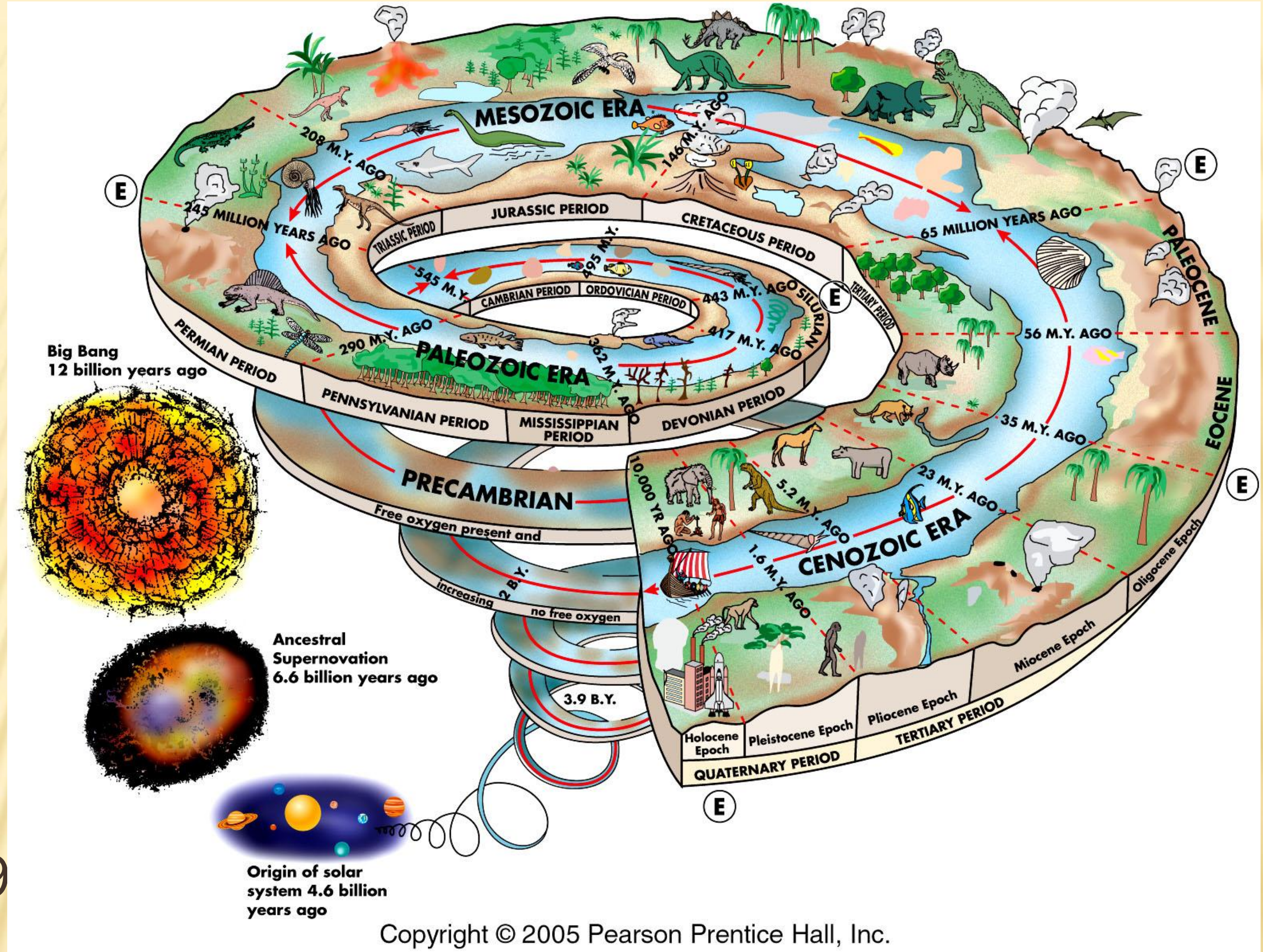


UNIT - 9

GEOLOGIC TIME

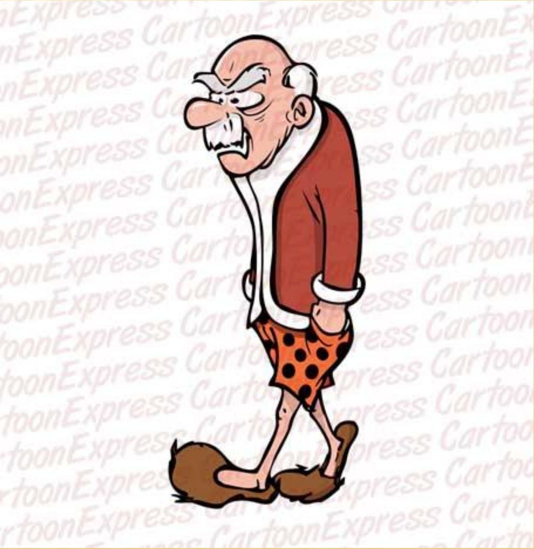
GEOLOGIC TIME

- Normally we think of time in terms of days or years but geologists commonly refer to events that happened millions or billions of years ago
- For example earth is approximately 4.6 billion years old

GEOLOGIC TIME

