

The Geologic Time Scale



Earth is 4.6 billion years old.

Earth has existed for 4.6 billion years. That time has been marked by events large and small: millions of different species have evolved and become extinct, the climate has changed several times, the tectonic plates that make up Earth's crust have shifted dramatically, and many thousands of meteorites have smashed into the planet. As scientists began discovering evidence of these past events, they needed a way to categorize them for easier reference. Thus, the geologic time scale was born.

Early Discoveries and Geologic Principles

In the 1500s and 1600s, people (mainly miners) became interested in relationships between the layers of rock they encountered. It wasn't until 1669 that Nicolaus Steno, a Danish biologist and geologist, developed a pair of geologic principles still in use today. The first, now known as the **Law of Original Horizontality**, states that rock layers are deposited horizontally. The natural extension of this law is that any rock layers that diverge from the horizontal must have been altered by some geologic event after they were deposited. The second principle Steno put forth has since been coined the **Law of Superposition**. It states that the



Rocks are deposited horizontally, in continuous lateral layers, with the oldest layers at the bottom.

Reading Sample

TWFF

This section has been removed



Magma from beneath Earth's surface intruded into, and is younger than, the rock layers surrounding it.

In 1795, Scottish scientist James Hutton put forth an additional geologic principle, the **Principle of Uniformitarianism**. This principle states that throughout geologic time, the natural processes by which geologic formations develop are uniformly frequent and of uniform magnitude and intensity. In the early 1800s, Scottish geologist Charles Lyell's observations lent further support to Hutton's principle. Hutton's work led to the formulation of an additional principle, the **Law of Cross-Cutting**

Relationships, which puts forth that a fault or rock formation that cuts through another rock formation is younger than the formation through which it runs.

Alongside the discoveries pertaining to uniformitarianism, Georges Cuvier, a French zoologist, was studying fossils found within rock layers. He discovered that many fossils were different from living organisms; they were evidence of extinct life forms. He also noted that fossils in successive rock layers represented a succession themselves. His observations of the gradual differences in fossils within different layers led to the

Principle of Faunal Succession, which states that fossils exist in rock layers in a specific order. English engineer and surveyor

William Smith used this principle in the late 1700s to create a geological map of England and Wales.



Fossils help geologists place rock layers in different areas in relative time.

The Importance of the Principles of Geology

Reading Sample

TWIF

This section has been removed

rock layers suggests some kind of geologic event. Similarly, the Principle of Lateral Continuity helps scientists place erosion events in relative time and the Law of Cross-Cutting Relationships helps them place intrusive or earthquake events in relative time. Finally, the Principle of Uniformitarianism allowed geologists to observe the effects of current geologic events on rock formations and extrapolate that to past geologic events, thus enabling them to recognize events that occurred in Earth's past. These principles together make reconstructions of the distant past possible: what occurred, the relative time in which it occurred, how it affected existing and forming rock layers, what organisms existed during that time period, and how events affected living organisms.

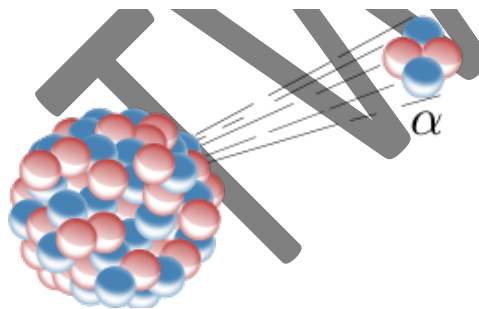
From Relative to Absolute Timelines

Reading Sample



This section has been removed

However, it wasn't until the 1900s that the field of **geochronology** really took off.



Radioactive decay of unstable isotopes makes radiometric dating possible.

