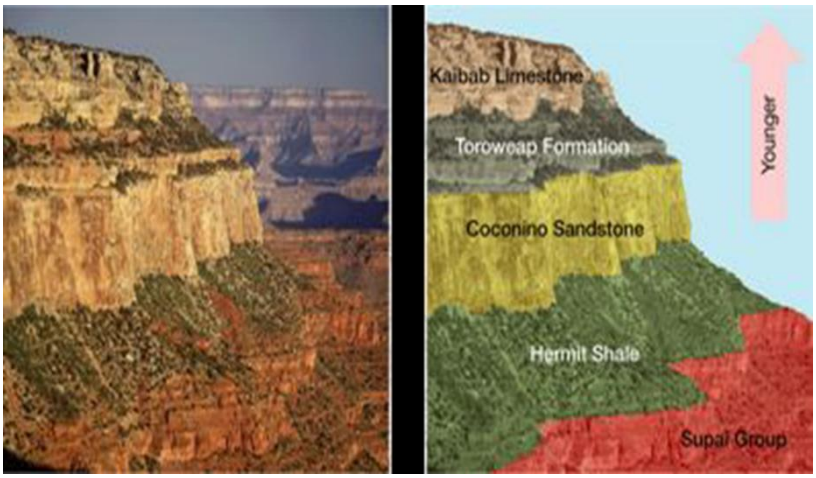
TOPIC 7: INTERPRETING GEOLOGIC HISTORY
Workbook chapter 6

Relative Dating of Geologic Events

Relative dating is the determination of the age of a rock or event in relation to the age of other rocks or events. Relative dating places events in sequential order, from oldest to youngest. In doing so, there are principles or laws that are applied.

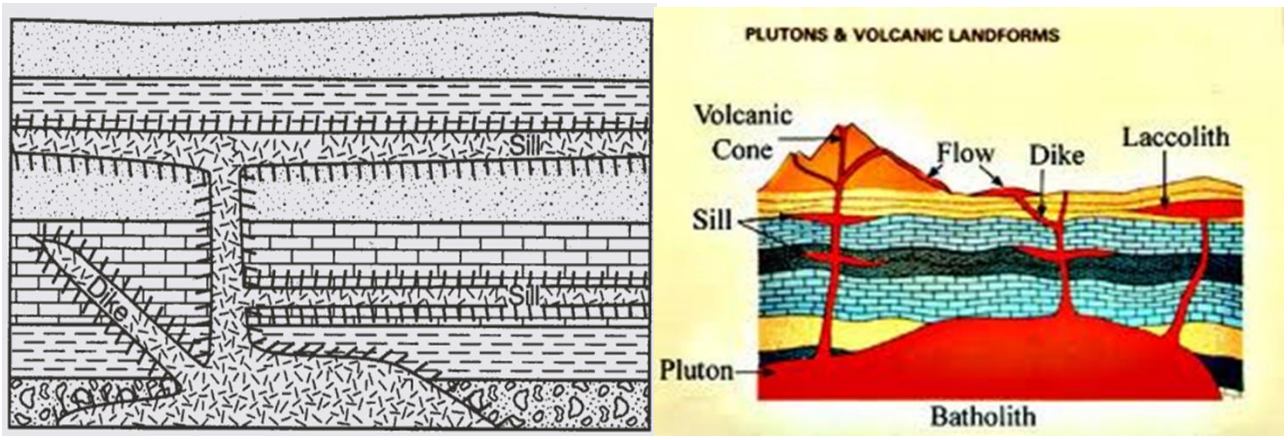
1. **Uniformity of Process**: geologic processes that happen today also occurred in the past. In this way, geologic history can be interpreted using present observations. **Uniformity of process** states that the chemical, physical, geological, and biological characteristics of nature remain the same throughout time.

2. **Law of Superposition:** Younger sedimentary rock layers are deposited on top of older layers. Therefore the rock layers on top are younger than those on the bottom.



3. **Law of Original Horizontality:** Sedimentary rock originally forms when sediment is deposited in flat, horizontal layers over many years. Folding or faulting, that changes this horizontality, must have occurred **after** the sedimentary rock was deposited.

4. **Rule of Cross-Cutting Relationships:** A geologic feature that cuts through other geologic units is younger than those units. The cutting feature may be an igneous intrusion.



Igneous intrusion causing contact metamorphism

An extrusion forms when lava flows on earth's surface and solidifies. An extrusion is always younger than any of the rocks below it:

In summary: All cross-cutting relationships are younger than the rocks they cut across. A rock is older than any fault, joint, tilting, vein, or intrusion that appears in it.