- Geologists measure geologic time in two different ways

- Relative Age and Absolute Age



GEOLOGIC TIME

RELATIVE AGE

- Determination of relative age is based on a simple principle:

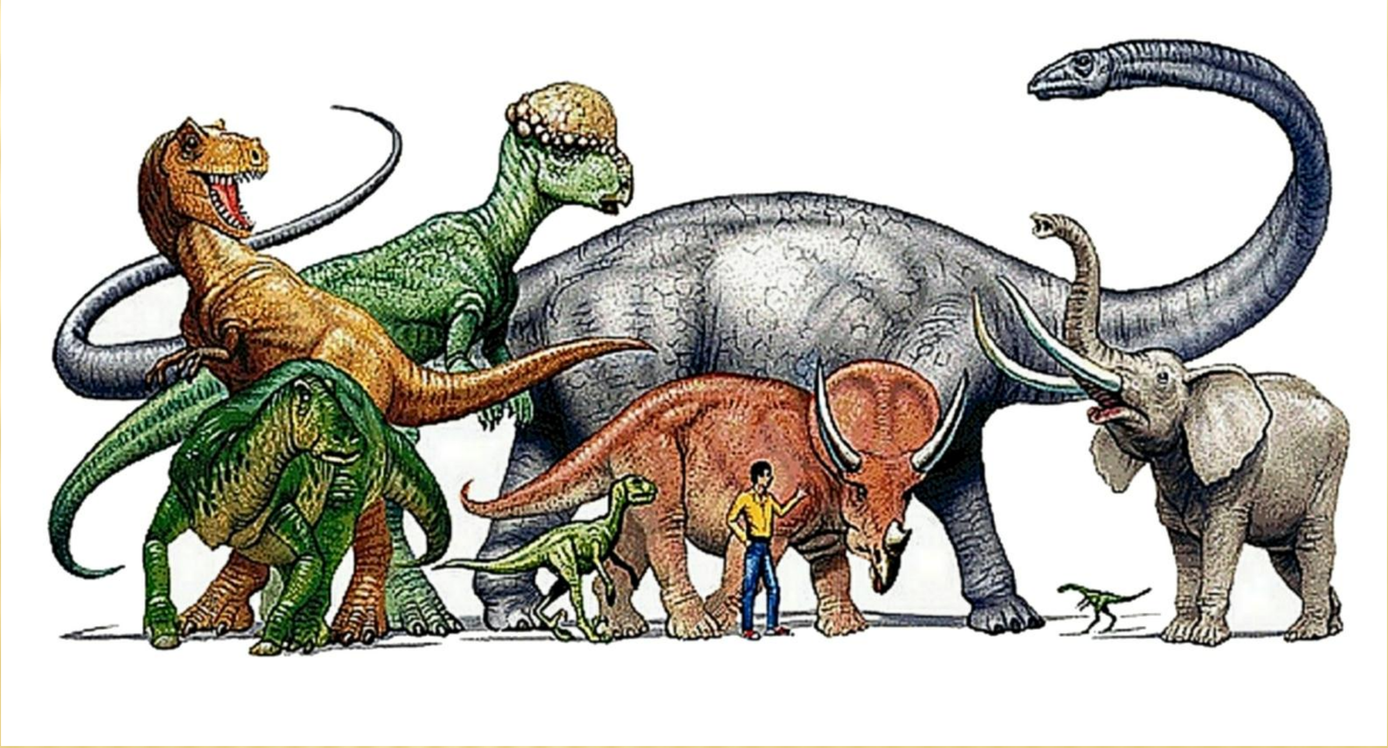
- In order for an event to affect a rock, the rock must exist first. Thus, the rock must be older than the event.