Geochronology is the study of the absolute age of rocks and rock formations. It was made possible by **radiometric dating**, a scientific practice whereby specimens are dated using **radioactive isotopes**. A radioactive isotope is a form of an element that a) differs from the base element in the number of neutrons it contains (it is an **isotope**) and b) is unstable and breaks down, or decays, into a different isotope or element (it is **radioactive**). The rate of decay of radioactive isotopes is

known. Thus, by measuring the ratio of radioactive isotopes to the isotopes or elements they decay into within a specimen, researchers can determine how long ago the sample formed. Radiometric dating allowed geologists to place layers and fossils in time. This led to the development of the **geologic time scale**.

The Geologic Time Scale

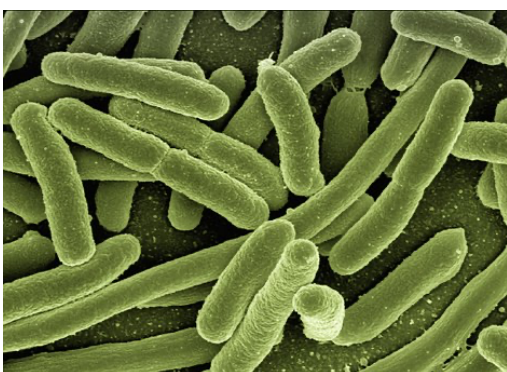
The geologic time scale organizes Earth's history into several different divisions. These divisions, in order of size, are **eons**, **eras**, **periods**, **epochs**, and **ages**. They are bounded by events such as mass extinctions, the appearance or rapid increase of certain types of life forms, or abrupt changes in global climate. They are named with a simple naming convention: **-zoic** means animal life, **paleo** means ancient, **meso** means middle, **neo** means new, and **ceno** means recent. Not every division is named using this convention, but it is a useful way to remember how time intervals fit together.

Eons, the longest time intervals of the geologic time scale, are hundreds of millions of years long. There are currently three recognized eons: the **Archean**, the **Proterozoic**, and the **Phanerozoic**. A fourth (technically the first) eon-length time division called the **Hadean** is sometimes placed before the Archean in the time scale. The Hadean represents a pregeologic time period. None of the rocks present during the Hadean still exist today. Our solar system was forming during this time and Earth would have been a cooling ball of molten rock.

The **Archean** eon lasted about 1.5 billion years (from about 4 to 2.5 billion years ago), is divided into four eras, and is the eon during which life first appeared on Earth in the form of bacteria. The four eras of the Archean are the Neoarchean, the Mesoarchean, the Paleoarchean, and the Eoarchean.

EON	ERA	PERIOD	EPOCH	Ma
Phanerozoic	Cenozoic	Quaternary	Holocene	0.011 -
			Pleistocene	0.8 -
		Tertiary	Pliocene	2.4 -
			Miocene	3.6 -
			Oligocene	5.3 -
			Eocene	11.2 -
			Paleocene	16.4 -
				23.0 -
		Paleogene		28.5 -
				34.0 -
				41.3 -
				49.0 -
				55.8 -
				61.0 -
	Mesozoic	Cretaceous		65.5 -
				99.6 -
		Jurassic		145 -
				161 -
		Triassic		176 -
				200 -
	Paleozoic	Permian		228 -
				245 -
				251 -
				260 -
		Pennsylvanian		271 -
				299 -
		Mississippian		306 -
				311 -
		Devonian		318 -
				326 -
		Silurian		345 -
				359 -
		Ordovician		385 -
				397 -
		Cambrian		416 -
				419 -
Precambrian	Proterozoic	Late Neoproterozoic (Z)		423 -
		Middle Mesoproterozoic (Y)		428 -
		Early Paleoproterozoic (X)		444 -
	Archean	Late		488 -
		Early		501 -
	Haydean			513 -

The Geologic Time Scale organizes Earth's 4.6-billion-year history.



Most life during the Proterozoic was bacterial.

