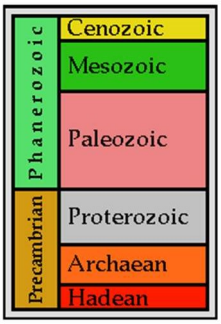
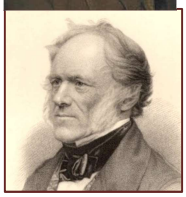
Chapter Outlines



NOTE: This is intended to help students 'organize' their understanding of each topic. It is <u>not</u> a comprehensive study guide for quizzes or midterms, i.e. <u>study your text!</u>

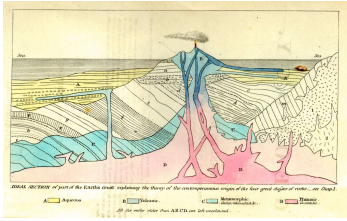
Geologic Time

The earth is estimated to be about 4.5 billion years old. Our knowledge of its history comes from a number of sources. The geologic time scale is constructed through scientific methods and calculations as well as from the interrelationships of geological features as observed in the field. The **principle of uniformitarianism** *("the present is the key to the past")* allows us to accurately measure the rates of geologic processes we see today and apply them to the geologic past. For example, we know layers of sediment build up on the ocean floor at the rate of about 1 millimeter per year *(varies greatly by location).* Thus, it would take over one million years of sedimentation to form a unit of shale 1,000 meters thick.



- **Age of Earth**
  - Prior to the 19th century, accepted age of Earth was based on ***religious beliefs***
    - Biblical: ~6,000 years for Western culture
    - Chinese/Hindu: Old beyond comprehension
  - ***James Hutton, MD***: "*Father of Geology*" *(1726 – 1797)*
    - realized geologic processes require vast amounts of time
    - 'principle of uniformitarianism' grew from his ideas
  - ***Charles Lyell*** *(1797 – 1875)*
    - popularized Hutton's concepts in the book '*Principles of Geology'.*

From Lyell's book 'Principles of Geology'



- Geologic time *(absolute time)* is deep! 'Billions of years' is just a start. But, in geology, **<u>relative time</u>** is often more useful than **<u>absolute time</u>**. Reminder…uniformitarianism states the geologic processes working today were also in action in the past, and the distant past.
  - Relative time *(relative sequence of geologic events)* is organized by the **Geologic Time Scale**. It was originally created by the use of fossils, without any reference to actual dates in years.

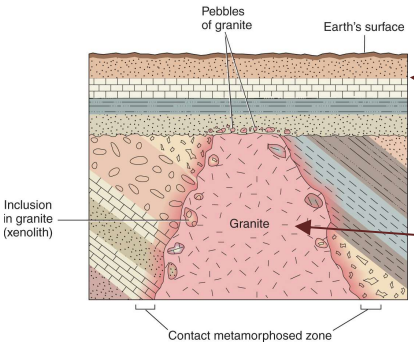
TABLE 8.2 Geologic Time Scale

Era	Period		Epoch
Cenozoic	*Quaternary*		Holocene (Recent)
		Neogene	Pleistocene
	***Tertiary*		Pliocene
			Miocene
		Paleogene	Oligocene
			Eocene
			Paleocene
Mesozoic	*Cretaceous*		
	Jurassic		
	Triassic		
Paleozoic	*Permian*	Carboniferous*	
	Pennsylvanian		
	Mississippian		
	Devonian		
	Silurian		
	Ordovician		
	Cambrian		
Precambrian Time			

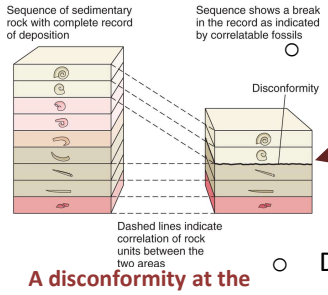
- Largest division are **Eons** *(oldest to youngest)*: Hadean, Archean, Proterozoic, Phanerozoic,
  - The oldest three *(Hadean, Archean, & Proterozoic)* are commonly combined and called the **<u>Pre-Cambrian.</u>**
- **Eras: Paleozoic, Mesozoic, Cenozoic** *(these three are important in this class)*
- **Periods**: Cambrian, Ordovician, Silurian, Devonian, Mississippian, Pennsylvanian, Triassic, Jurassic, Cretaceous, Tertiary, Quaternary.
- **Epochs**: Paleocene, Eocene, Oligocene, Miocene, Pliocene, Pleistocene, and Holocene *(also called 'Recent')*

Determining relative time is aided by the use of several accepted principles:

- **Principle of original horizontality** – Sedimentary beds were horizontal *(or nearly horizontal)* when formed.
- **Principle of superposition** – in undisturbed horizontal beds, lower beds are older than higher beds. *(these upper beds are younger)*
- **Lateral continuity** – beds continue horizontally until they either taper or thin at their edges.
- **Cross-cutting relationships** – a feature that cuts through another feature must be younger *(this granite intrusion is younger than the angled beds).*
- **Inclusions** – a rock found within another rock *(country rock fragments within solidified magma)* must be older.
- **Principle of faunal succession** – fossil species occur in a definite and recognizable succession through time. Index fossils and fossil assemblages are key.