FOLDED ROCKS

GEOLOGIC TIME

ABSOLUTE AGE

- Absolute age is age in years
- Dinosaurs became extinct 65 million years ago



RELATIVE GEOLOGIC TIME

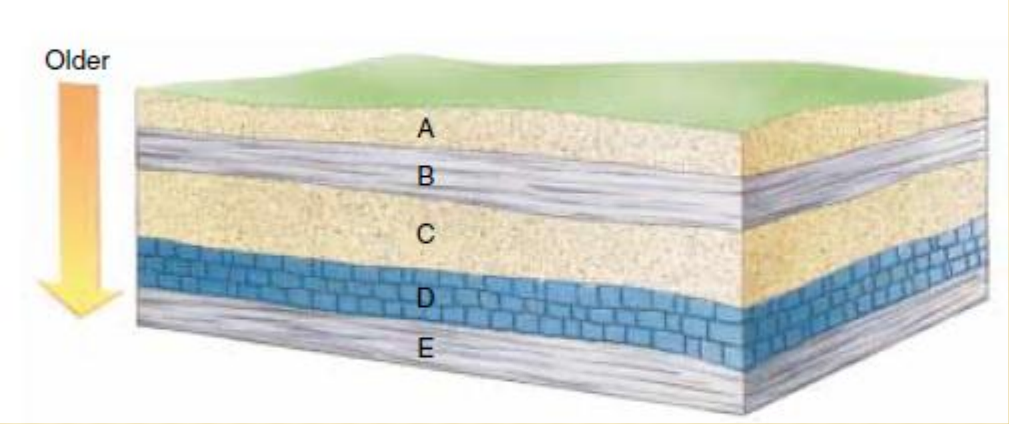
The principle of original horizontality

- It is based on the fact that sediment usually accumulates in horizontal layers.
- If sedimentary rocks lie at an angle, we can infer that tectonic forces tilted them after they formed

RELATIVE GEOLOGIC TIME

The principle of superposition

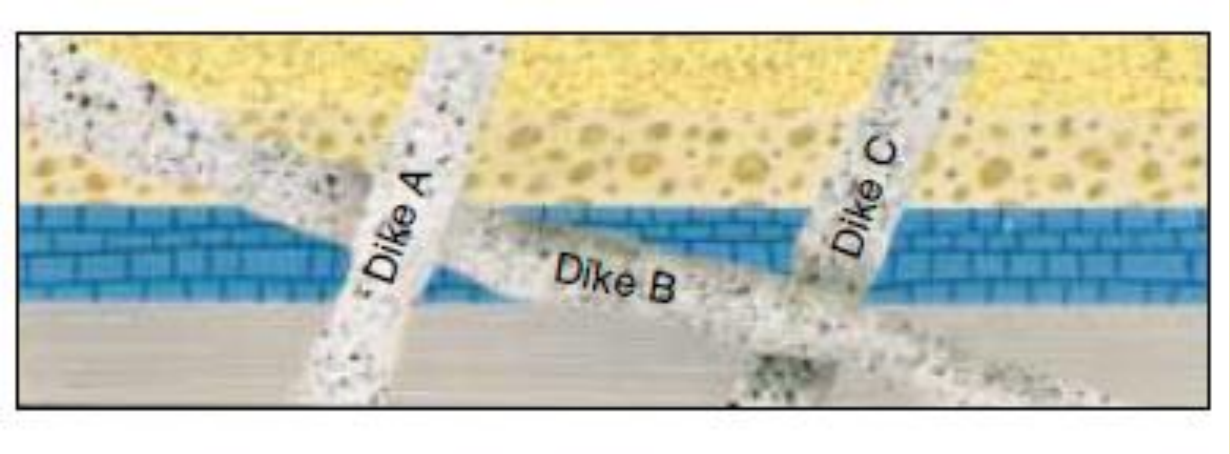
- It states that sedimentary rocks become younger from bottom to top (as long as tectonic forces have not turned them upside down).
- This is because younger layers of sediment always accumulate on top of older layers. In the figure below the sedimentary layers become progressively younger in the order E, D, C, B, and A.



