Geology and Art, Fall 2004
Introduction & Geologic Time II, Lecture 2
Dynamic Earth, Chapter

Skinner, B. J., Porter, S. C., and Park, J., 2004, *Dynamic Earth, An Introduction to Physical Geology*: John Wiley & Sons. (ISBN 0-471-15228-5)

Geologic Ages (Dating)

Relative Age: the order in which a sequence of past events occurred. It does not describe how long ago or the interval between events. Prior to radiometric methods, relative time was the only method of assigning ages.

Determining Relative Age (review) – tools for identifying relative age relationships

- Law of original horizontality
- Principle of stratigraphic superposition
- Cross-cutting relationships: any intrusive rock or fault must be younger than the rock it cuts through
- Inclusions: fragments of other rocks contained within a body of rock must be older than the host rock
- Fossils and faunal succession: the animals and plants on Earth have changed in a definite order through time (from simple to complex forms), by relating fossils in rock with faunal succession, relative ages can be defined
- Unconformities: (temporal) gaps in the rock record which reflect no deposition or periods of erosion (removal); an unconformity is a contact between rocks of two different ages – angular unconformitites, disconformities, nonconformities

Absolute (Numerical) Age: a quantitative determination of the age of a rock is made (radiogenic isotopes)

Prior to the 20th century attempts had been made to calculate the age of the Earth based on sedimentation rates, salt content of the ocean, and cooling of the Earth but it wasn't until radioactivity was discovered in 1896 that a process that runs continuously, is not reversible, is not influenced by other processes, and leaves a continuous record was identified.

"Radioactitiy" was discovered by Henri Becquerel, Marie Curie, and Pierre Curie around the turn of the century. They won the Nobel Prize in physics in 1903.

Determining Absolute Time

As early at 1905 Ernest Rutherford suggested that the ages of uranium minerals could be determined by measuring the amount of He that had accumulated in them (He is a decay product).

Development of radiometric age dating started in the 1930's (He method) but the first accurate dates were not determined until the 1950s.

Radioactive isotopes decay from parent isotope to daughter isotope

Isotope: same number of protons, different number of neutrons. The number of protons defines the element, the number of neutrons defines the isotope.

Stable Isotopes: are stable and do not decay

Unstable Isotopes: are unstable and spontaneously decay at a constant rate (parent to daughter). For example ^{14}C decays to ^{14}N

The decay rate is not affected by physical or chemical changes

Radiometric dating

The constant decay rate of an isotope can be used to record time if the parent and daughter isotopes remain immobile; this frequently occurs when the parent is incorporated in the structure of a mineral

$P = P_0 e^{-\lambda t}$ — P = present amount of parent isotope

$P_0 = P e^{\lambda t}$ — P_0 = initial amount of parent isotope

λ = decay constant (specific to the isotope)

t = time since the daughter started to accumulate

e = base of the natural logarithm (2.71828…)

$D^* = P_0 - P$

$D^* = Pe^{\lambda t} - P = P(e^{\lambda t} - 1)$

D^* = daughter isotope produced since time t

if there is some of the daughter isotope present initially:

$D = D_0 + D^*$

$D = D_0 + P(e^{\lambda t} - 1)$

to solve for t:

$t = (1/\lambda) \ln((D - D_0)/P + 1)$

Half-life: the time required for one half a given amount of parent isotope will decay to its daughter.

$t = (1/\lambda) \ln((D/P + 1)$

$t = (1/\lambda) \ln((1/1 + 1)$

uranium has two important unstable isotopes: ^{238}U and ^{235}U

decay constants (λ): $^{238}U = 1.55125\text{x}10^{-10}$ years^{-1} (99.2743%)

$^{235}U = 9.8485\text{x}10^{-10}$ years^{-1} (0.0057%)

$t = (1/1.55125\text{x}10^{-10} \text{ years}^{-1}) \ln(2) = 4.457\text{x}10^{9}$ years

$t = (1/9.8485\text{x}10^{-10} \text{ years}^{-1}) \ln(2) = 7.038\text{x}10^{8}$ years

Mass spectrometers are used to determine the concentrations of the parent and daughter isotopes in a sample (pg)

Problems that must be considered:

- What are you dating?
- How much daughter was in the mineral to begin with?

- Was any parent or daughter lost due to diffusion?
- Is the dating method reasonable for the sample?

	λ	$T_{0.5}$
^{238}U decays to ^{206}Pb	$1.55125x10^{-10}$ years^{-1}	4.5 billion
^{235}U decays to ^{207}Pb	$9.8485x10^{-10}$ years^{-1}	713 million
^{232}Th decays to ^{208}Pb	$4.95x10^{-11}$ years^{-1}	14.1 billion
^{87}Rb decays to ^{87}Sr	$1.42x10^{-11}$ years^{-1}	48.8 billion
^{40}K decays to ^{40}Ar	$0.585x10^{-10}$ years^{-1}	1.25 billion
^{147}Sm decays to ^{143}Nd	$6.54x10^{-12}$ years^{-1}	106 billion