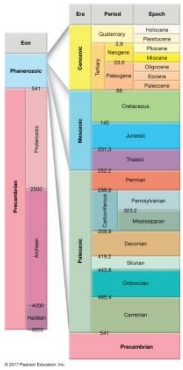
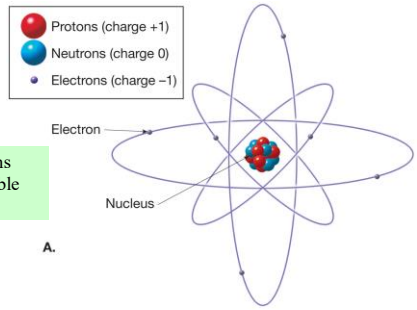
Absolute Dating

- Absolute age dating assigns actual dates (in years before the present) to rocks or geological events
- Used to construct the Geologic Time Scale
- Utilizes radiometric dating techniques



1

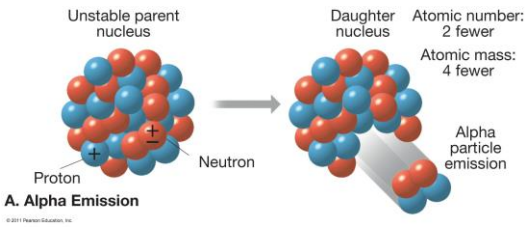
Protons and Neutrons in Nucleus of Atoms



Most atoms have a stable nucleus

2

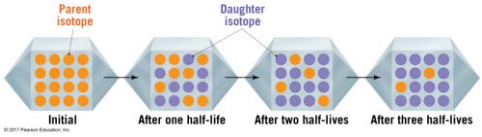
A Radioactive Element Has An Unstable Nucleus



Unstable nucleus decays to a more stable form and becomes a new element in the process

3

Radioactive Decay



- Parent is the original unstable radioactive isotope
- Daughter is the new, more stable isotope formed as a result of radioactive decay of parent
- Over time, unstable parent isotopes decay to more stable daughter isotopes at a rate measured in half lives

4

Types of Radioactive Decay

- **Alpha emission**
- **Beta emission**
- **Electron capture**

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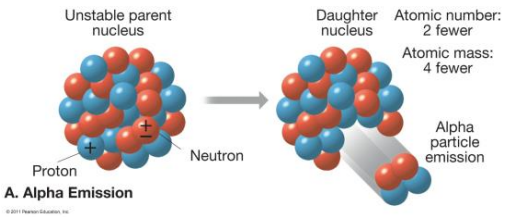
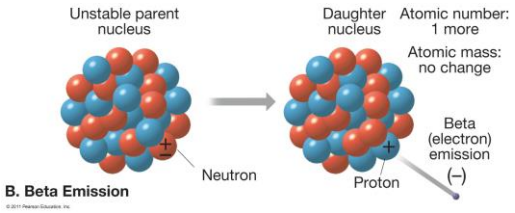


Alpha emission results in loss of 2 protons and 2 neutrons:
- Atomic number decreases by two
- Atomic mass decreases by four

6



Beta emission changes a neutron into a proton:
- Atomic number increases by one
- No change in the atomic mass

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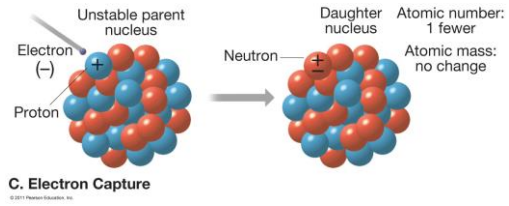
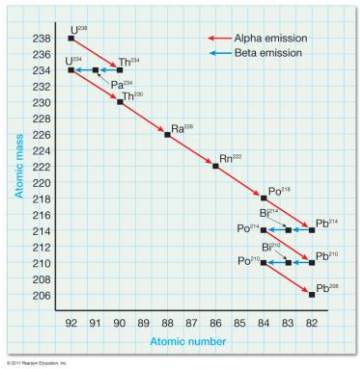


Electron capture changes a proton into a neutron:
- Atomic number decreases by one
- No change in the atomic mass

