Lecture 6: Stratigraphy
(Why do we think dinosaur bones are old?)

Apatosaurus skeleton (source)

There are many intuitive reasons to think the Earth is old

- The surface of the Earth is scarred from massive past events
- Different layers of rock (called **strata)** with different fossils in them.

Sonoma coastline (source)

The science of Earth: geology

- **Geology:** scientific study of the physical Earth, its composition, and the processes that change it over time

- The Earth is **dynamic:** energy is continually moving through the planet.

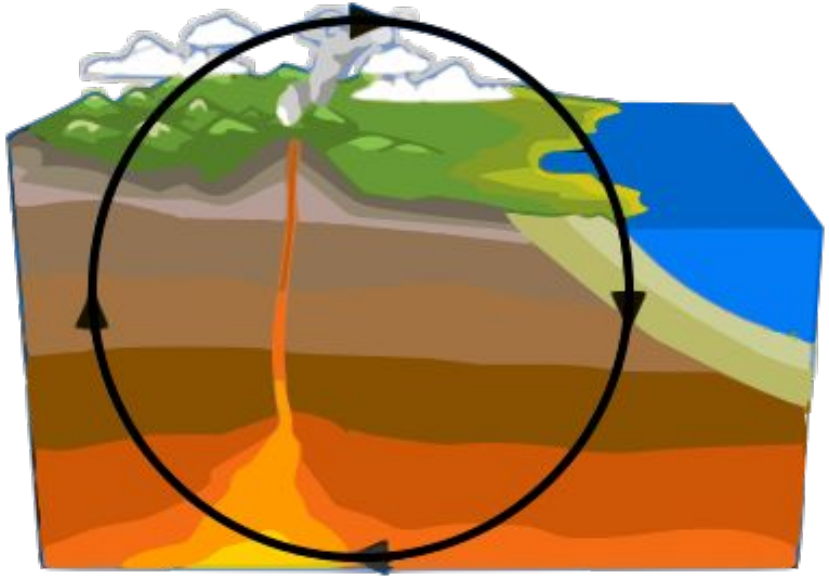
- This contrasts with “dead” planets and extraterrestrial bodies

Artistic representation of the Earth’s interior (source)

Cyclical Earth processes

- A founding principle of geology is **uniformitarianism**: the processes that operate today operated the same way in the past

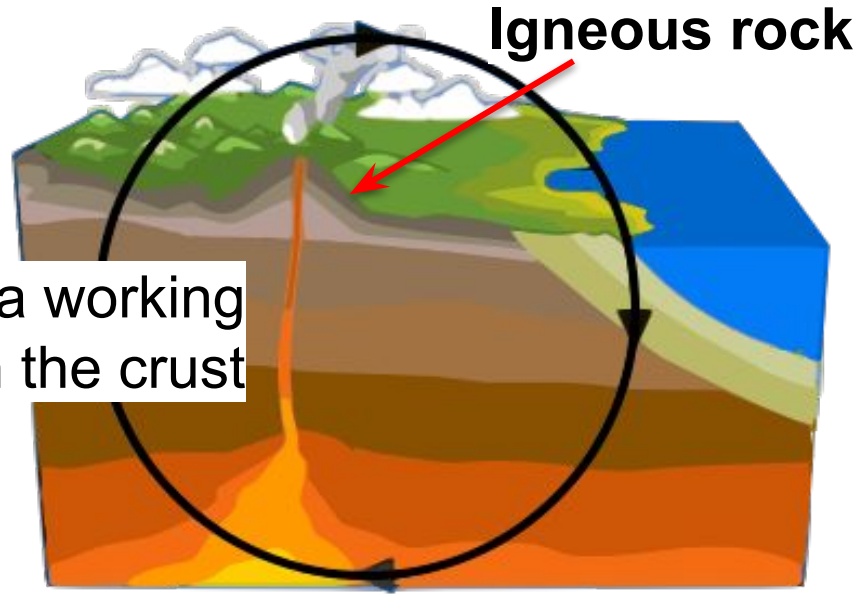
- By studying modern Earth processes we can make inferences about the past



Rock cycle (image modified by source)

The rock cycle

- Radioactivity in the Earth's core generates convection, bringing liquid magma to the surface that cools into **igneous rocks**

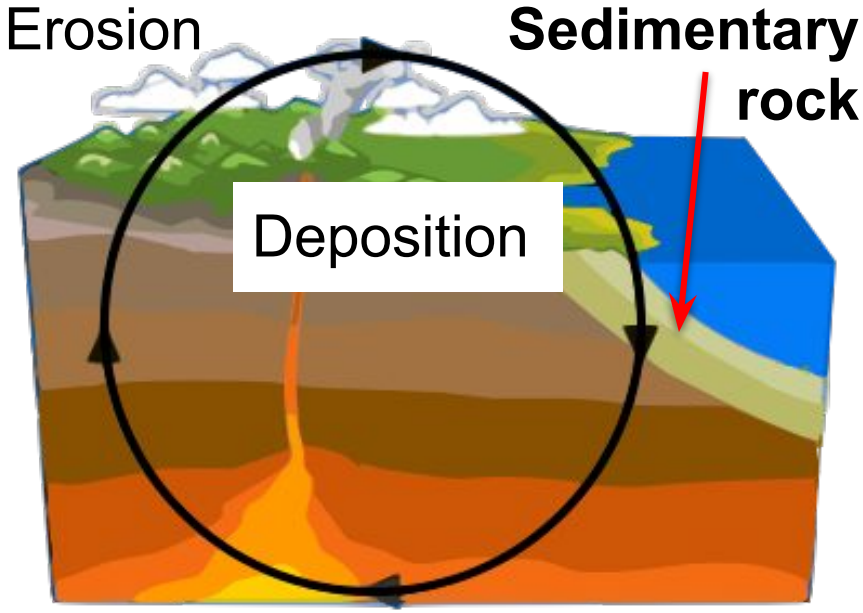


Rock cycle (image modified by source)