RELATIVE GEOLOGIC TIME

The principle of cross-cutting relationships

- It states that a rock must first exist before anything can happen to it.
- The figure below shows sedimentary rocks intruded by three granite dikes.
- Dike B cuts dike C, and dike A cuts dike B, so dike C is older than B, and dike A is the youngest. The sedimentary rocks must be older than all of the dikes.



RELATIVE GEOLOGIC TIME

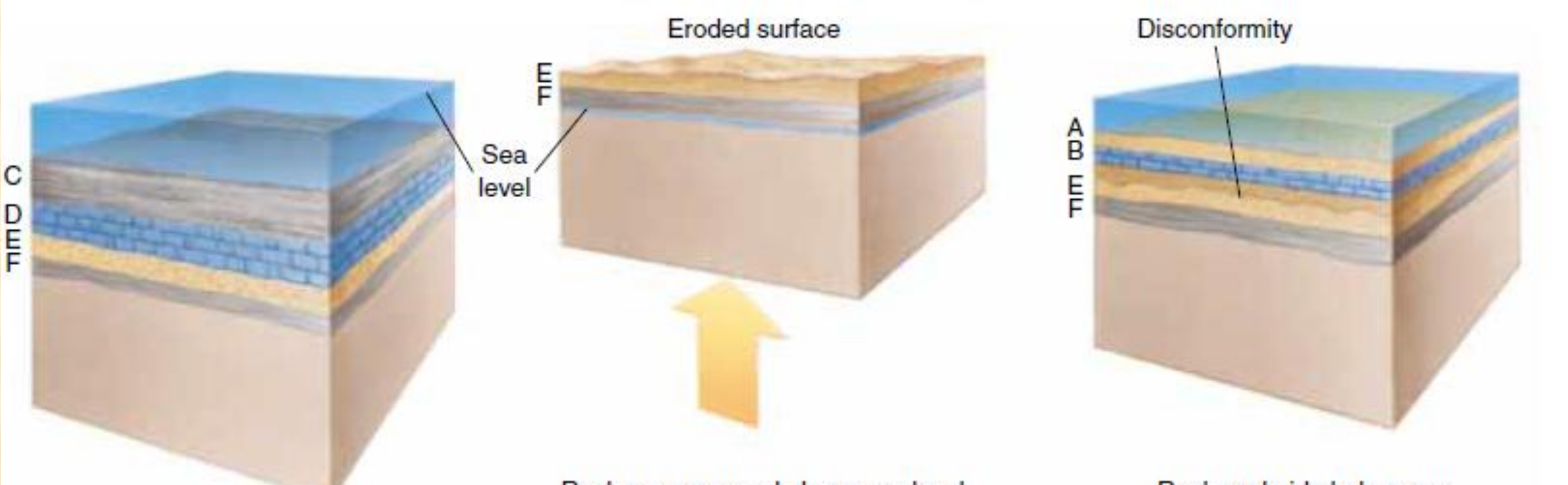
The principle of unconformities

- Layers of sedimentary rocks are conformable if they were deposited without interruption. An unconformity represents an interruption in deposition, usually of long duration.
- During the interval when no sediment was deposited, some rock layers may have been eroded
- Thus, an unconformity represents a long time interval for which no geologic record exists in that place. The lost record may involve hundreds of millions of years
- There are several types of unconformities

UNCONFORMITIES

Disconformity

- In this case the sedimentary layers above and below the unconformity are parallel.
- Geologists identify disconformities by determining the ages of rocks using methods based on fossils and absolute dating



Sediment is deposited below sea level.