8

Radioactive decay series for ^{238}U

When uranium-238 decays, a series of intermediate daughter isotopes form and undergo further decay until ultimately stable lead-206 results



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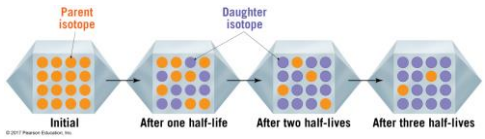
Half Life



Half life is the time required for half the number of radioactive nuclei in a sample to decay to a new element

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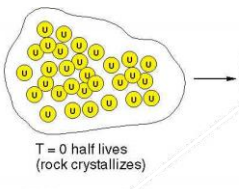

Initially-crystallized minerals in a rock incorporate radioactive isotope (U) with a half-life of 1 billion years

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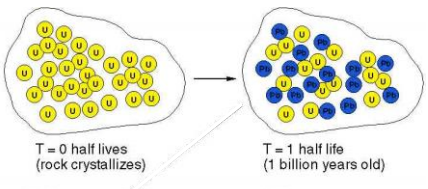

After one half-life, 50% of the original unstable isotopes have decayed to daughter isotopes: The rock is 1 billion years old

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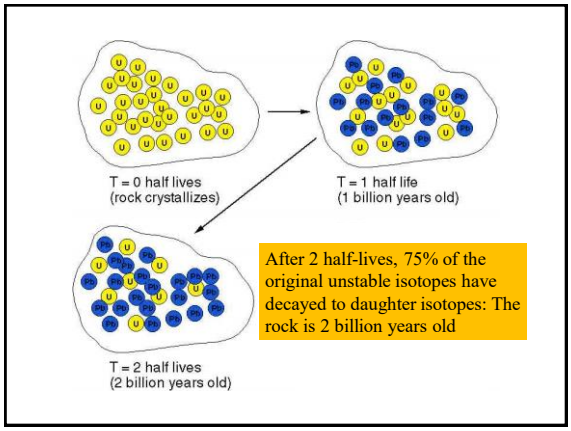

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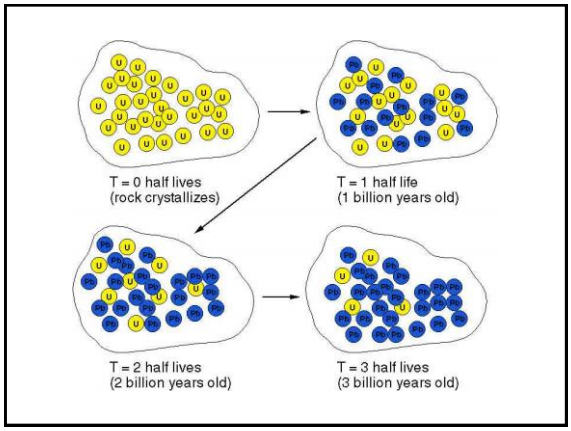

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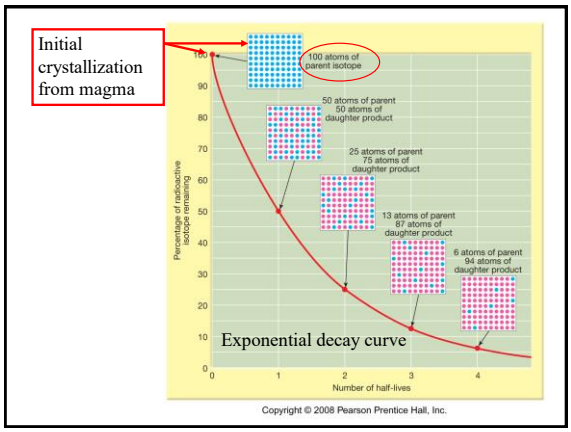