The rock cycle

- Weathering from wind and rain degrades rock. The rock piles up in certain areas (most often right off the shoreline) as sediment

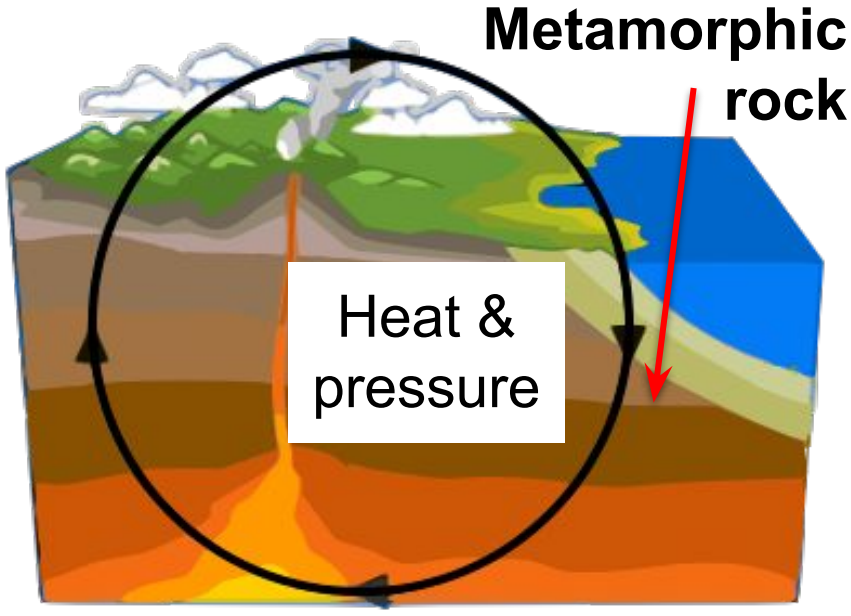
- Over time heat and pressure turn the sediment into **sedimentary rock**



Rock cycle (image modified by source)

The rock cycle

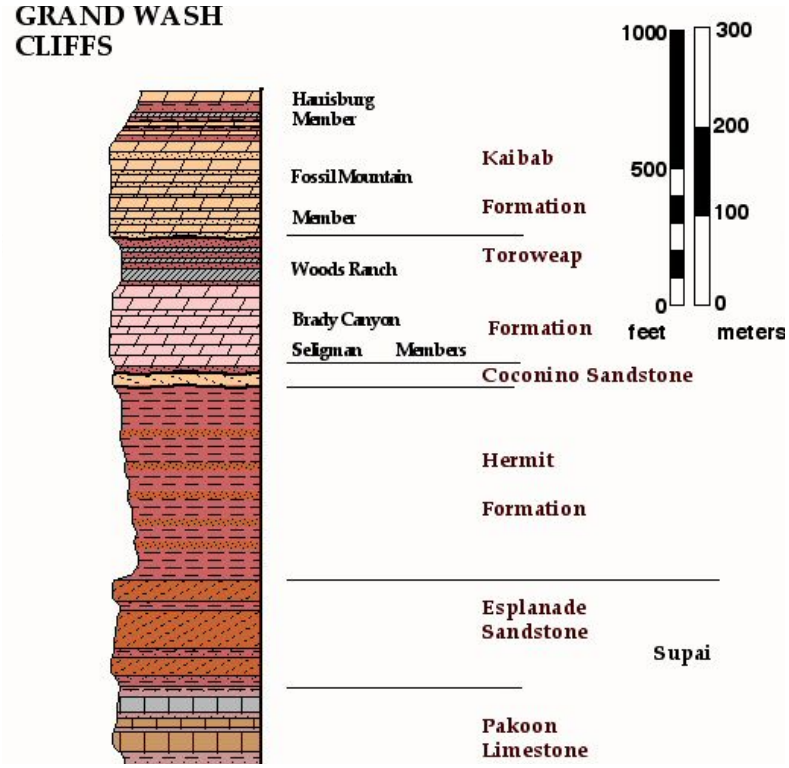
- Additional heat and pressure eventually produces **metamorphic rock**)



Rock cycle (image modified by source)

Telling relative time through stratigraphy

- **lithostratigraphy** (Greek: “lithos” = rock) Dating rocks based on their order and mineral composition
- **Stratigraphic columns** are maps that describe the vertical layering of rock in a particular location
- Comparable layers of rock can be found throughout the world



Stratigraphic column for the Grand Wash Cliff area, Arizona (source)

The law of superposition

- **The law of superposition**: in undeformed stratigraphic sequences, the oldest strata lie at the bottom while the youngest strata are at the top

- The deeper you go, the farther back in **time**

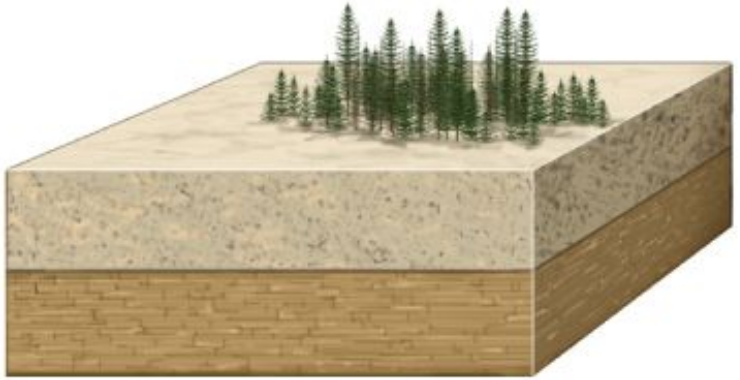


Illustration of the law of superposition (source)