FOSSILS

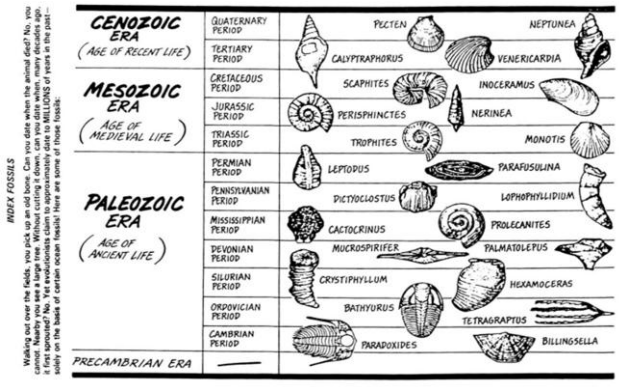
A **fossil** is a remnant or trace of an ancient organism that has been preserved in sedimentary rock.

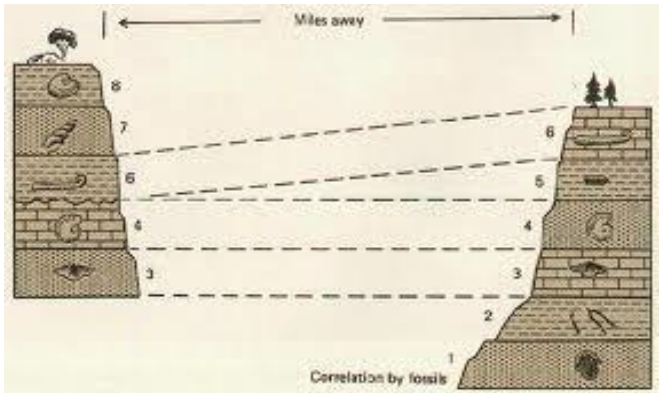
<u>Body Fossils</u> are whole bodies or pieces of a once living organism. **Examples**: frozen wooly mammoth, bones, teeth, insect in amber, shells, petrified wood

<u>Trace Fossils</u>: preserved evidence of the biological activity of an organism.
Examples: resting or hiding traces (burrows), traces of locomotion (footprint)

INDEX FOSSILS

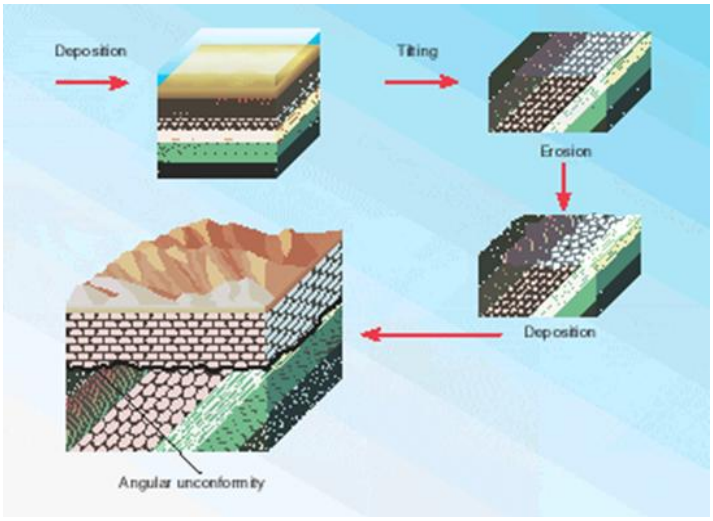
For the fossil remains of a particular type of organism to be considered an index fossil, **it must have lived over a wide geographical area and must have existed for a relatively short period of time.** Index fossils are used to correlate or match sedimentary rock layers from the same time period.

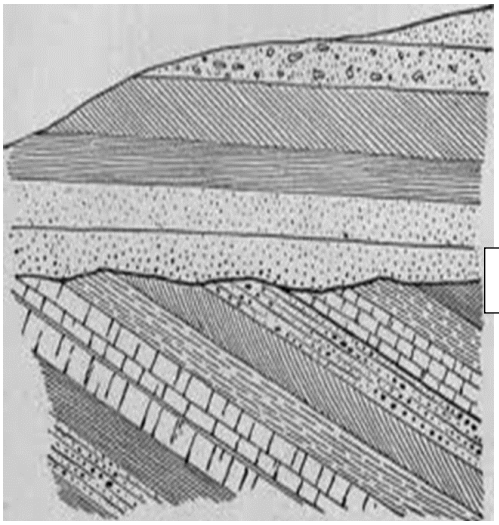




<u>UNCONFORMITIES</u>

An unconformity occurs when uplift causes bedrock to weather and erode, **removing part of the rock record**. When new sediments are deposited on top of the eroded surface, and unconformity is made.

