcontinent collided with Eurasia to form the Himalayas. The collision of Africa and Europe resulted in the Alps.

The warm climate of the Mesozoic Era turned cooler in the Cenozoic, both on land and in the oceans. Polar ice caps formed. Temperature differences between the poles and the equator became extreme.

The Cenozoic Era is divided into two periods: the Tertiary and the Quaternary. The Quaternary Period stretches from about 2.6 million years ago to the present. The climate of the Quaternary has been characterized by an ice age, with much of Europe, North America, and Asia having been covered in thick sheets of ice. The evolution of modern humans occurred during the late Quaternary.

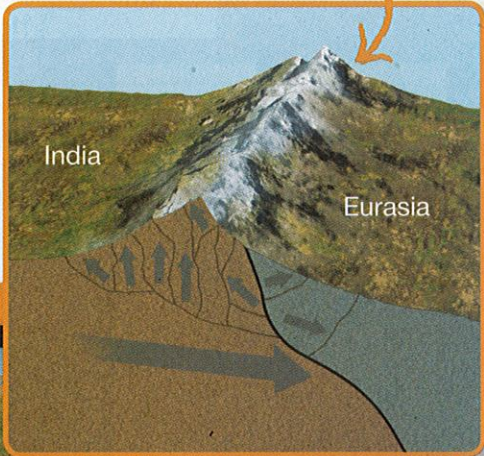
Cenozoic Earth



Think Outside the Book

15 Compare Trace the continents as they appear today and cut out the continents to form a jigsaw puzzle. Try to fit the continents back together, and compare your results to Pangaea.

The Himalayas formed from the collision of India with Eurasia during the Cenozoic Era.



16 Compare Use the table to compare the two most recent eras. After each era, list three or four major events that occurred during that division of time.

Mesozoic

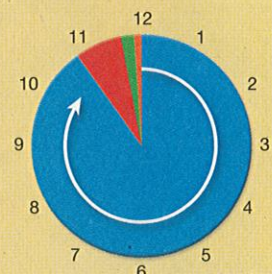
Cenozoic

Visual Summary

To complete this summary, fill in the blank with the correct word or phrase. Then, use the key below to check your answers. You can use this page to review the main concepts of the lesson.

Early geologists proposed different theories to explain how Earth has changed over time.

17 Today, geologists realize that changes on Earth occur both _____ and _____



- 1 Precambrian Time
- 2 Paleozoic Era
- 3 Mesozoic Era
- 4 Cenozoic Era

The Geologic Time Scale

Scientists have organized Earth's history into a system called the *geologic time scale*.

Eras are defined by important events such as mass extinctions and changes in Earth's features.

18 The geologic time scale organizes Earth's history into time divisions called eons, eras, _____, and _____

19 The continents assumed their present positions during the _____



Answers: 17 suddenly and gradually; 18 periods, epochs; 19 Cenozoic Era

20 **Synthesize** Why do geologists and biologists refer to the same time scale when describing events in Earth's ancient history?

Lesson Review

Vocabulary

Draw a line to connect the following terms to their definitions.

- | | |
|-----------------------|---|
| 1 catastrophism | A a chart that divides Earth's history into intervals of time |
| 2 geologic time scale | B the principle that states that the same geologic processes shaping Earth today have been at work throughout Earth's history |
| 3 geology | C the principle that states that all geologic change occurs suddenly |
| 4 uniformitarianism | D the scientific study of the origin, history, and structure of Earth and the processes that shape it |

Key Concepts

5 **Explain** Why did geologists develop the geologic time scale?

6 **Infer** How do scientists estimate the age of Earth to be 4.6 billion years old?

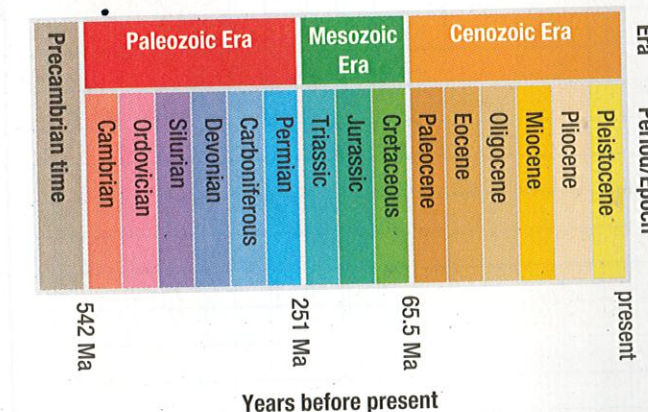
Critical Thinking

7 **Distinguish** Would an earthquake support the principle of uniformitarianism or the principle of catastrophism? Explain.

8 **Evaluate** Some cartoons have shown early humans keeping dinosaurs as pets. From what you know about Earth's history, is this possible? Why or why not?

Use this diagram of the geologic time scale to answer question 9.

Geologic Time Scale



9 **Analyze** How does this time scale distort Precambrian time? What other part of the time scale is distorted?