Additional laws of lithostratigraphy: cross-cutting relationships

- When one rock is intruded by another, that rock must be older than the intrusion
- Rock layers A and B must be older than the intrusion C that disturbs them

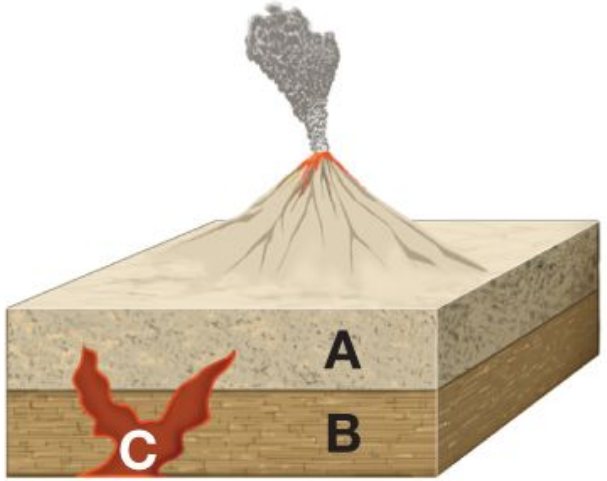


Illustration of the law of crosscutting relationships (source)

Additional laws of lithostratigraphy: lateral continuity

- Layers of rock are continuous until they encounter other bodies that block their deposition or until they are acted upon by agents that appeared after deposition took place

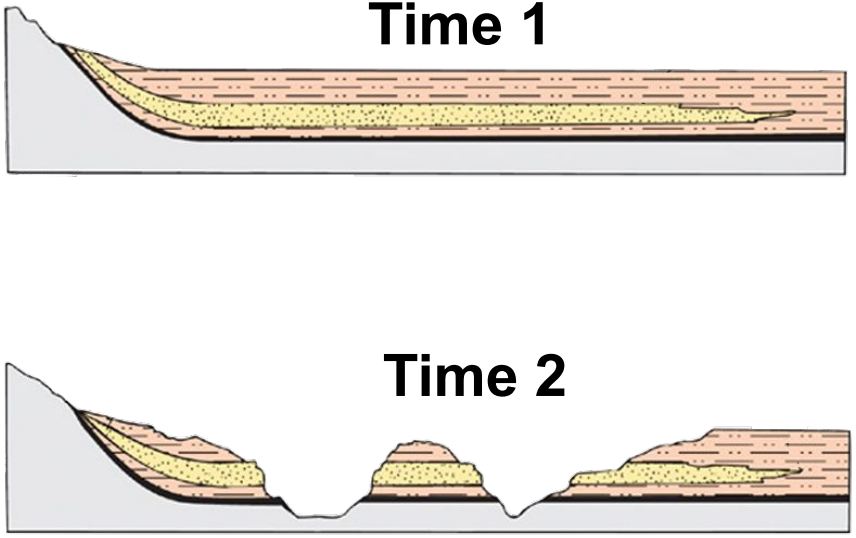
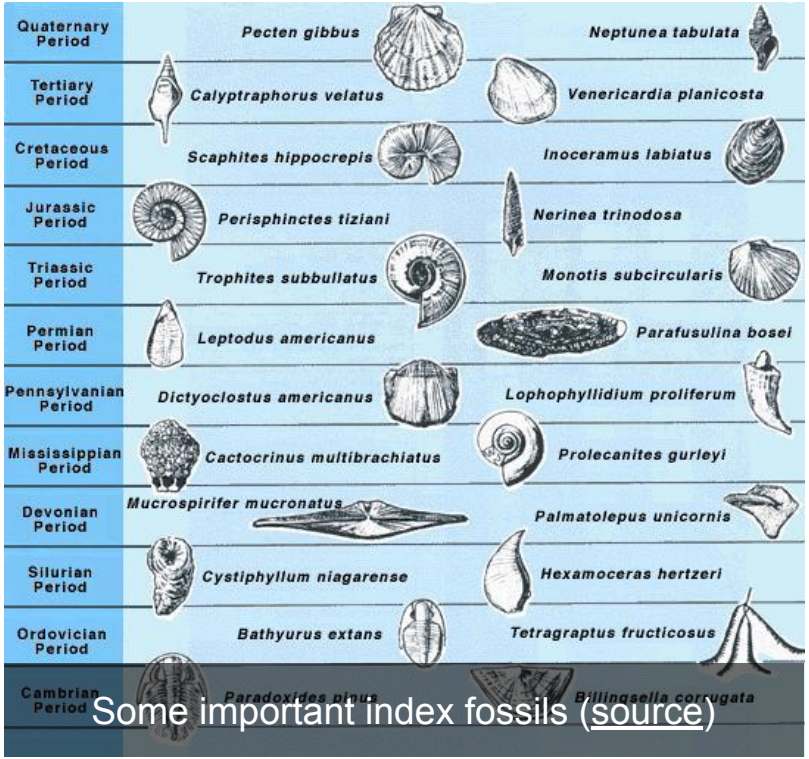


Illustration of the law of lateral continuity (modified from source)