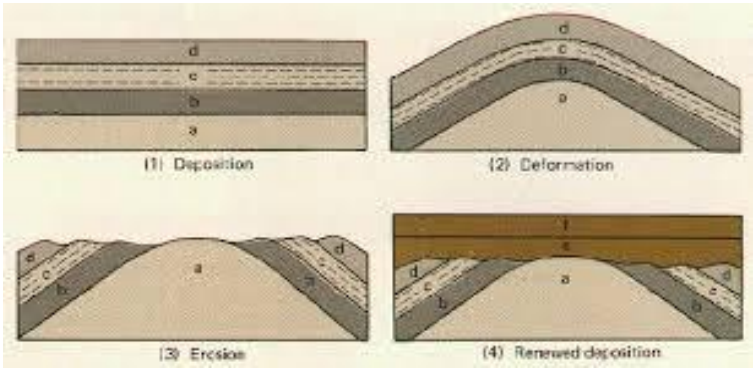




<-unconformity

Dating Unconformities

Rocks above an unconformity are always much younger than the rocks below an unconformity. Unconformities usually correlate with times of mountain building, called **orogenies.** An unconformity can help a geologist gauge the age of the rocks above and below it, as well as the general time of the unconformity itself.



Geologic History from the Rock Record

Geologists have divided geologic time into divisions based on fossil evidence. These divisions of time are called eons, eras, periods, and epochs, and create a geologic timescale.

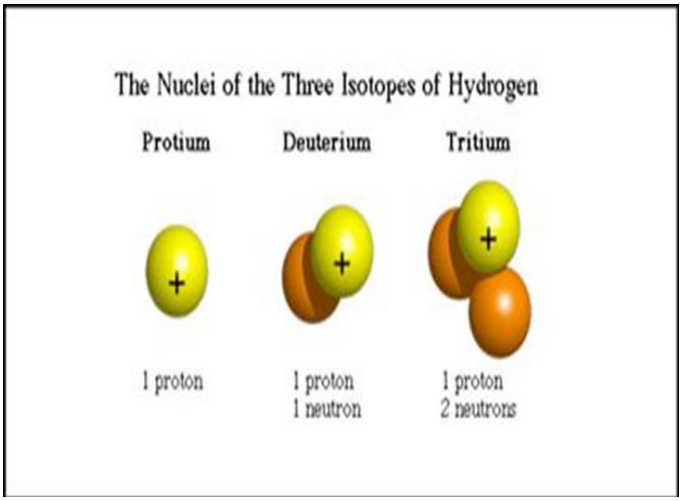
EON	ERA	PERIOD	MILLIONS OF YEARS AGO
Phanerozoic	Cenozoic	Quaternary	1.6
		Tertiary	66
	Mesozoic	Cretaceous	138
		Jurassic	205
		Triassic	240
	Paleozoic	Permian	290
		Pennsylvanian	330
		Mississippian	360
		Devonian	410
		Silurian	435
		Ordovician	500
		Cambrian	570
Proterozoic	Late Proterozoic Middle Proterozoic Early Proterozoic		2500
Archean	Late Archean Middle Archean Early Archean		3800?
Pre-Archean			

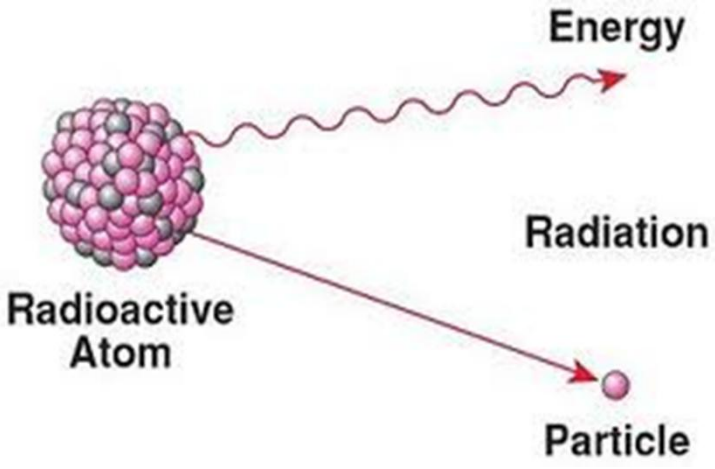
ABSOLUTE DATING

The principles of superposition, original horizontality, etc., help determine the relative age of rock. **Absolute dating**, which involves radioactive dating, provides a more exact rock age.

Isotopes

Most elements exist in several varieties called isotopes. Isotopes of an element have different atomic masses. Many isotopes are unstable. In order to become stable, atoms of these isotopes emit particles and/or electromagnetic energy in a process called radioactive decay.

