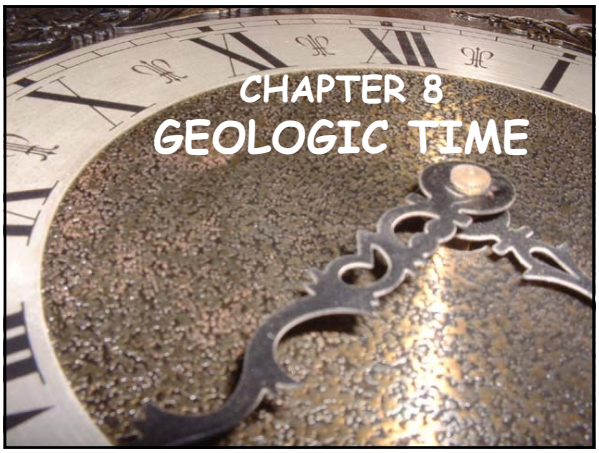
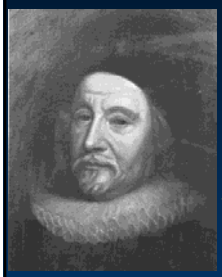


Time - indicated by change

- We are aware of changes in daily life

Day and Night
The passage of seasons

Age of the Earth



Bishop Ussher (1581-1656)

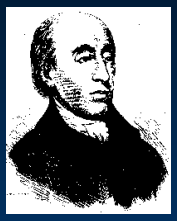
Used historical content of scriptures to estimate Earth's Age

Concluded Earth is ~6000 Years old

Catastrophism - Noah's flood

Age of the Earth

James Hutton (1726-1797) postulated a very old Earth



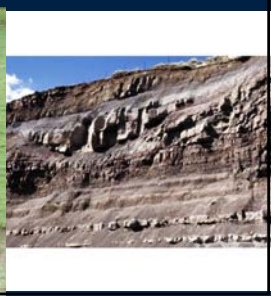
"..that we find no vestige of a beginning, no prospect of an end."

James Hutton: Theory of the Earth (1795)

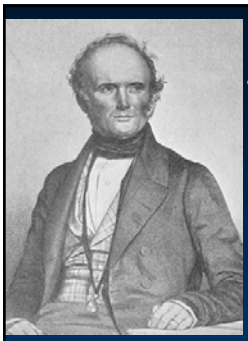
Uniformitarianism

"The present is the key to the past"

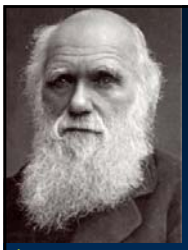
- Laws of nature don't change with time
- Past events explained and estimated by modern processes

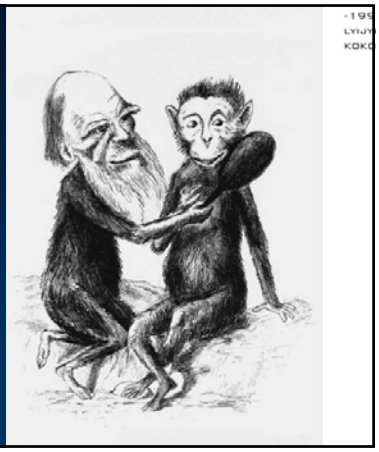


Uniformitarianism



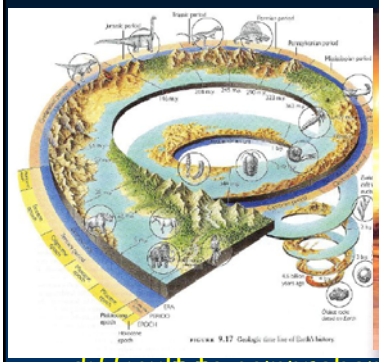
- Charles Lyell (1797-1875) implemented and popularized Hutton's principle