Biostratigraphy: fossil succession

Biostratigraphy (Greek: “bios” = life) Dating rocks based on their fossils

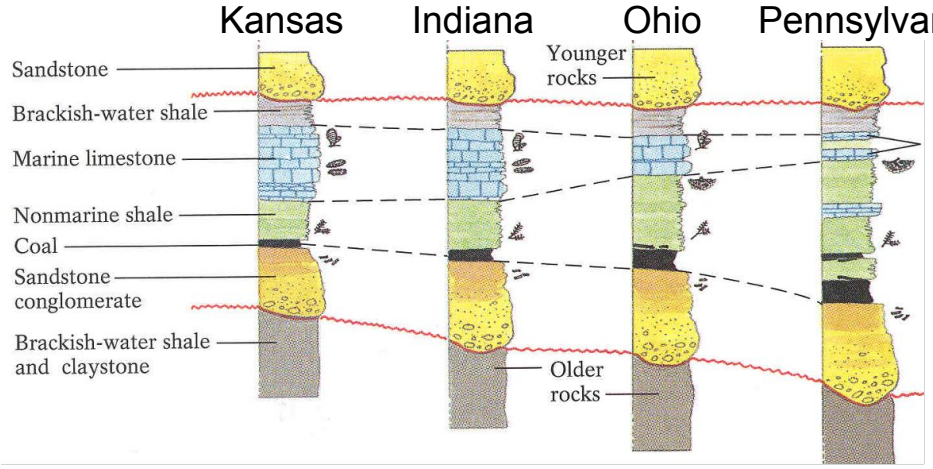
- **Index fossils**: fossils from organisms that had a broad distribution but were short-lived
- These fossils are particularly useful for correlating geologic columns between locations

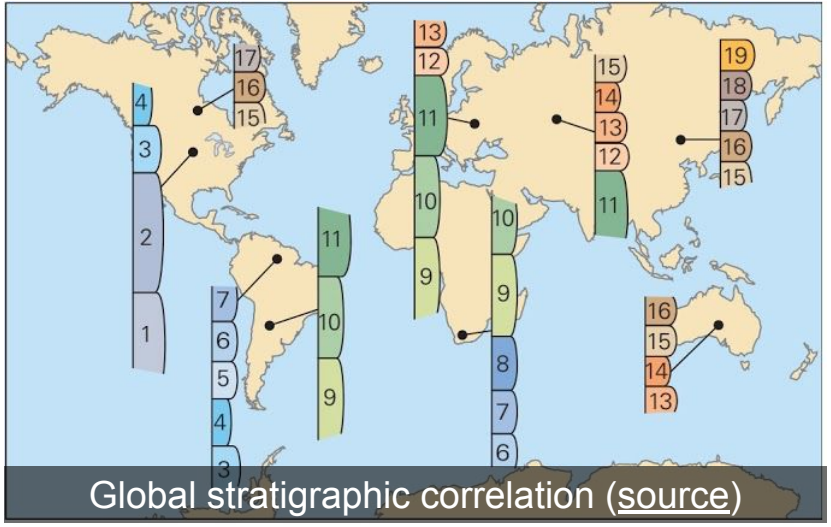


Some important index fossils (source)

Correlating strata across Earth

- Through lithostratigraphy and biostratigraphy, geologists have correlated rock strata across the entire globe

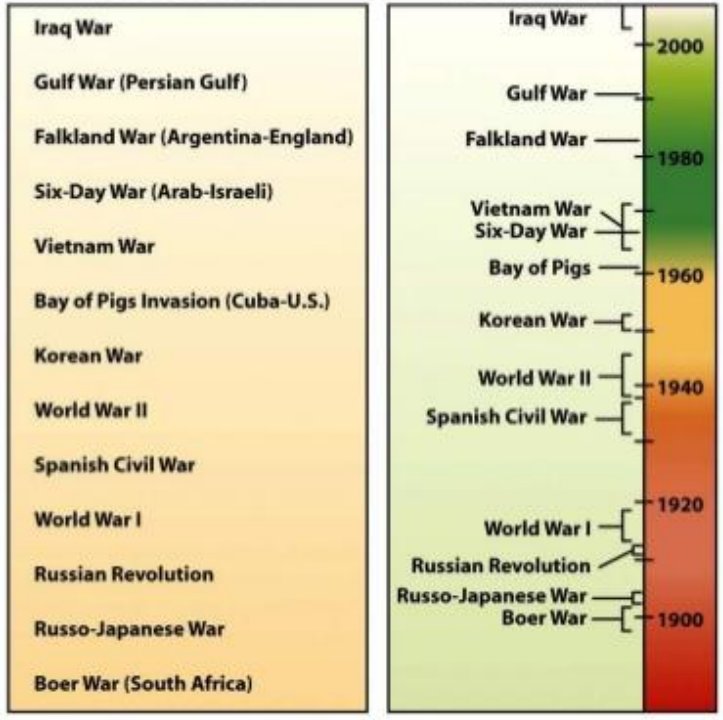




Next step: telling absolute time

- The large number of layers in the rock and their complex relationships demonstrate a long period of time, but how long?