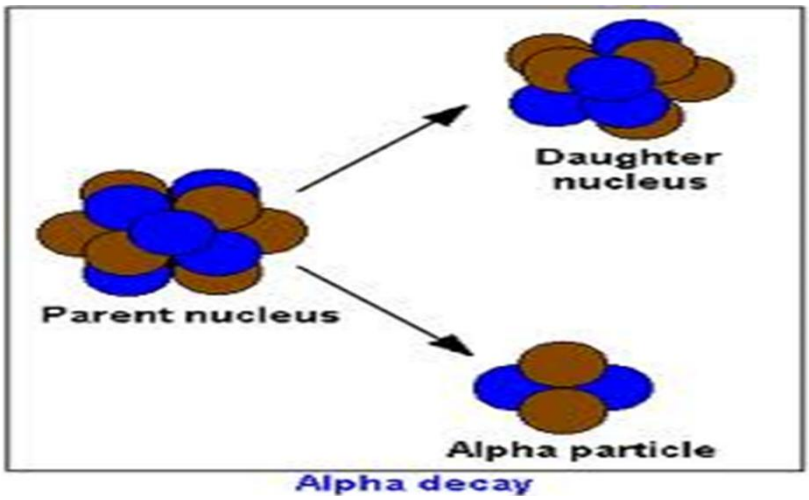




Radioactive Decay

When the **unstable, parent isotope** emits particles and/or energy, it becomes a **more stable, daughter isotope.** For example, when unstable rubidium-87 undergoes radioactive decay, it forms stable strontium-87.

Potassium 40 →Argon 40
Uranium 238 → Lead 206 (See ESRT)



Alpha decay

Half-Life

A **half-life** is the time required for half of the atoms in a given mass of a radioactive isotope to decay into its daughter isotope.

Ex: the half-life of Uranium-238 (U-238) = 4.5 billion years
After 4.5 billion years, half of the U-238 atoms will decay into Lead-206 (Pb-206) and the rest will remain U-238.

After 9 billion years (2 half-lives), half of the remaining radioactive U-238 atoms will have decayed into Pb-206, leaving one-fourth of the original U-238 atoms unchanged.

PROBLEM:

Your guardian has just made 24 of your favorite cookies. She is allowing you to eat half of the cookies in the cookie jar every three days. How long will it take for only 3 cookies to remain in the cookie jar?

After 3 days: 12 cookies left
After 6 days: 6 cookies left
After 9 days: 3 cookies left

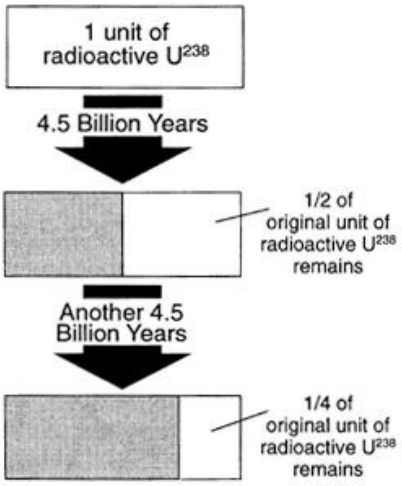
Answer: 9 days

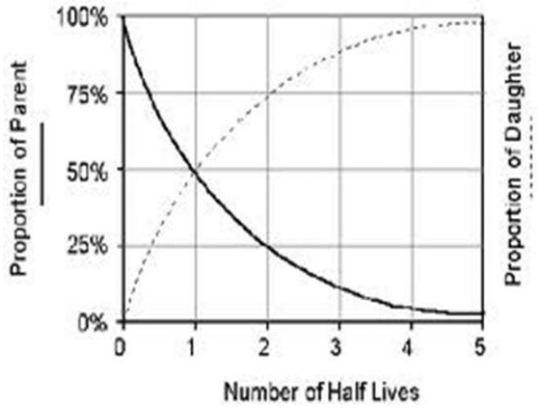
Cookie half-life: 3 days; stable daughter isotope: digested cookies!

Radioactive Dating

By comparing the amount of the radioactive parent isotope with the amount of the stable daughter isotope, we can accurately estimate the age of rock layers.

Number of Half-lives	Percent Parent Isotope Remaining	Percent Daughter Isotope Remaining	Fraction/(Ratio)
1	50%	50%	½ parent isotope left (1:1)
2	25%	75%	¼ parent isotope left (1:3)
3	12.5%	87.5%	1/8 of parent isotope left (1:7)
4	6.25%	93.75%	1/16 of parent isotope left (1:15)





PROBLEM:

How **old** is a rock if it contains 125g of U-238 and 875g of its daughter isotope, Pb-206?