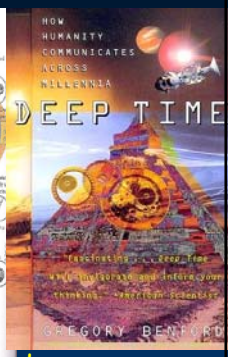




-Darwin accepted uniformitarianism in developing theory on the origin of species

Geology - Deep Time





- difficult to comprehend

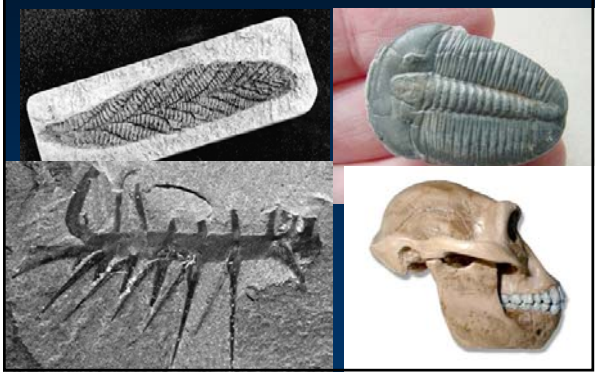
Uniformitarianism

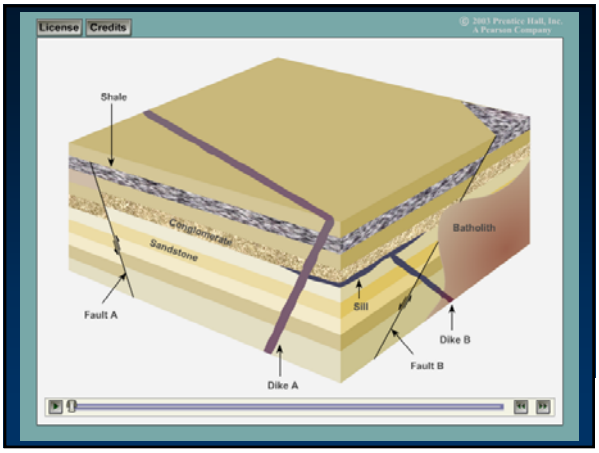
- The rock record preserves a history of past geologic events