- **Geochronology** (Greek: “geo” = Earth; “chronos” = time) provides absolute dates for strata

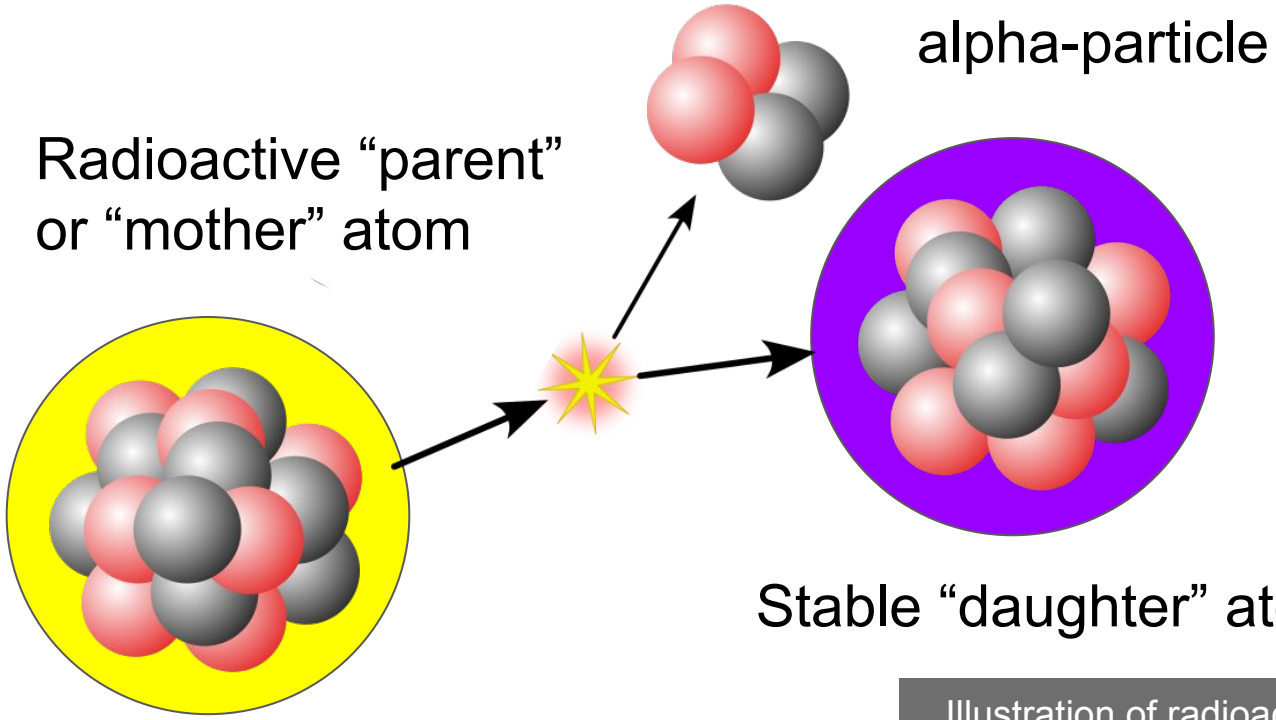


Relative vs absolute dating (source)

Radioactive material is found in igneous rocks

Zircon crystals in pegmatite (source)

Methods of geochronology: radioactive decay

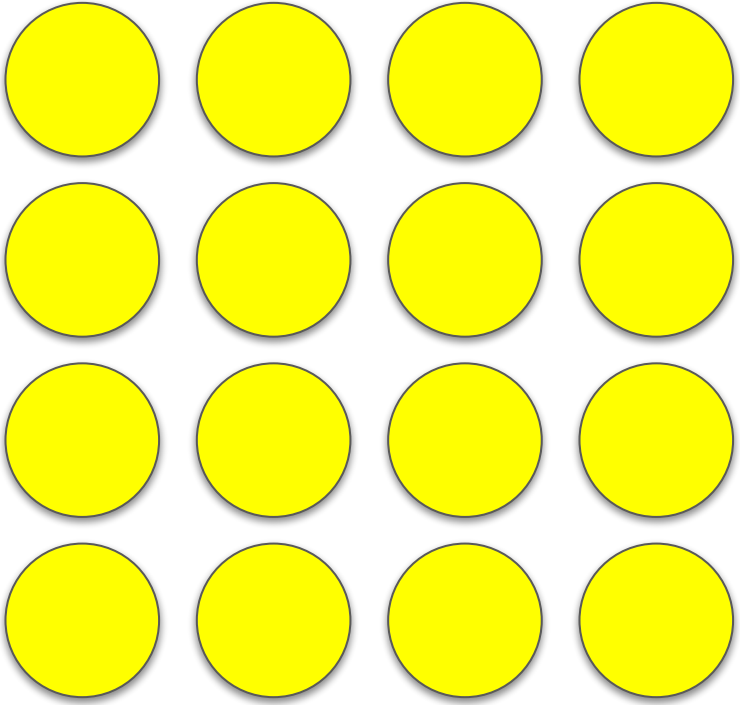


- **Radioactive decay**: the process where an unstable atom loses energy by radiation

Illustration of radioactive decay (modified from source)

Radioactive decay

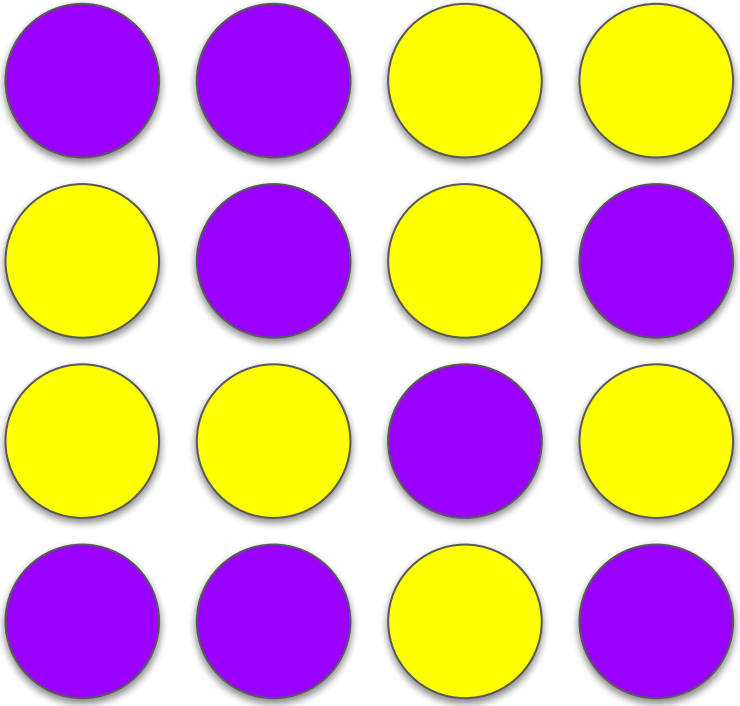
Time 0: 0/16 decayed



- Nuclear physicists cannot predict when any individual atom will decay from a radioactive parent to daughter
- They can calculate how long it takes for groups of radioactive atoms to decay
- **Half life**: the amount of time it takes for half of all radioactive atoms in a sample to decay