The **Proterozoic** eon followed the Archean and spans the time between 2.5 billion years ago and 542 million years ago. It is divided into three eras, the Paleoproterozoic, the Mesoproterozoic, and the Neoproterozoic. During this eon, continents began to develop on Earth. Most life during the Proterozoic was bacterial, but around 1.8 million years ago, eukaryotic life emerged. The atmosphere of Earth changed during the Proterozoic, with oxygen becoming more abundant. During the time eukaryotes were evolving, the oxygen content of the atmosphere was about 15% of today's levels. During the last hundred

million years of the Proterozoic, oxygen-dependent, multicellular animals evolved. Within the

Reading Sample



This section has been removed



Trilobites were a dominant animal species of the early Paleozoic.

The **Paleozoic Era** lasted from about 542 to 251 million years ago, over half of the Phanerozoic eon. It is sometimes called the Age of Fishes, though many other organisms existed in large numbers during this time. Early in this era, the supercontinent Pannotia broke up due to tectonic plate movement. The major animals of the early Paleozoic were trilobites, brachiopods, and mollusks. Echinoderms and corals emerged later. Late in the Ordovician Period, life began to emerge onto land, with vertebrates appearing in the fossil record during the Devonian Period.

Many land plants evolved during the Paleozoic as well, with early conifers and ferns emerging near the end of the era. The Paleozoic ended with the formation of the supercontinent Pangea

as well as the largest mass extinction in Earth history: about 96% of all marine invertebrate life and 70% of all terrestrial vertebrates perished.

The **Mesozoic Era**, also called the Age of Reptiles, is the era in which dinosaurs emerged, diversified, and became extinct. It began 251 million years ago and ended 65.5 million years ago, also bringing the precursors to many modern plant and animal groups. It is bounded by two large mass extinctions, the end-Permian extinction (mentioned above) and the Cretaceous-Paleogene extinction, in which all non-avian dinosaurs and many marine species were wiped out. During the Triassic Period, reptiles began to increase, and dinosaurs appeared. Late in the Triassic, Pangea began to break up, dividing into Laurasia and Gondwana. The first mammals also appeared late



Dinosaurs lived during the Mesozoic Era.

in the Triassic, along with lizards, turtles, flying pterosaurs, sharks, plesiosaurs, and ichthyosaurs. The oceans were dominated by mollusks. The end of the Triassic saw a relatively minor extinction event: 35% of all animals perished, with most crocodilian and amphibious species living in the tropics disappearing. Birds, placental and marsupial mammals, salamanders, frogs, and toads emerged in the terrestrial fossil record of the Jurassic Period,



Palm-like trees emerged during the Jurassic Period.

while ammonites dominated the seas. Trees resembling modern palms evolved during this period as well. Midway through the Jurassic, Laurasia and Gondwana began breaking up, with North America moving away from Eurasia and Gondwana. The end of the Jurassic saw Africa break away from South America and Australia and Antarctica split from India. The Cretaceous Period contained some of the most famous dinosaur species, such as *Triceratops*, and was

the period of the first flowering plants. The Cretaceous also saw a rapid diversification of marine life. The Rocky Mountains began to form during this period. By the end of the Cretaceous, Madagascar had broken with Africa and South America had begun to drift northwest.

Reading Sample



This section has been removed

to humans). The Pleistocene Epoch of the Quaternary Period contained many species that are



Homo sapiens first appear in the fossil record from the Pleistocene.

closely related to those alive today. Our species, *Homo sapiens*, emerged during the Pleistocene. Terrestrial mammals and birds were larger than today's counterparts, with woolly mammoths and mastodons, giant deer, and birds with 25-foot wingspans. During the Pleistocene, the last major ice age (period of dramatic global cooling) occurred. The Pleistocene closed with an extinction event perhaps due to human overhunting, though

some researchers suggest widespread disease or climatic change is the true culprit. The end of the last ice age ushered in the Holocene, the current epoch, about 11,700 years ago. All of recorded human history exists within the Holocene, though our species was widespread before it began. We have only to look around at the great diversity of life on Earth to see what organisms characterize the Holocene.