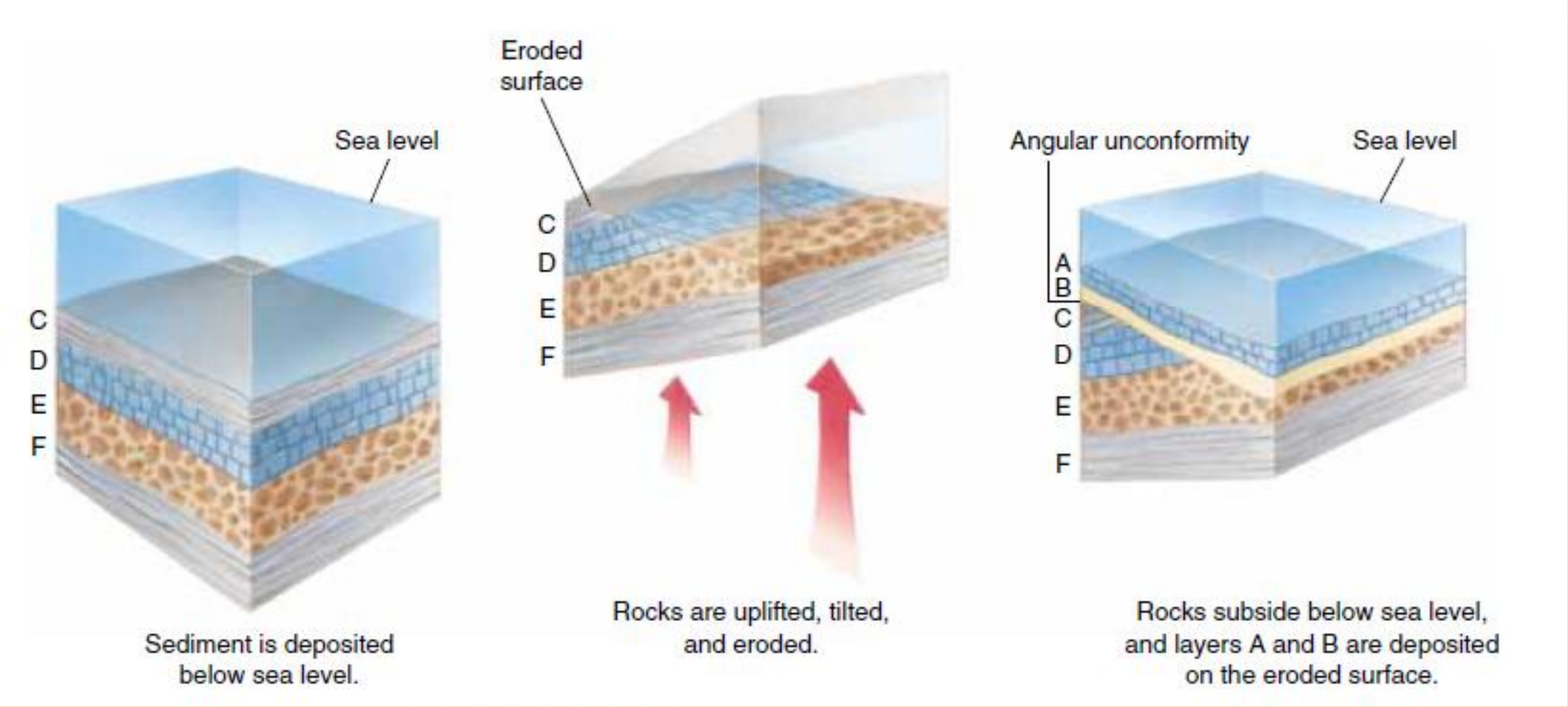
Rocks are exposed above sea level and layers C and D are removed by erosion.

Rocks subside below sea level and layers A and B are deposited on the eroded surface.