Radioactive decay

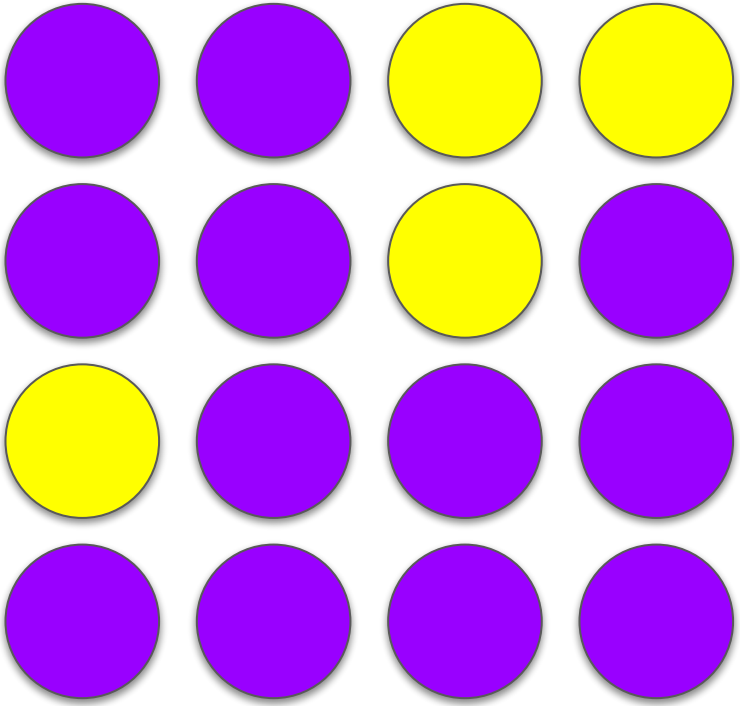
Half-life 1: 8/16 decayed



- Nuclear physicists cannot predict when any individual particle will decay from a radioactive parent to daughter isotope
- They can calculate how long it takes for groups of radioactive isotopes
- **Half life**: the amount of time it takes for half of all radioactive isotopes to decay

Radioactive decay

Half-life 2: 12/16 decayed



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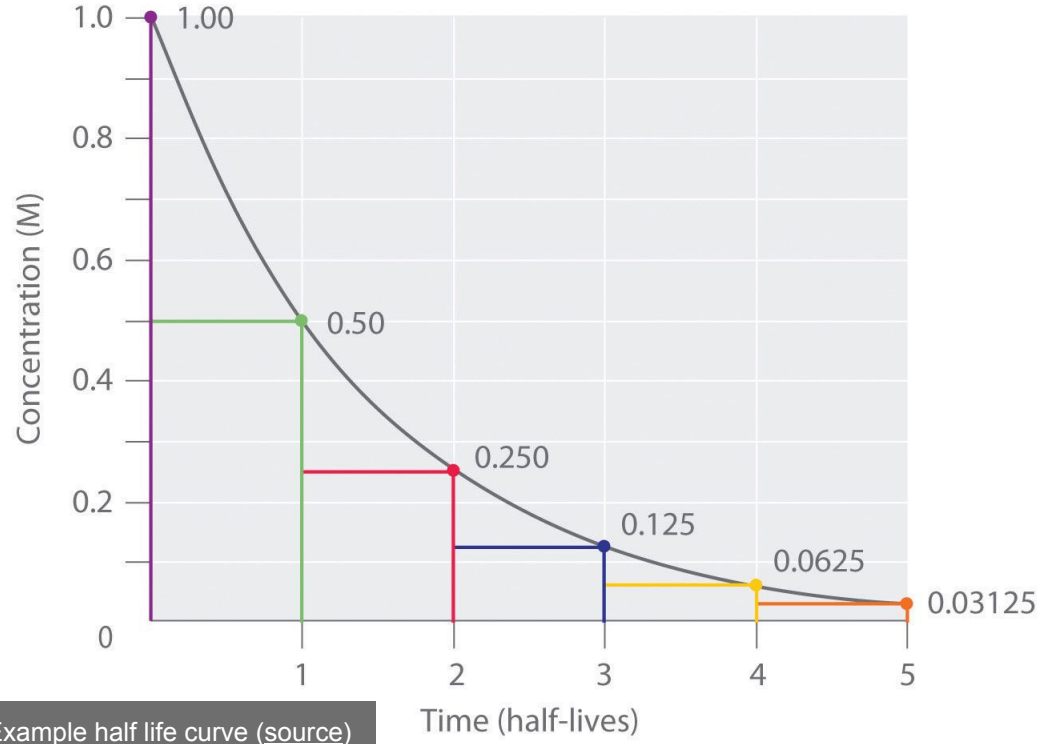
Radioactive decay