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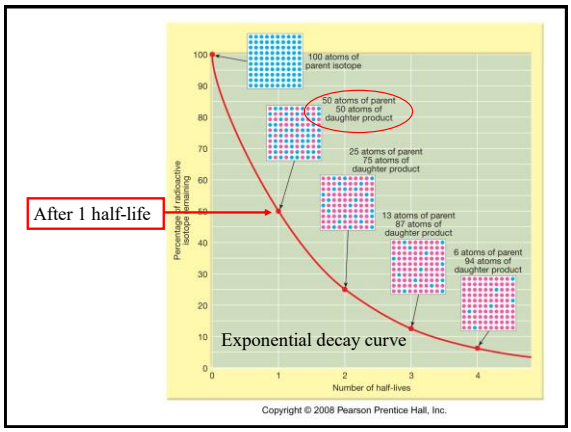

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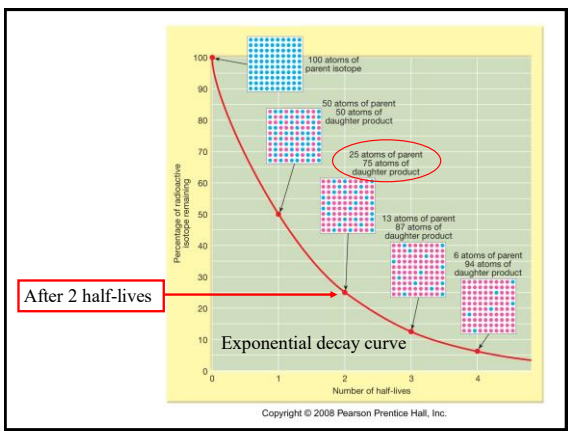

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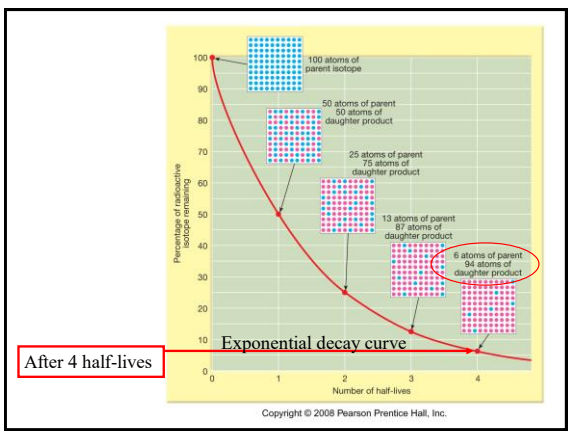

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TABLE 9.1 Isotopes Frequently Used in Radiometric Dating

Radioactive Parent	Stable Daughter Product	Currently Accepted Half-Life Values
Uranium-238	Lead-206	4.5 billion years
Uranium-235	Lead-207	704 million years
Thorium-232	Lead-208	14.1 billion years
Rubidium-87	Strontium-87	47.0 billion years
Potassium-40	Argon-40	1.3 billion years

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Radiometric Dating

- If the following are known:
  - Half life of the isotope being measured
  - Parent/daughter ratio in the sample
- Then the age of the sample can be calculated

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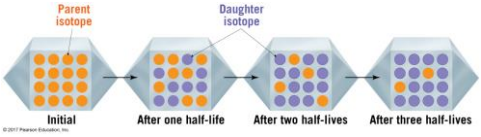
What is the age of a sample if the half-life is 5 million years and the…

- Parent:Daughter ratio is 1:1?
- 25% Parent & 75%Daughter?
- After four half-lives?

- 5 million years
- 10 million years
- 20 million years



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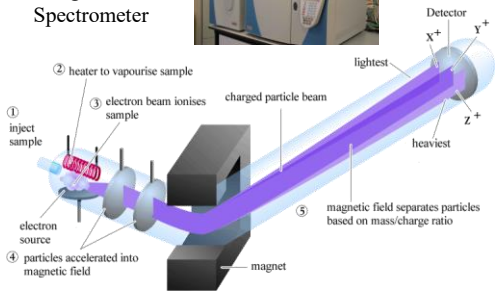
Parent/Daughter Ratios Measured Using A Mass Spectrometer



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Resetting Isotopic Ages

The isotopic clock can be reset by metamorphism when temperatures become high enough for daughter isotopes to escape the minerals where they accumulated