UNCONFORMITIES

Angular unconformity

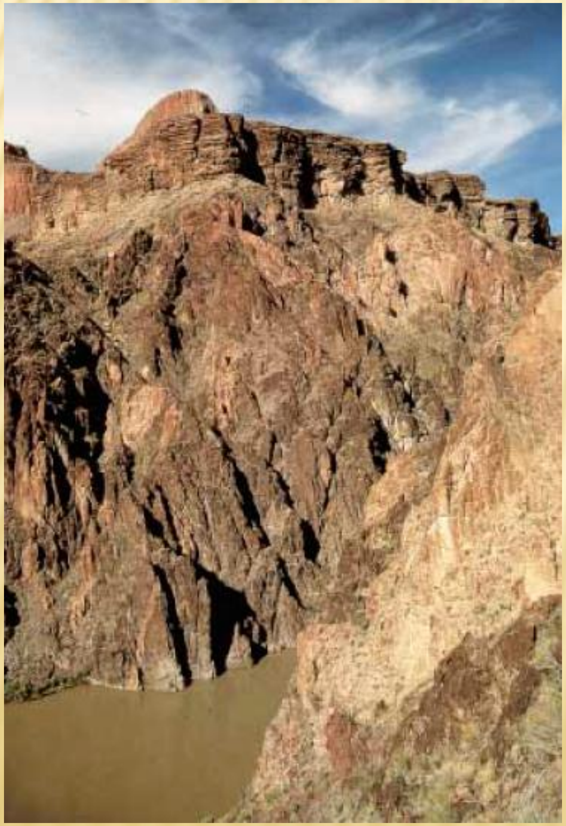
- In this case tectonic activity tilted older sedimentary rock layers before younger sediment accumulated