Reading Comprehension Questions:

1. How old is Earth?
2. What
3. What is the difference between chronostratigraphy and geochronology?
4. List
5. Which eon is the longest?
6. In
7. In what time period did continents begin to develop?
8. What
9. Which
10. In what time period did dinosaurs first emerge?
11. In
12. What time period saw the first flowering plants?
13. In what time period is all of recorded human history contained?

Extension Questions:

14. What major development of the Phanerozoic Eon helped make current lifeforms possible? Explain.
15. The
16. Do you

Reading Comprehension Questions:

Reading Sample



This section has been removed

References

- Berggren WA (2015) Cenozoic Era. *Geochronology*. Retrieved 3 July 2018 from <https://www.britannica.com/science/Cenozoic-Era>.
- Fairbridge RW and Agenbroad LD (2009) Holocene Epoch. *Geochronology*. Retrieved 3 July 2018 from <https://www.britannica.com/science/Holocene-EPOCH>.
- Fiorello TR, Collins AG, Waggoner BM, Speer BR, Rieboldt S, and Smith D (2011) The Paleozoic Era. *Geologic Time Scale*. Retrieved 2 July 2018 from <http://www.ucmp.berkeley.edu/paleozoic/paleozoic.php>.
- Fiorello AR, Polly PD, Collins AG, Speer BR, Whitney C, and Smith D (2011) About the Geologic Time Scale. *Geologic Time Scale*. Retrieved 2 July 2018 from <http://www.ucmp.berkeley.edu/exhibit/histgeoscale.php>.
- Ghose T (2015) Mesozoic Era: Age of the Dinosaurs. *Live Science*. Retrieved 3 July 2018 from <https://www.livescience.com/38596-mesozoic-era.html>.
- Graham I (2015) The Geological Time Scale. *Australian Museum*. Retrieved 2 July 2018 from <https://australianmuseum.net.au/the-geological-time-scale>.
- Idaho Museum of Natural History (n.d.) Geologic Principles. *Education Resources Center*. Retrieved 2 July 2018 from https://imnh.iri.isu.edu/Exhibits/Online/geo_time/geo_principles.htm#cross.
- King HM (n.d.) Geologic Time Scale: A Time Line for the Geological Sciences. *Geology.com*. Retrieved 2 July 2018 from <https://geology.com/time.htm>.
- National Park Service (2018) Geologic Time. *Geology*. Retrieved 2 July 2018 from <https://www.nps.gov/subjects/geology/geotime.htm>.
- National Park Service (n.d.) Cross-Cutting Relationships. *Geologic Time*. Retrieved 2 July 2018 from https://www.nature.nps.gov/views/KCs/Time/HTML/07_Cutting.htm.
- Nicolaus Steno (n.d.) *Earth Observatory*. Retrieved 2 July 2018 from <https://earthobservatory.nasa.gov/Features/Steno/steno5.php>.
- Olson EA, Johnson GD, and Mallory VS (2001) Geochronology. *Earth Science*. Retrieved 2 July 2018 from <https://www.britannica.com/science/geochronology>.
- Polly D, Collins A, Rieboldt S, and Smith D (2011) The Mesozoic Era. *Geologic Time Scale*. Retrieved 3 July 2018 from <http://www.ucmp.berkeley.edu/mesozoic/mesozoic.php>.
- Polly D, Guralnick R, Collins A, Speer B, Rieboldt S, and Smith D (2011) The Cenozoic Era. *Geologic Time Scale*. Retrieved 3 July 2018 from <http://www.ucmp.berkeley.edu/cenozoic/cenozoic.php>.
- Polly D, Speer B, Waggoner B, and Smith D (2011) The Pleistocene Epoch. *Cenozoic Era*. Retrieved 3 July 2018 from <http://www.ucmp.berkeley.edu/quadernary/pleistocene.php>.
- Speer BR, Waggoner BM, and Smith D (2011) The Archean Eon and the Hadean. *Geologic Time Scale*. Retrieved 2 July 2018 from http://www.ucmp.berkeley.edu/precambrian/archean_hadean.php.
- Tang CM (2013) Mesozoic Era. *Geochronology*. Retrieved 3 July 2018 from <https://www.britannica.com/science/Mesozoic-Era>.