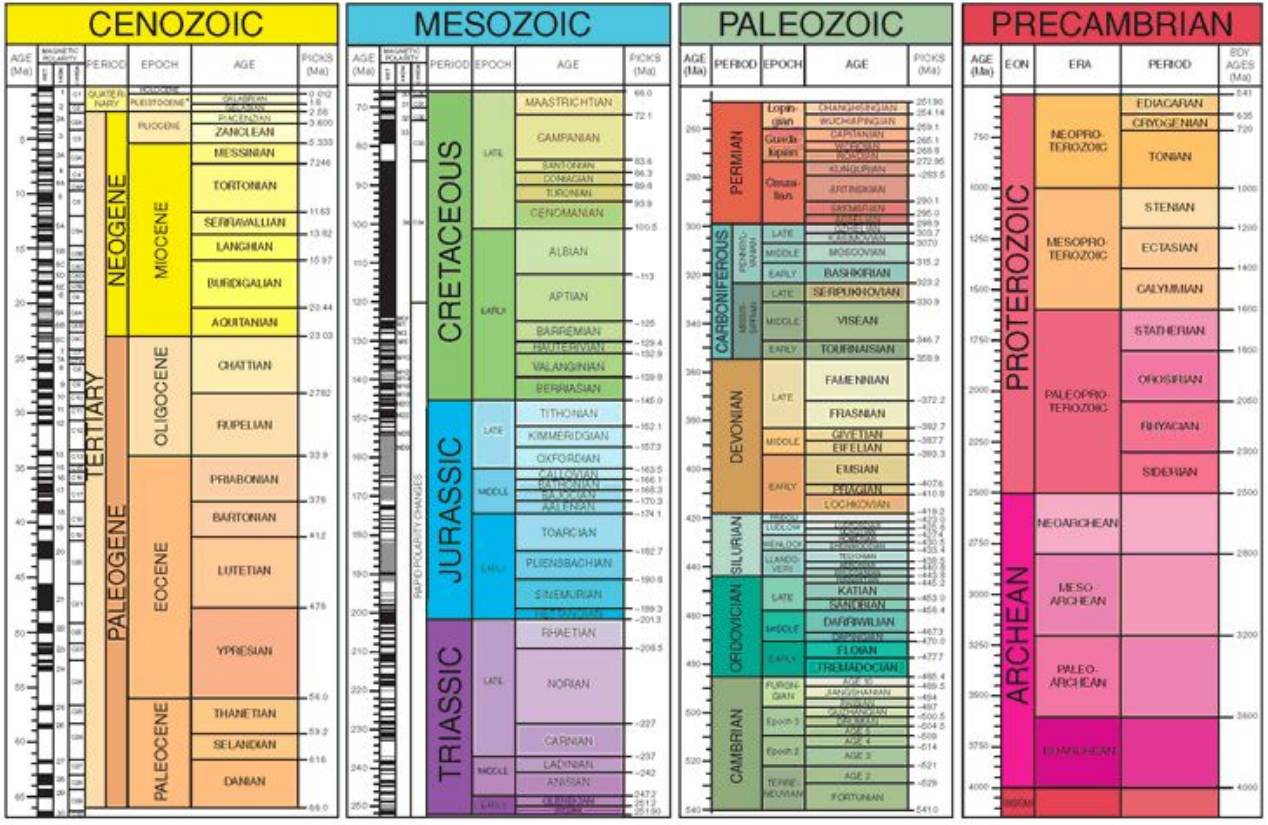


Example half life curve (source)

Parent	Daughter	Half-Life
potassium-40	argon-40	1.3 billion years
uranium-235	lead-207	700 million years
uranium-234	thorium-230	80,000 years
carbon-14	nitrogen-14	5,700 years

The modern geologic time scale

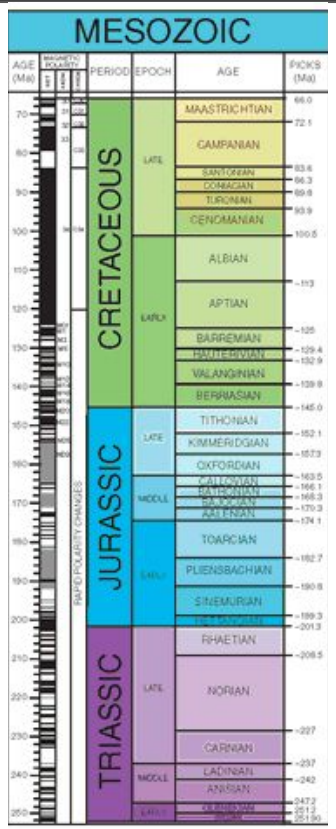
- One of the great accomplishments of science
- The Eras of time are being subdivided with greater detail as more data is acquired



The Mesozoic as “the age of dinosaurs”

- Dinosaur fossils are constrained to the **Mesozoic Era** (251.902 ± 0.024 – 66.0 Ma*)

- It is subdivided into the **Triassic** (252 – 201 Ma), **Jurassic** (201 – 145 Ma), & **Cretaceous** (145 - 66 Ma) periods.



