

Some things to know about geologic time

Relative dating involves discerning the order in which geologic events occurred (*i.e.*, *this* occurred before *that*), but does not involve determination of the number of years that have passed since any given geological event occurred.

The principle of **original horizontality**, used in relative dating, notes that sedimentary beds are generally deposited in horizontal or near-horizontal layers. Hence, they were originally horizontal, even though later deformation might result in tilting or folding.

The principle of **superposition**, used in relative dating, notes that older sedimentary strata are buried by younger sedimentary strata. Hence, in an undeformed sequence of sedimentary beds, the age of the beds increase with increasing depth. In other words, the youngest beds are on top, and the oldest beds are on bottom, of an undeformed sequence of sedimentary beds.

The principle of **inclusion**, used in relative dating, notes that a particle included in a rock must be older than the rock that surrounds it. For example, imagine a limestone boulder within a sedimentary conglomerate. The limestone of the boulder must be older than the conglomerate. As a second example, imagine a xenolith (a piece of the surrounding wall rock that detached and was incorporated in the magma) surrounded by granite. The material in the xenolith must be older than the granite.

The principle of **cross-cutting relationships**, used in relative dating, notes that a rock that is cut by a fault, a crack (or vein), or an igneous dike must have existed before the fault, crack or dike cut across it. Hence, the fault, crack or dike is younger than the rock that is cut by it. This is like the solution to the trivial question, "Which is older, a tear in a piece of paper or the piece of paper?" The paper had to exist first before it could be torn, so the paper is older than the tear.

The principle of **faunal succession**, used in relative dating, recognizes that the types of fossils found in sedimentary rocks of one age are different than the types of fossils found in sedimentary rocks of another age, assuming that enough time has transpired for evolution to change the fossil fauna. Hence, if you have two sites that each have sedimentary rocks containing the same types of fossils, the sedimentary rocks at the two sites must be the same age.

The boundaries of the various subdivisions of the geologic time scale (that is, the eons, eras, periods, epochs and stages) throughout the Phanerozoic (the last 542 million years) are generally marked by observable changes in fossil groups. Many, if not all of these changes are interpreted to have resulted from concentrations of extinctions, including mass-extinction events.

All 92 naturally occurring elements have isotopes. Stable isotopes are persistent throughout geologic time, but radiogenic isotopes are unstable and decay to form other elements/isotopes over time. Most radiogenic isotopes decay rapidly (*i.e.*, have short half lives) and are not generally useful for dating of geologic materials. The most useful radiogenic isotopes for a geologist are those that decay slowly to produce stable daughter products that are retained in the rock, so that the ratio of unstable parent isotopes to stable daughter isotopes can be measured using a mass spectrometer.

The half life of a radiogenic isotope is the amount of time it takes for one half of the unstable atoms to decay. For essentially all of the radiogenic isotopes used in geologic dating studies, the half life is a constant.

Imagine you have a mineral sample that contains 96 atoms of radioactive isotope potassium-40 at the time the mineral grain crystallized. It contains none of the stable daughter product, argon-40, at the time of initial crystallization. After one half life (1.25 billion years), half of the potassium-40 atoms decay to argon-40, so there will be 48 K-40 atoms and 48 Ar-40 atoms. After two half lives (2.5 billion years), half of the remaining K-40 atoms decay so that there will be 24 K-40 atoms and 72 Ar-40 atoms in the mineral grain at that time. After three half lives (3.75 billion years), half of the remaining K-40 atoms decay so that there will be 12 K-40 atoms and 84 Ar-40 atoms in the mineral grain at that time. And so on.

The effective maximum age that we can measure with isotopic dating using carbon-14 is currently around 50,000 years.

The effective maximum age that we can measure with isotopic dating using uranium-lead, thorium-lead, samarium-neodymium, rubidium-strontium, and potassium-argon isotopic systems extends across the entire age of the Earth.

The current best scientific age for the beginning of the Universe, space-time and the “Big Bang” is about 13.8 billion years.

The current best scientific age of the Earth is around 4.55 billion years.

The Moon formed around 4.51 billion years ago, possibly after a Mars-sized object struck the early Earth.

The oldest rocks that have been dated on the surface of Earth are around 4 billion years old.

The oldest chemical evidence of life on Earth is around 3.8 billion years old.

The oldest fossil evidence of life on Earth is around 3.5 billion years old.

The oldest fossils of animals that had hard parts (*e.g.*, shells, bones, teeth) are around 542 million years old. These fossils mark the beginning of the Phanerozoic Eon as well as the Paleozoic Era, and the end of the Precambrian Eon.

The end of the Paleozoic and the beginning of the Mesozoic was marked by a great mass extinction of organisms, which occurred about 250 million years ago.

The end of the Mesozoic and the beginning of the Cenozoic was marked by a slightly smaller mass extinction of organisms including dinosaurs, which occurred about 65 million years ago.

We live in the Cenozoic Era.

The oldest mammal fossils are around 220 million years old.

The oldest primate fossils are around 70 million years old.

Humans did not evolve from apes, chimpanzees, monkeys or orangutans, but we share common ancestors with these modern primates.

- The common ancestor shared by humans, apes, chimpanzees and monkeys lived around 30 million years ago.
- The common ancestor shared by humans, chimpanzees and apes lived around 8 million years ago.
- The common ancestor shared by humans and chimpanzees lived around 6 million years ago. Humans walk on two legs, while chimpanzees walk on 4 most of the time.

The oldest fossils of *Homo sapiens* (our species) are around 200 thousand years old, and were found in Africa. *Homo sapiens* is an African species that spread throughout the world from Africa.