- chang
Geologic t

Uniformitarianism

Fossils record evolution of life on Earth

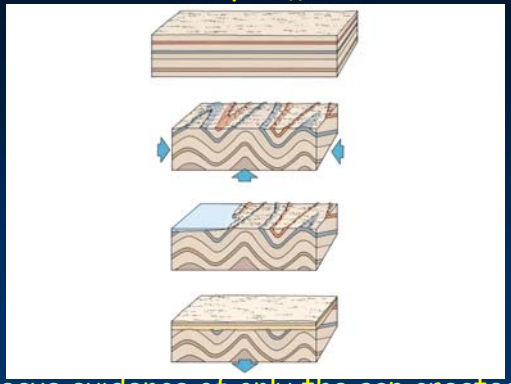




Unconformities

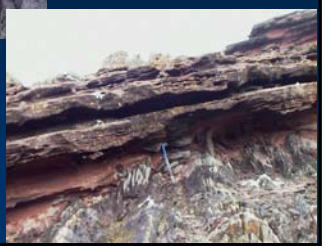
- Sequences of rock contain gaps

Unconformities



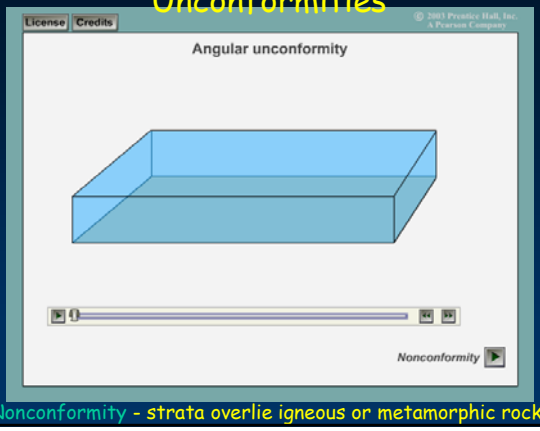
Leave evidence of only the gap created

Unconformity at Siccar Point, Scotland

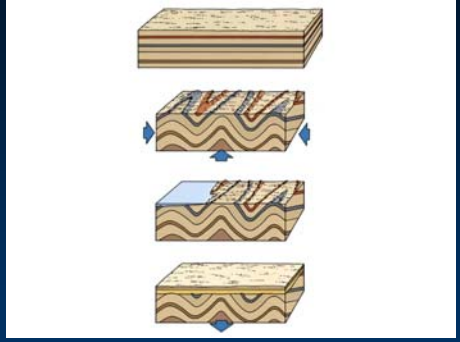


Photos courtesy of M. Noll

Unconformities

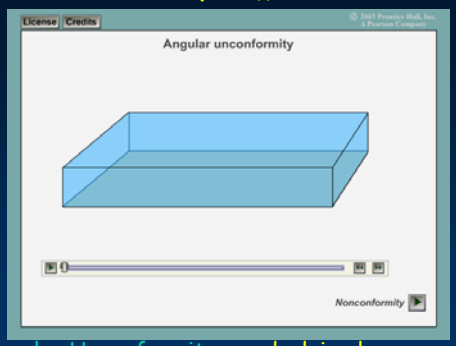


Nonconformity - strata overlie igneous or metamorphic rocks



Development of an angular unconfomity

Unconformities



Angular Unconformity - underlying layers are not parallel to the strata above

Unconformities

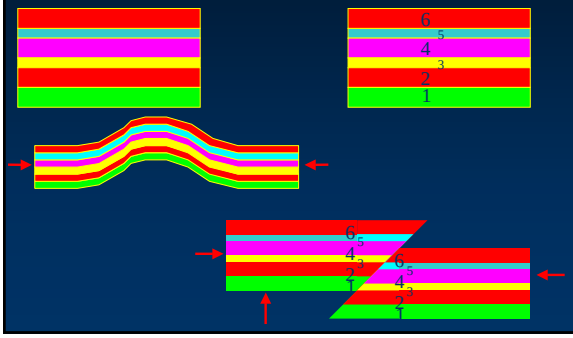
Disconformity - a period of erosion separates episodes of deposition

Relative Ages

- Reading the Rock Record
  - Stratigraphy

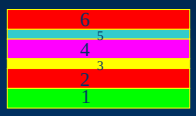
Original Horizontality

- Order to sedimentation
- Inclined or folded strata have been disturbed



Superposition

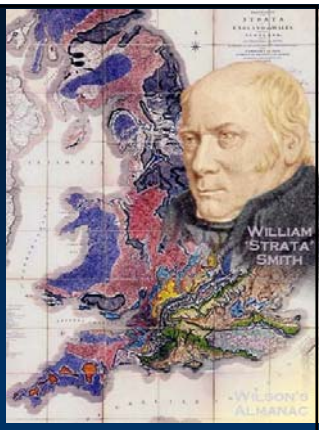
- youngest layer on top, oldest layer at bottom
- Relative age may be determined by stratigraphic order, or sequence



Faunal Succession

Index fossils

- Groups of plant & animal fossils define chronological order
- Theory developed by William "Strata" Smith before Darwin