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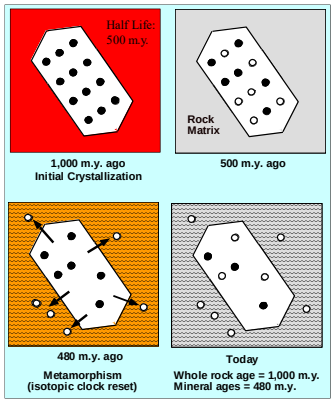

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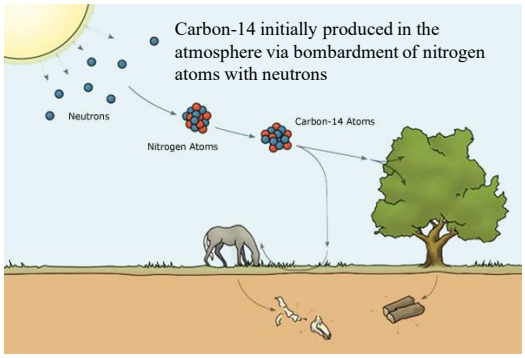

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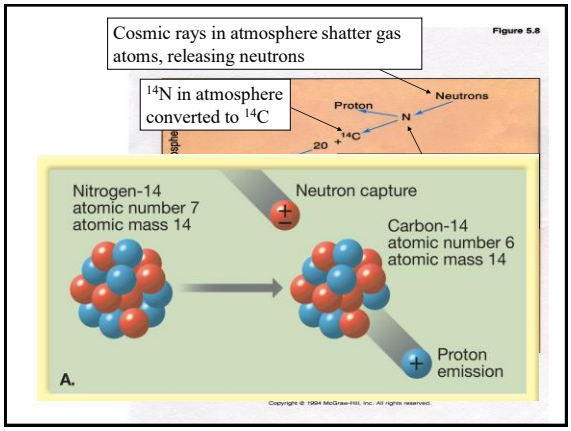

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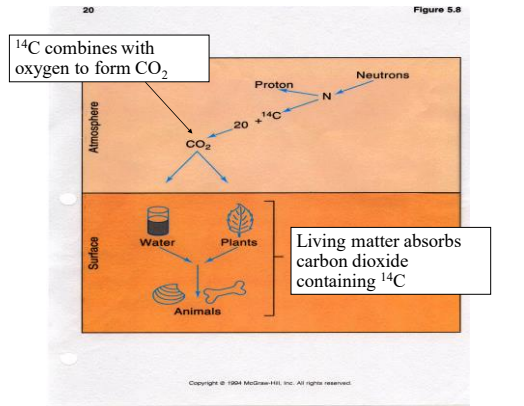

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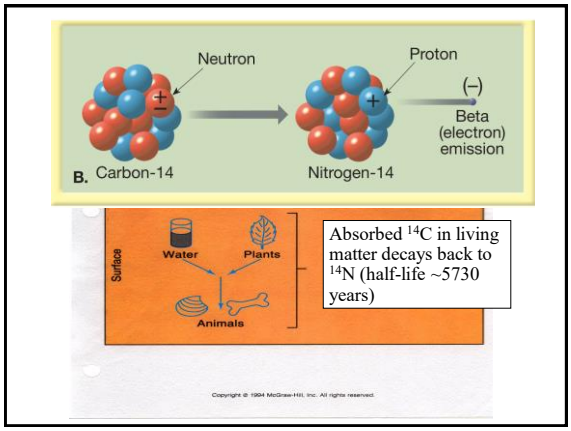

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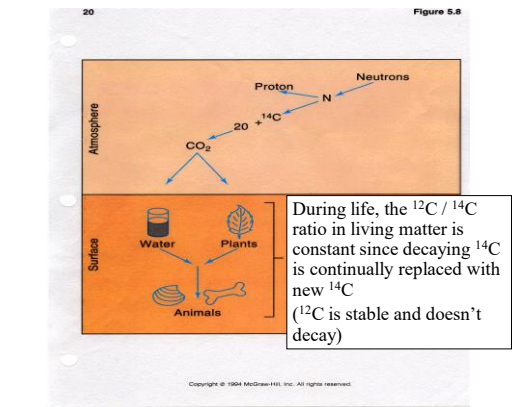