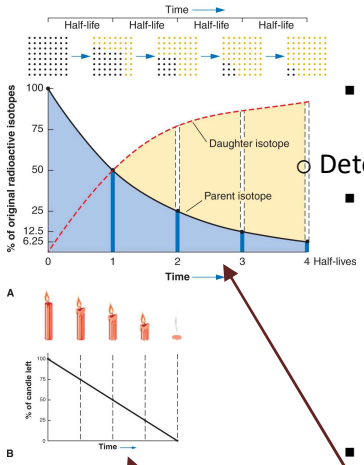
This illustration has examples of:
- ✓ **Original horizontally**
- ✓ **Superposition**
- ✓ **Lateral continuity**
- ✓ **Cross-cutting relationship**
- ✓ **inclusions**



A disconformity at the arrow (dashed lines represent strata correlations)

- The stratigraphic record often has gaps *(periods of non-deposition and/or erosion),* which are called **unconformities.** There are three types:
  - **Disconformity** – time gap between parallel beds
  - **Angular unconformity** – same as Disconformity except the lower *(older)* beds are tilted
  - **Non-conformity** – same as Disconformity except the lower *(older)* rocks are plutonic or metamorphic
- Determining age relationship between geographically separated rock units using **correlation**.
  - Physical correlation
    - physically tracing the rock unit
    - Matching based on distinctive properties of a rock unit
  - Correlation by the matching of fossils

- Back to absolute time…
  - Numerical dating gives absolute age for Earth of about ***4.55 billion years***
    - This oldest age is obtained from ***meteorites*** because they are believed to have been unchanged since the formation of the solar system. Earth and the rest of solar system very likely formed at this same time.
    - The oldest rock found on Earth so far is 4.03 billion years old *(Canada).* Oldest mineral is a zircon at 4.4 billion years *(Australia).*
  - Determining the absolute age of a rock is based on the decay of **radioactive isotopes**.
    - The use of the isotope uranium 238 is common for very old rocks. The use of the isotope carbon 14 is common for younger items.
      - Uranium 238 converts *(decays in steps)* spontaneously to lead 206 at the rate of ½ of its atoms every 4.5 billion years. By measuring the ratio of uranium 238 to lead at any given instant, you can determine the material's exact age.
      - This decay begins at the rock's formation (solidification) and remains at a constant rate over time.
    - For dating within more recent time ***(last 40,000 years),*** **carbon-14** is commonly used.
      - The percentage of the isotope carbon-14 in a living organism is a known constant. Once that organism dies, the carbon-14 begins to decay to a 'daughter' element at the rate of ½ of its atoms every 5,730 years. Measuring how much carbon-14 still remains in the residue of that organism will tell you exactly when it died.

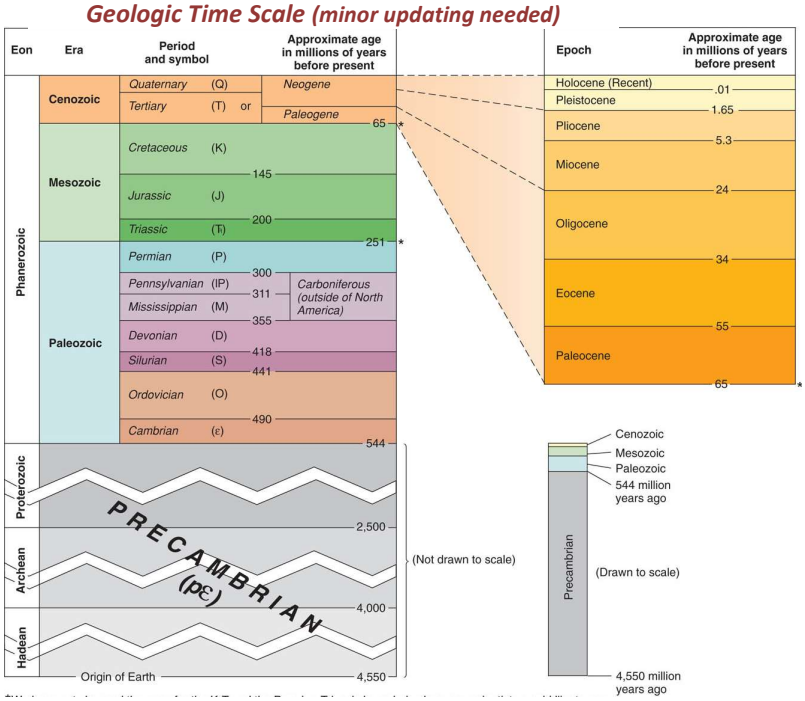


Radioactive isotopes decay by 'half-lives' **i.e. %/time**

A candle decays (burns) lineally i.e. 'unit of length'/time

- Human civilization *(recorded history)* has only been on Earth for 0.000001 of the life-span of this planet. Is that a significant/relevant concept? Try not to let the huge time span trouble you. Just think of the freedom Earth has… of having all the time in the world!

Geologic Time Scale (minor updating needed)



Steps in the decay of U-238 to lead