Faunal Succession

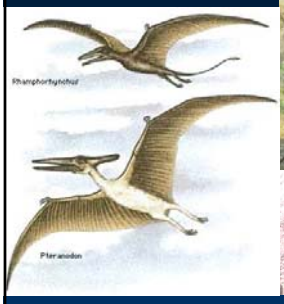
Precambrian Eon

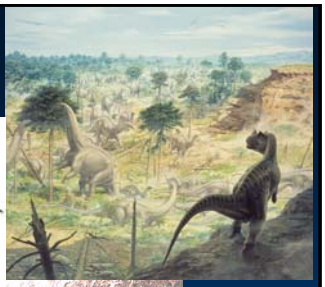
Faunal Succession

Phanerozoic Eon

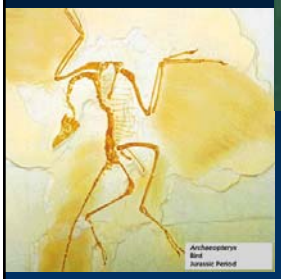
Paleozoic Era

Faunal Succession
Phanerozoic Eon
Mesozoic Era



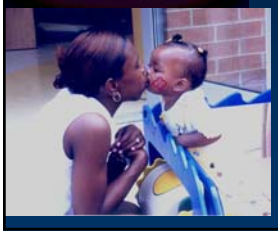



Faunal Succession
Phanerozoic Eon
Mesozoic Era

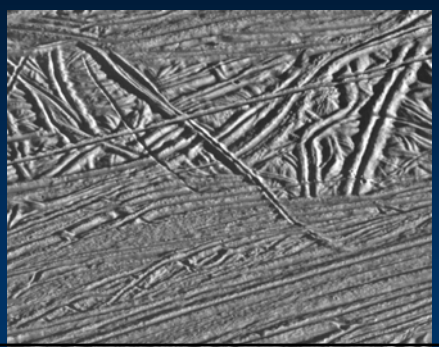


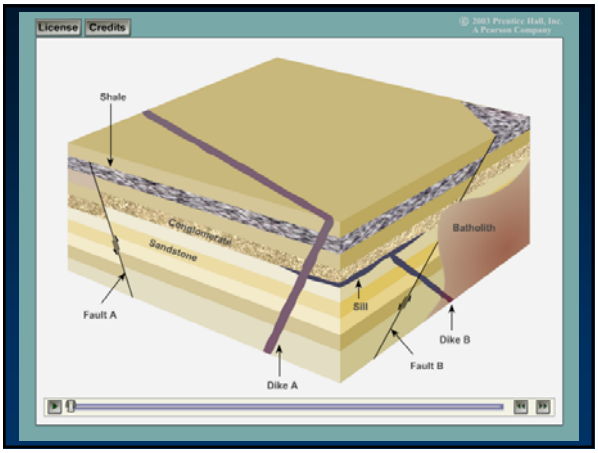

Faunal Succession
Phanerozoic Eon
Cenozoic Era


Faunal Succession
Phanerozoic Eon
Cenozoic Era


Crosscutting Relationships
- Igneous rock bodies and geologic structures may cut through pre-existing formations



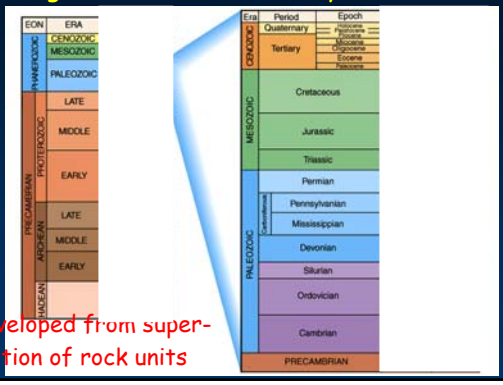


Inclusions

- Older rock fragments (Clastics) included in newer rock
  - Conglomerates contain older pebbles

Geologic Time Scale

- Age correlations made by fossils



-developed from super-position of rock units

Absolute Ages

- Age of rocks in calendar years
- Requires internal "clock"

- Early attempts at Absolute age of Earth
  - -Accumulation of sediments
  - -Concentration of sea salt
  - -Cooling of the Earth

Radiometric Age Dating

- Radioactivity - One element undergoes irreversible transformation to another element
- Nuclear reactions
- Isotope
  - Atoms of the same element having different masses

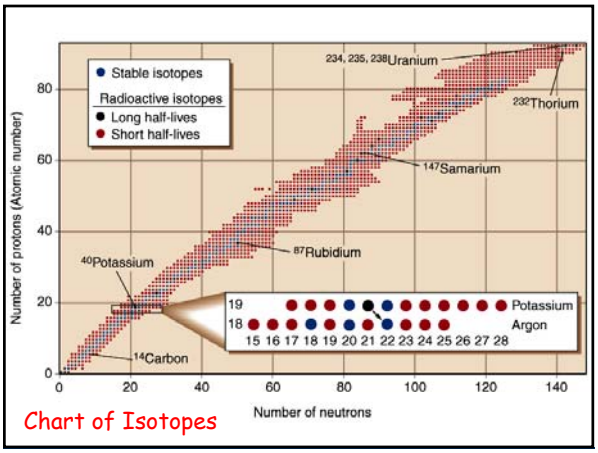


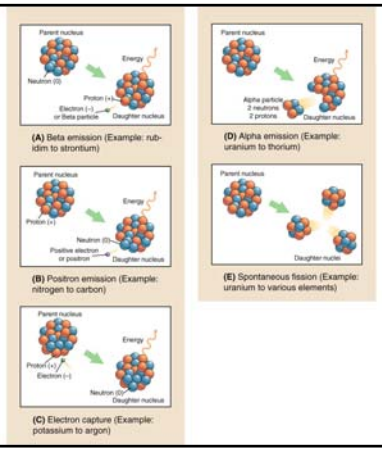
Chart of Isotopes

- Two types of isotopes
  - Stable - Nucleus does not spontaneously undergo change
  - Radioactive - Nucleus is unstable and will undergo spontaneous change at a constant rate
  - Isotopes of Potassium (K)

Isotope	P	N	Nat. Abundance	Half Life
$_{19}K^{39}$	19	20	93.26%	stable
$_{19}K^{40}$	19	21	0.01%	1.28 billion years
$_{19}K^{41}$	19	22	6.73%	stable

Radioactive Decay

- Atoms may spontaneously change into another element
  - Parent isotope -> daughter isotope
  - Ratio of parent to daughter determines age