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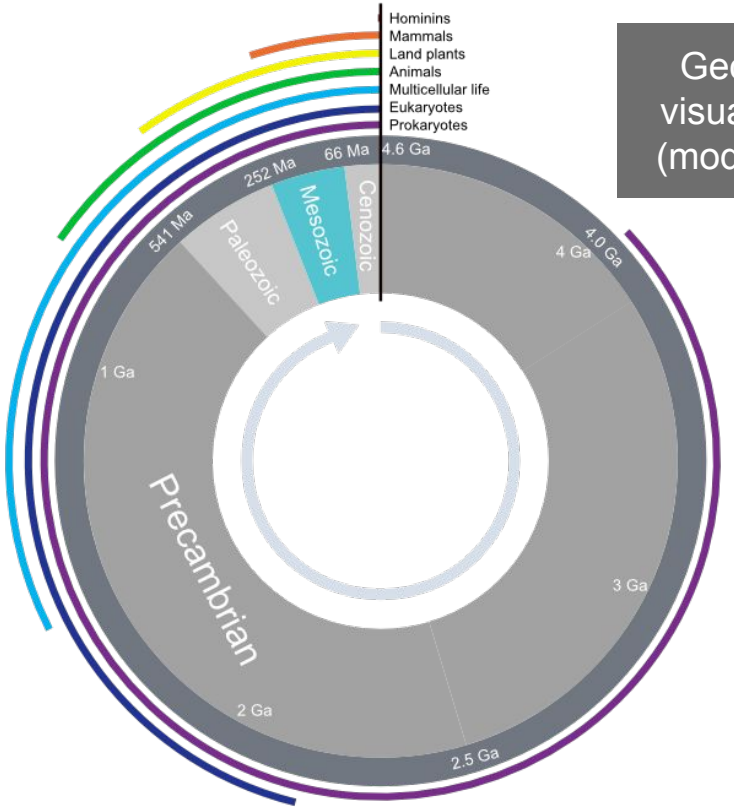
Common geologic abbreviations:

Ma or Mya = million years ago

My or Myr = million years

The Mesozoic as “the age of dinosaurs”

- The Mesozoic is a fraction of Earth’s total history
- Dinosaurs are one small part of the story of life



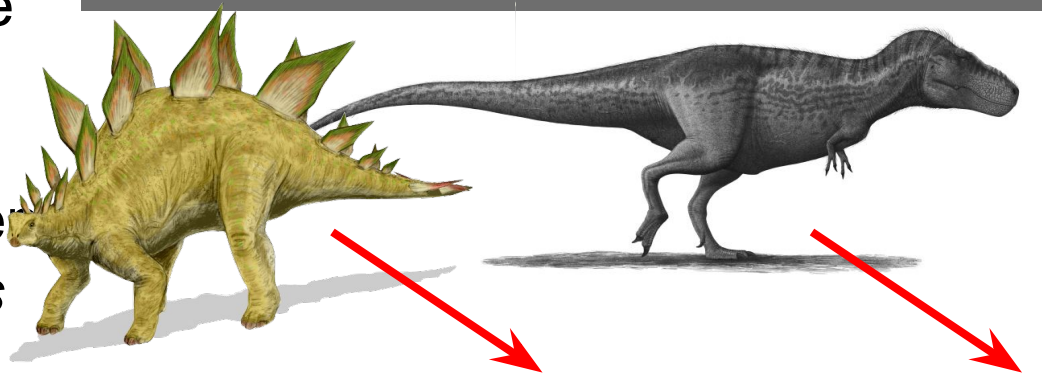
Geologic time scale visualized as a “clock” (modified from source)

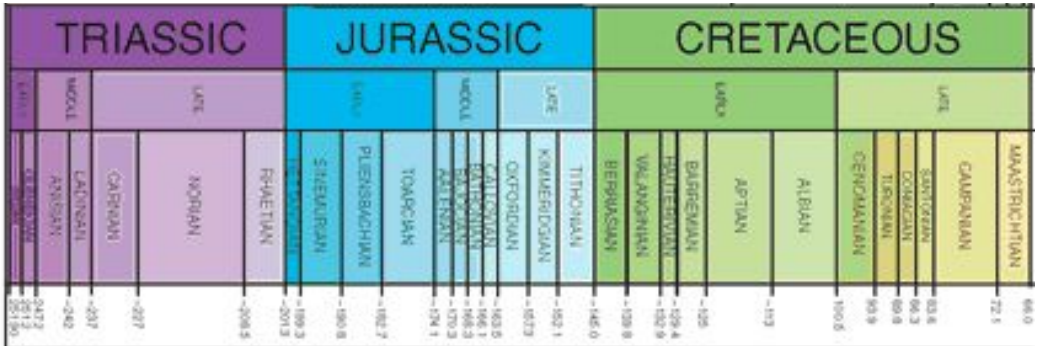
Want to find out more? Take “GEL3: History of Life” with me Winter 2025!

The Mesozoic as “the age of dinosaurs”

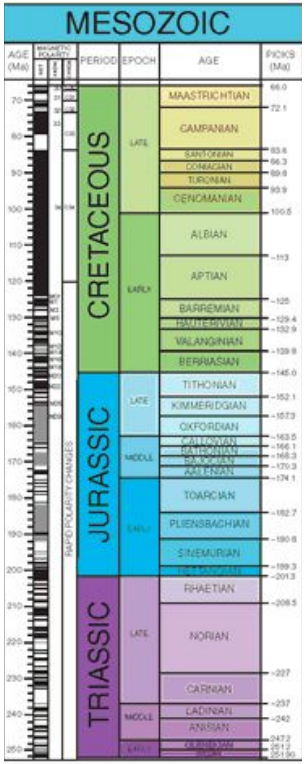
- That is also a long expanse of time (~186 myr)
- The time difference between dinosaurs like *Stegosaurus* and *Tyrannosaurus* (~82 my) is larger than the difference between *Tyrannosaurus* and us (~66 my)

Stegosaurus (source) and *Tyrannosaurus* (source)





Conclusion



- Stratigraphy is the science of determining the order rocks were deposited and reconstructing their history
- Geochronology converts the relative dates of geologic formations into absolute dates
- These sciences demonstrate that dinosaurs lived between 251-66 mya