The Editors of Encyclopædia Britannica (1998) Uniformitarianism. *Geology*. Retrieved 2 July 2018 from <https://www.britannica.com/science/uniformitarianism>.

The Editors of Encyclopædia Britannica (2009) Eon. *Geologic Time*. Retrieved 2 July 2018 from <https://www.britannica.com/science/eon-geologic-time>.

The Editors of Encyclopædia Britannica (2015) Phanerozoic Eon. *Geochronology*. Retrieved 2 July 2018 from <https://www.britannica.com/science/Phanerozoic-Eon>.

The Editors of Encyclopædia Britannica (2018) Geologic Time. *Encyclopædia Britannica*. Retrieved 2 July 2018 from <https://www.britannica.com/science/geologic-time>.

The Editors of Encyclopædia Britannica (2018) James Hutton. *Encyclopædia Britannica*. Retrieved 2 July 2018 from <https://www.britannica.com/biography/James-Hutton>.

The Laws of Superposition and Cross-Cutting Relationships. (1997) *USGS*. Retrieved 2 July 2018 from <https://pubs.usgs.gov/gip/fossils/laws.html>.

The Principle of Lateral Continuity (2018) *Geology In*. Retrieved 2 July 2018 from <http://www.geologyin.com/2014/02/the-principle-of-lateral-continuity.html>.

U.S. Department of the Interior (2017) What is Geologic Time? *Geology and National Parks*. Retrieved 2 July 2018 from <https://geomaps.wr.usgs.gov/parks/gtime/index.html>.

U.S. Department of the Interior (n.d.) The Age of the Earth. *Geological Survey*. Retrieved 2 July 2018 from <https://www.nature.nps.gov/geology/education/concepts/ageofearth.pdf>.

U.S. Geological Survey (1997) The Relative Time Scale. *Fossils*. Retrieved 2 July 2018 from <https://pubs.usgs.gov/gip/fossils/scale.html>.

U.S. Geological Survey (2010) Divisions of Geologic Time. *Geology.com*. Retrieved 2 July 2018 from <https://geology.com/usgs/geologic-time-scale/>.

Waggoner B (1996) William Smith (1769-1839). *University of California Berkeley*. Retrieved 2 July 2018 from <http://www.ucmp.berkeley.edu/history/smith.html>.

Waggoner B (2000) Nicholas Steno (1638-1686). *University of California Berkeley*. Retrieved 2 July 2018 from <http://www.ucmp.berkeley.edu/history/steno.html>.

Waggoner BM, Collins AG, Hsu K, Kang M, Lavarias A, Prabaker K, Skaggs C, Reiboldt S, and Smith D (2011) The Cambrian Period. *Paleozoic Era*. Retrieved 2 July 2018 from <http://www.ucmp.berkeley.edu/cambrian/cambrian.php>.

Waggoner BM and Smith D (2011) The Holocene Epoch. *Cenozoic Era*. Retrieved 3 July 2018 from <http://www.ucmp.berkeley.edu/quadernary/holocene.php>.

Waggoner BM, Speer BR, Reiboldt S, and Smith D (2011) The Proterozoic Eon. *Geologic Time Scale*. Retrieved 2 July 2018 from <http://www.ucmp.berkeley.edu/precambrian/proterozoic.php>.

Windley BF (2007) Proterozoic Eon. *Geochronology*. Retrieved 2 July 2018 from <https://www.britannica.com/science/Proterozoic-Eon>.

Windley BF (2015) Geologic History of Earth. *Encyclopædia Britannica*. Retrieved 2 July 2018 from <https://www.britannica.com/science/geologic-history-of-Earth>.

Zimmerman KA (2016) Cenozoic Era: Facts About Climate, Animals & Plants. *Live Science*. Retrieved 3 July 2018 from <https://www.livescience.com/40352-cenozoic-era.html>.