Radioactive Decay

- Half-life
  - Rate of change
  - Time required for one half of the original mass of an isotope to undergo radioactive decay

Radiometric Dating

- Ratio of parent to daughter isotopes provides age of rock units

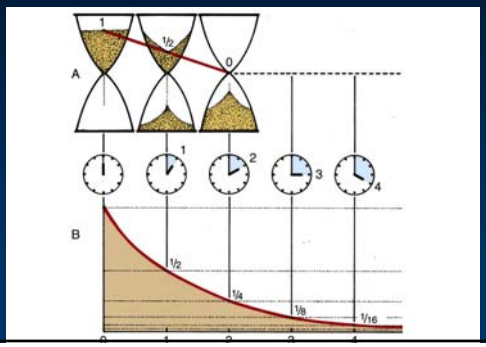
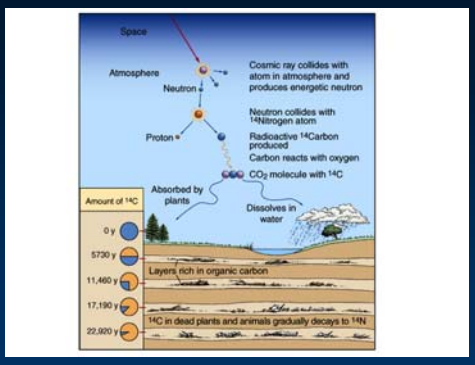


TABLE 8.1 Radioactive Isotopes Commonly Used in Radiometric Dating

Parent Isotope	Daughter Isotope	Half-life (years)
Uranium-238	Lead-206	4.5 billion
Uranium-235	Lead-207	704 million
Thorium-232	Lead-208	14.0 billion
Samarium-147	Neodymium-143	106 billion
Rubidium-87	Strontium-87	48.8 billion
Potassium-40	Argon-40	1.25 billion
Carbon-14	Nitrogen-14	5,730
Hydrogen-3	Helium-3	12.3

Radiometric Dating

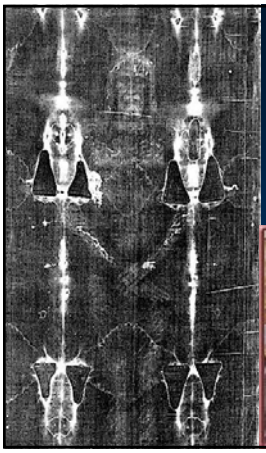
- Radiocarbon
  - ^{14}C is produced by neutron capture induced by cosmic rays hitting the Earth
  - It decays by beta emission to ^{14}N
  - Half-Life = 5730 y
  - Effective dating range of 100 to 70,000 y



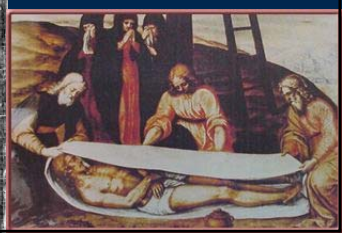
Carbon-14 radiometric clock

Problems with Radiometric Dating

- low concentrations/ratios of isotopes
- Open vs. closed chemical systems
- Inappropriate materials for dating

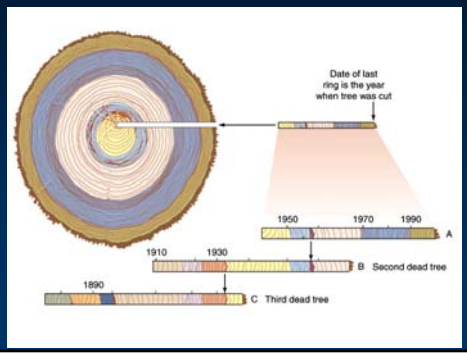


The Shroud of Turin
Case-study in Radiocarbon dating



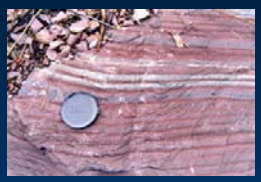
Other Dating Methods

- Tree rings



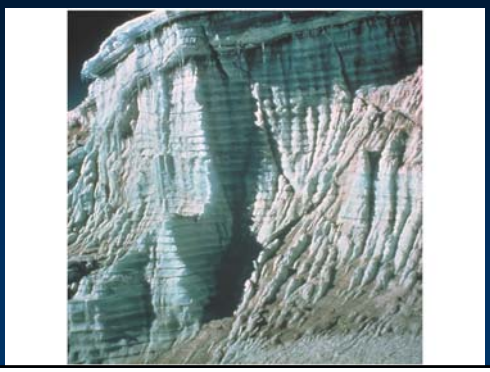
Other Dating Methods

- Varves
  - Rhythmic changes in sedimentary environment
  - Alternating thin layers of light and dark clays