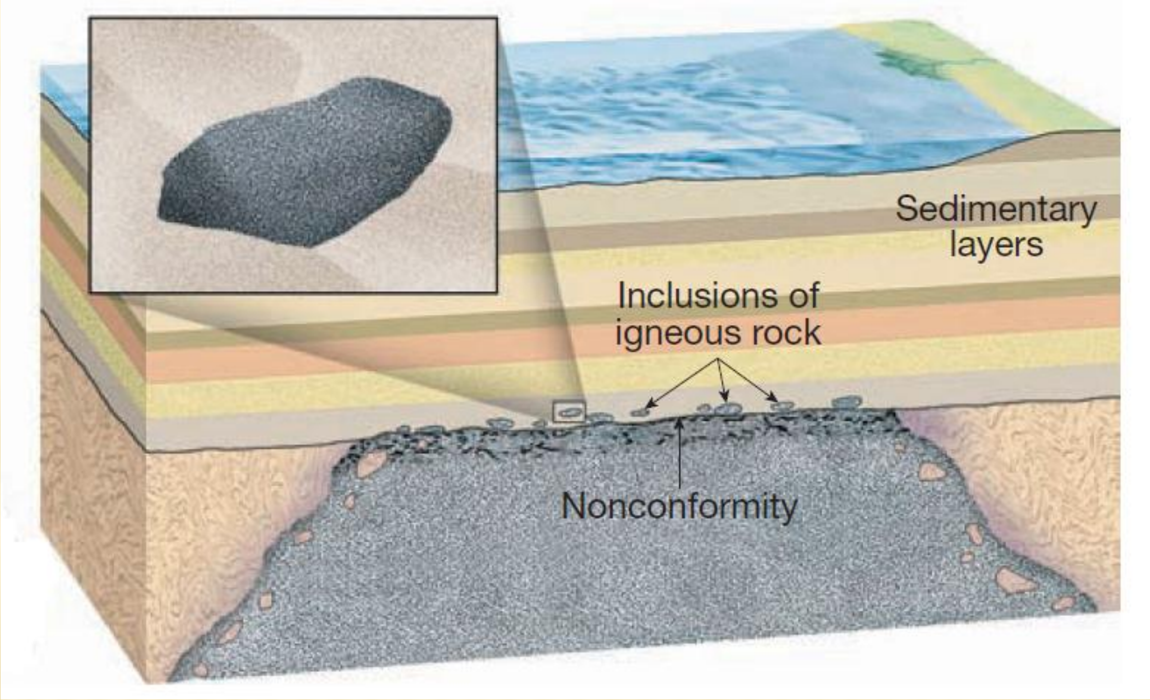


UNCONFORMITIES

Nonconformity

- In this case sedimentary rocks lie on igneous or metamorphic rocks

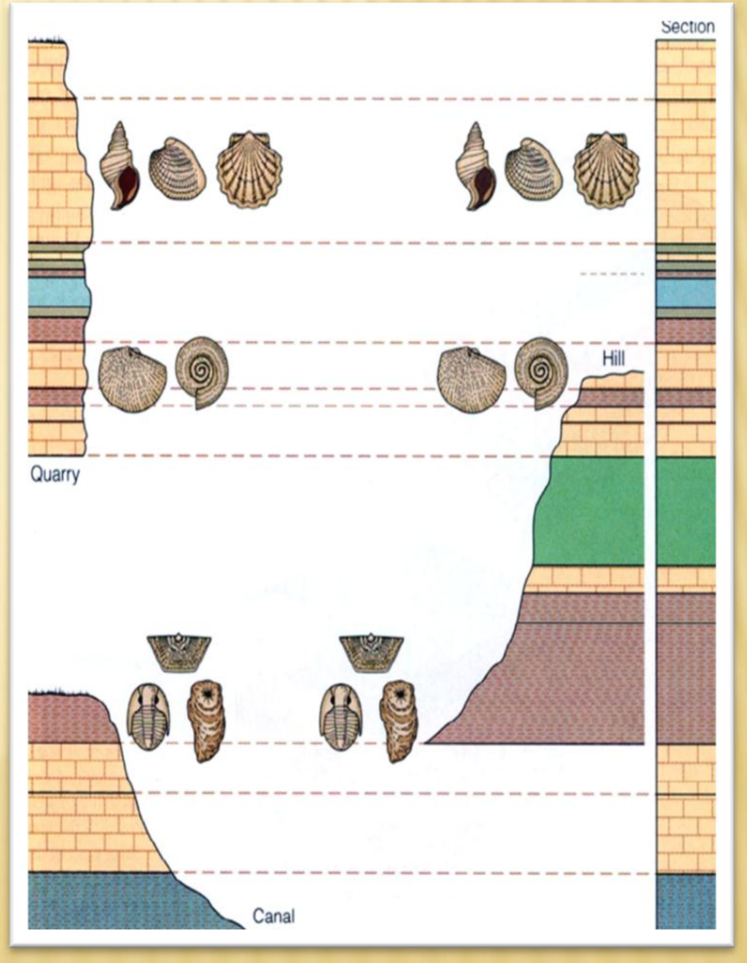




RELATIVE GEOLOGIC TIME

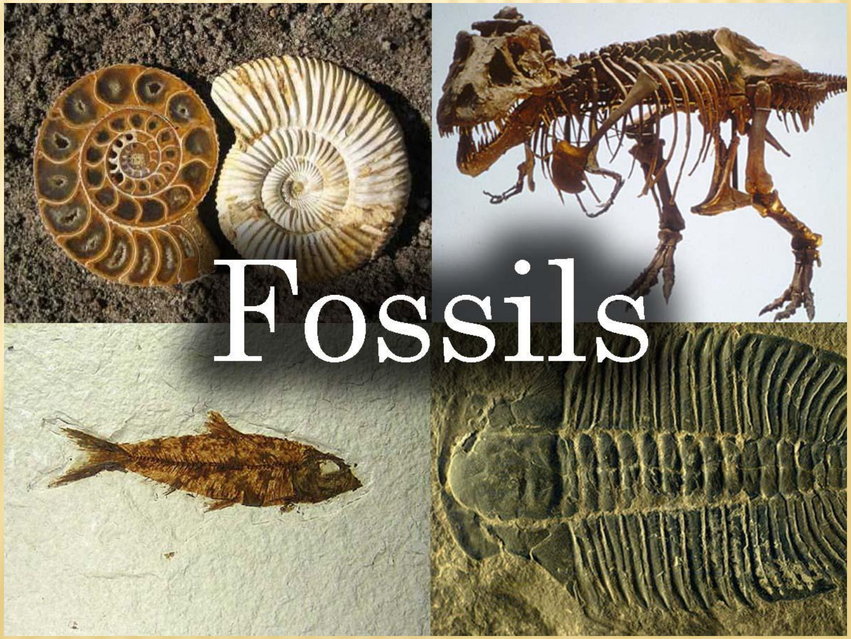
The principle of faunal succession

It states that fossil organisms succeeded one another through time in a definite and recognizable order and that the relative ages of rocks can therefore be recognized from their fossils



RELATIVE GEOLOGIC TIME

- Paleontologists study fossils, the remains and other traces of prehistoric life, to understand the history of life and evolution.
- Fossils also provide information about the ages of sedimentary rocks and their depositional environments



FOSSILS AND FAUNAL SUCCESSION

- The theory of evolution states that life forms have changed throughout geologic time.