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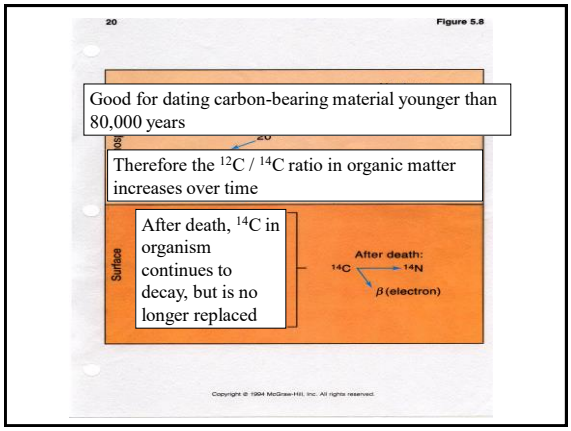

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Isotopic Dating of Igneous Rocks

- Igneous rocks can provide an approximate crystallization age using whole rock analysis
- Minerals also provide a crystallization age provided the rock has not experienced subsequent metamorphism

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Isotopic Dating of Metamorphic Rocks

- Minerals in a metamorphic rock can provide an age for the last metamorphic event
- If the rock experienced more than one episode of metamorphism, then usually only the most recent event can be dated

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Isotopic Dating of Sedimentary Rocks?

- In general, detrital (clastic) sedimentary rocks do not give meaningful ages because the minerals contained in these rocks were derived from other sources (parent rocks):
  - Clastic minerals in detrital sedimentary rocks only provide the age(s) of their parent source rocks
  - These ages do not reflect the time of sedimentation
- Multiple parent rocks of different ages can contribute sediment into the same basin:
  - This mixture of different ages in basin is meaningless

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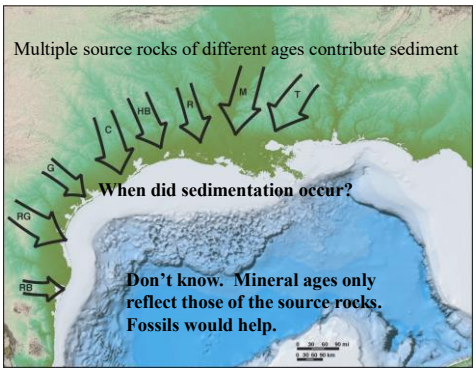

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Isotopic Dating of Sedimentary Rocks?

Isotopic dating of a sedimentary rock is possible if it contains authigenic minerals or material (e.g. glauconite, K-feldspar, organic matter) that formed during burial and diagenesis in the sedimentary basin

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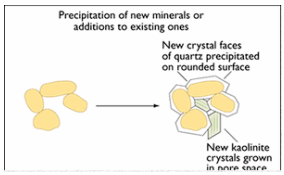
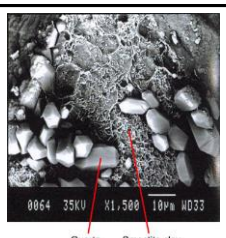
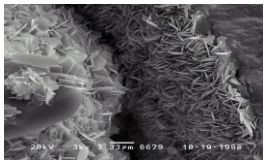
Authigenic Minerals Form In Pore Spaces During Sediment Burial







Authigenic clay minerals can date the time of sediment burial

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Bracketing the Ages of Sedimentary Rocks

The ages of sedimentary rock packages can be bracketed by dating underlying and overlying igneous and metamorphic rocks, interlayered volcanic ash deposits and cross-cutting igneous dikes.

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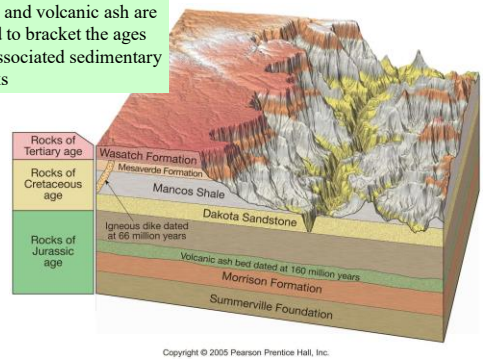
Known ages of igneous dike and volcanic ash are used to bracket the ages of associated sedimentary rocks