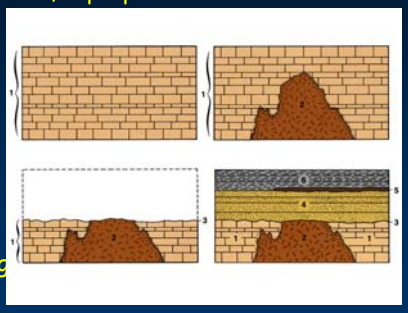
Other Dating Methods

- Ice Layers
  - Thin layers of ice formed by annual snow fall



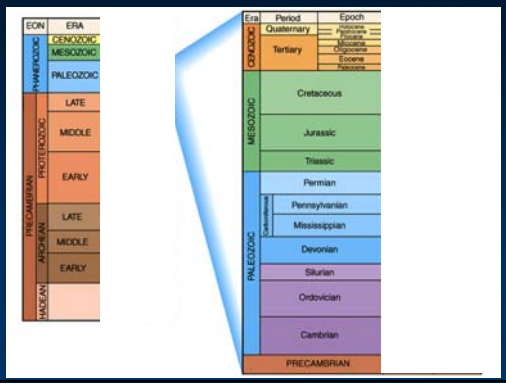
Calibration of Geologic Time Scale

- relative age dating methods
  fossils, superposition

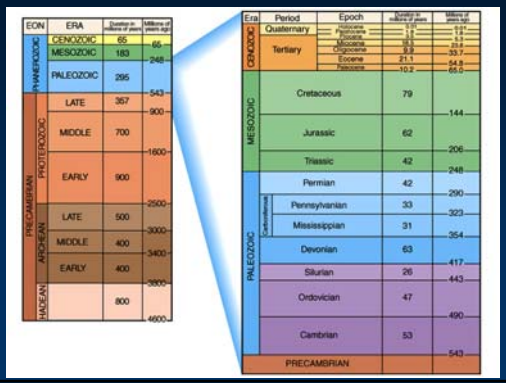


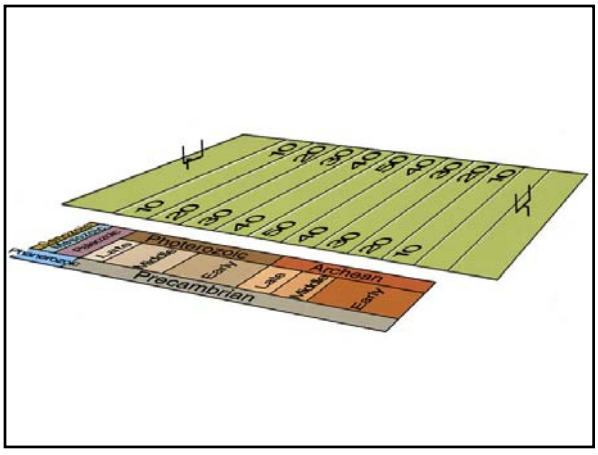
- Ag

The Fossil record and superposition provides relative Age of rock units



Radiometric age-dating calibrates, or quantifies, the age of Rock units.





The Magnitude of Geologic Time

- Earth History condensed to 1 year
  - Jan 1, 12:00:01 - Earth is formed
  - March 15 - Oldest remaining rocks
  - May - One celled organisms, algae first appear in the oceans
  - November (Thanksgiving) - First land plants and animals appear

The Magnitude of Geologic Time

- December 6-9 - Widespread swamps form coal deposits during the Pennsylvanian Period (320 to 286 million years ago)
- Dec 12-26 - Dinosaurs dominate (Mesozoic)
- Dec 31, ~5:00pm - first man-like creatures
- Dec 31, 11:58:45 - ice sheets retreat from the Great Lakes area

The Magnitude of Geologic Time

- Dec 31, 11:59:45 to 11:59:50 - Roman Empire
- Dec 31, 11:59:57 - Columbus discovers America
- Dec 31, 11:59:58.5 - Declaration of Independence is signed

End of Chapter 8