125 + 875 = 1000g total mass
125/1000 = 1/8 (12.5%) = 1/8 U-238 remaining

1/8 of parent isotope remaining = **3 half-lives**
125:875 = 1:7 = 3 half-lives

Half-life of U-238: 4.5×10^9 years (from ESRT)

$3(4.5 \times 10^9)$ = **13.5×10^9 or 1.35×10^{10} years old**

USING RADIOACTIVE ISOTOPES

Half-lives of radioactive elements are **not affected by environmental variables,** such as changes in heat and pressure. For example, half of a 100g sample of U-238 will decay in 4.5 billion years, even if it is suddenly subjected to great amounts of pressure. That is why the process is such a reliable means to determine absolute age.

Uranium-238 is extremely useful for dating rocks. Because its half-life is 4.5 billion years, it is most often used to date very old rocks.

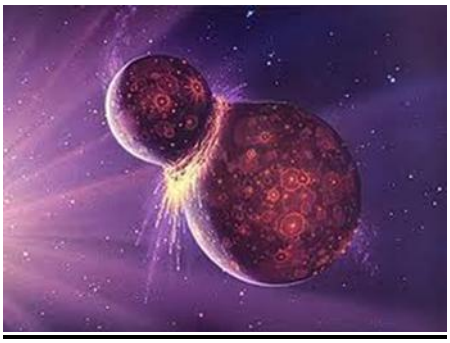
Carbon-14 is widely used to determine the absolute age of **organic** material less than 50,000 years old. Carbon-14 has a half-life of approximately 5,700 years, and decays into nitrogen-14. Carbon-14 dating is called radiocarbon dating.

EVOLUTION OF EARTH AND LIFE

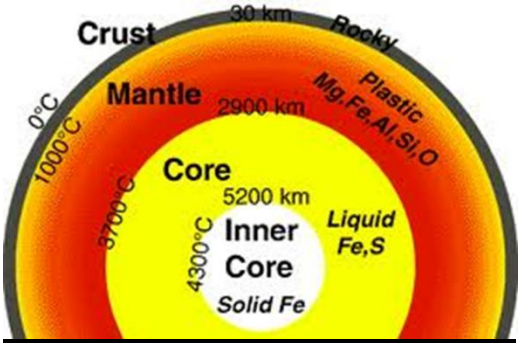
Variations in the fossil record can tell us about the Earth in the past. For example, fossils of ancient corals have been found in New York State. We can thus infer that New York was once under a shallow, warm sea and was much closer to the equator.

Through evidence like this, we know the earth's environments and resident life forms are constantly changing.

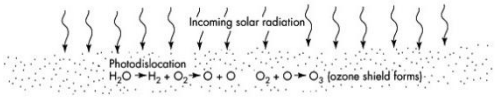
A BRIEF SUMMARY OF EARTH'S HISTORY

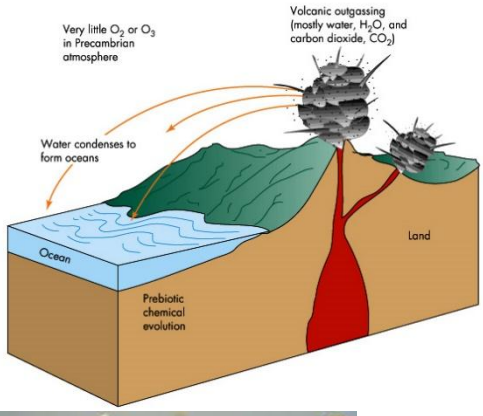


<---4.6 billion years ago (BYA): Earth and the moon formed

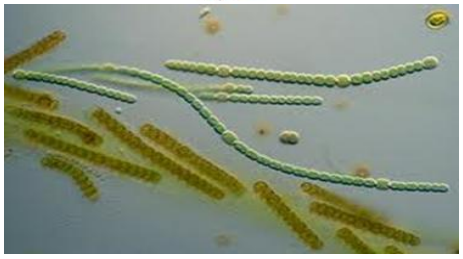


<---Earth materials separated into zones in Earth's interior according to density.





<---4.2 BYA: A solid crust formed. **Outgassing** caused the formation of an early atmosphere composed of carbon dioxide, water vapor, nitrogen, and other gases. 2.8 BYA, oxygen was present in the atmosphere.



<---Approximately 3.5 BYA: Once Earth's surface cooled sufficiently, precipitated water formed the oceans, and the early life forms developed.

Earliest humans (genus Homo) appeared on Earth 1-2 million years ago.