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Dating With Radioactivity

- **Importance of radiometric dating:**
  - **Radiometric dating is a complex procedure that requires precise measurement**
  - **Rocks from several localities have been dated at more than 3 billion years**
  - **Confirms the idea that geologic time is immense**

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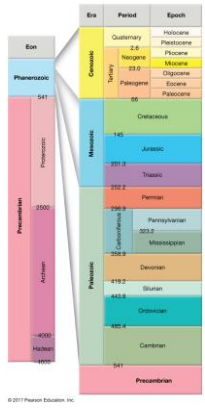
The Geologic Time Scale

The Geologic Time Scale – a "calendar" of Earth history:

- Subdivides geologic history into units
- Originally created using relative dating
- Absolute dates assigned later after the discovery of radioactivity in 1896



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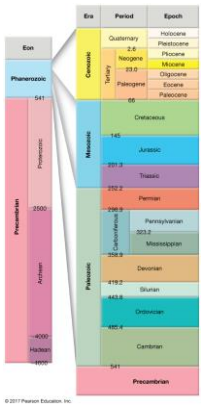
The Geologic Time Scale

Geologic Time Scale is subdivided into various units of time:

- Eons (largest divisions)
- Eras
- Periods
- Epochs (smallest divisions)



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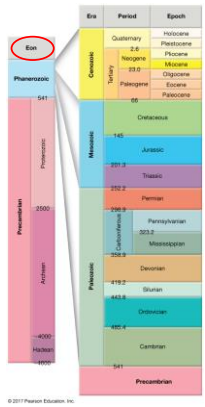
The Geologic Time Scale

Eons constitute the largest divisions:

- Phanerozoic ("visible life"), most recent Eon, began about 541 million years ago and continues to present
- Proterozoic (2500 – 541 m.y. ago)
- Archean (4000 - 2500 m.y. ago)
- Hadean – oldest (4600 - 4000 m.y. ago)



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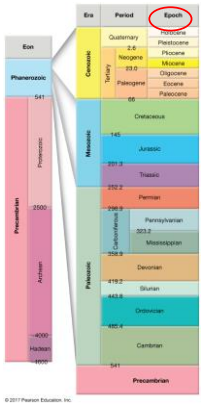
The Geologic Time Scale

- Eons subdivided into Eras
- Eras of the Phanerozoic Eon:
  - Cenozoic ("recent life")
  - Mesozoic ("middle life")
  - Paleozoic ("ancient life")
- Eras are divided into Periods
- Periods are divided into Epochs
- Time divisions are in millions of years



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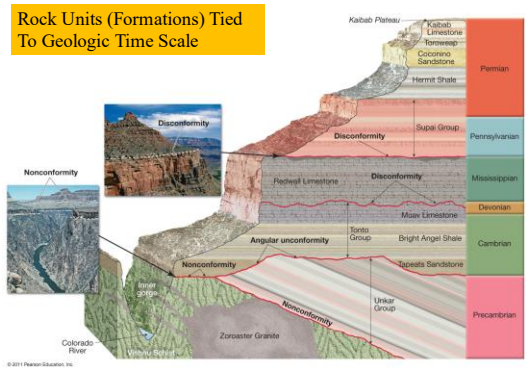
Rock Units (Formations) Tied To Geologic Time Scale



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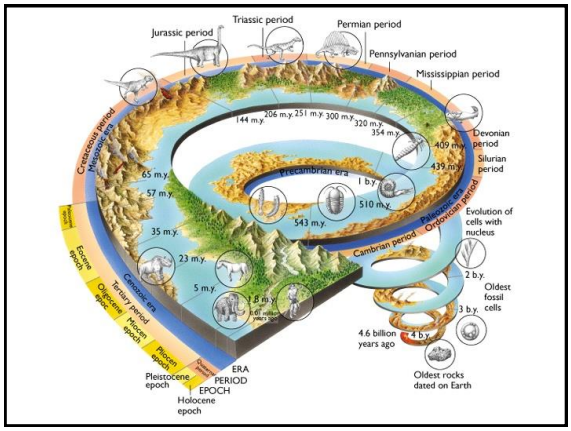

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