- Fossils are useful in determining relative ages of rocks because different animals and plants lived at different times in the Earth's history.

- For example, trilobites lived from 535 million to 245 million years ago, and the first dinosaurs appeared about 220 million years ago.

CORRELATION

- To assemble a complete and continuous a record, geologists combine evidence from many localities. To do this, rocks of the same age from different localities must be matched in a process called correlation

- There are two kinds of correlation
  - Time correlation and
  - Lithologic correlation

CORRELATION

- Time correlation: matching of rocks deposited at the same time (e.g. Mesozoic sedimentary rocks in the U.S. with Mesozoic sedimentary rocks in Mexico)
- Time correlation requires the use of index fossils to demonstrate rocks were deposited at the same time

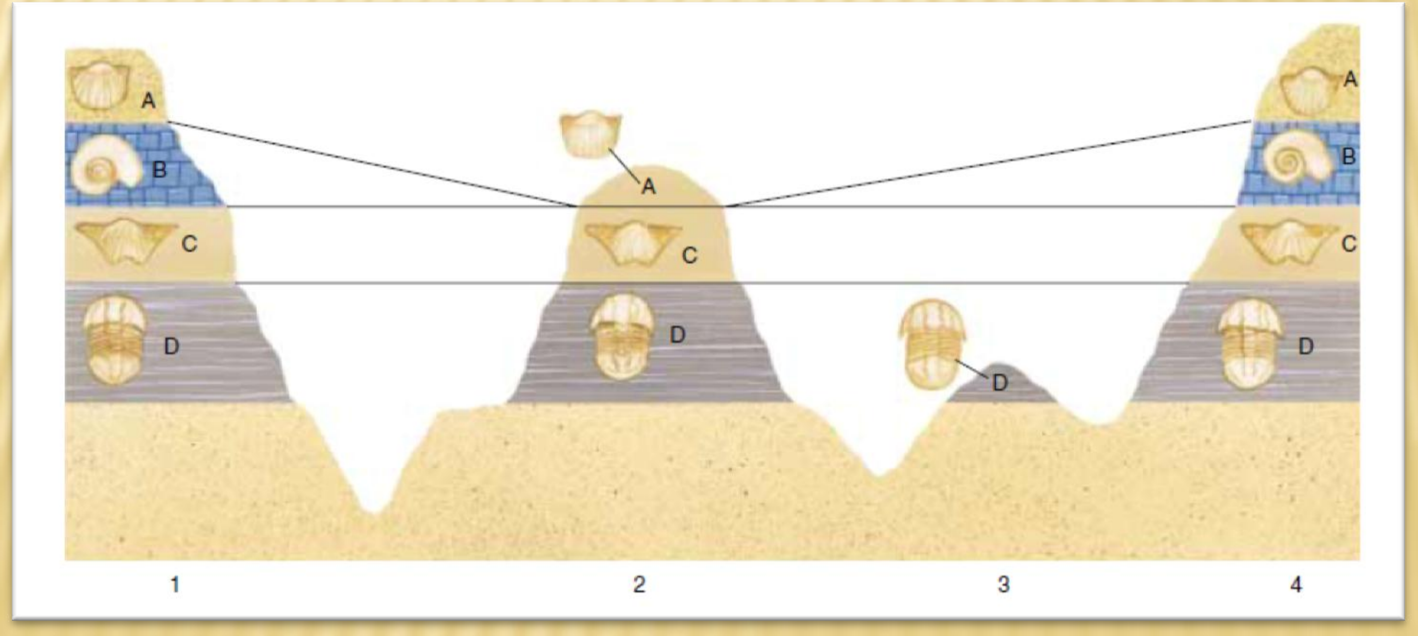
CORRELATION

- Index fossils are fossils used to define and identify geologic periods.

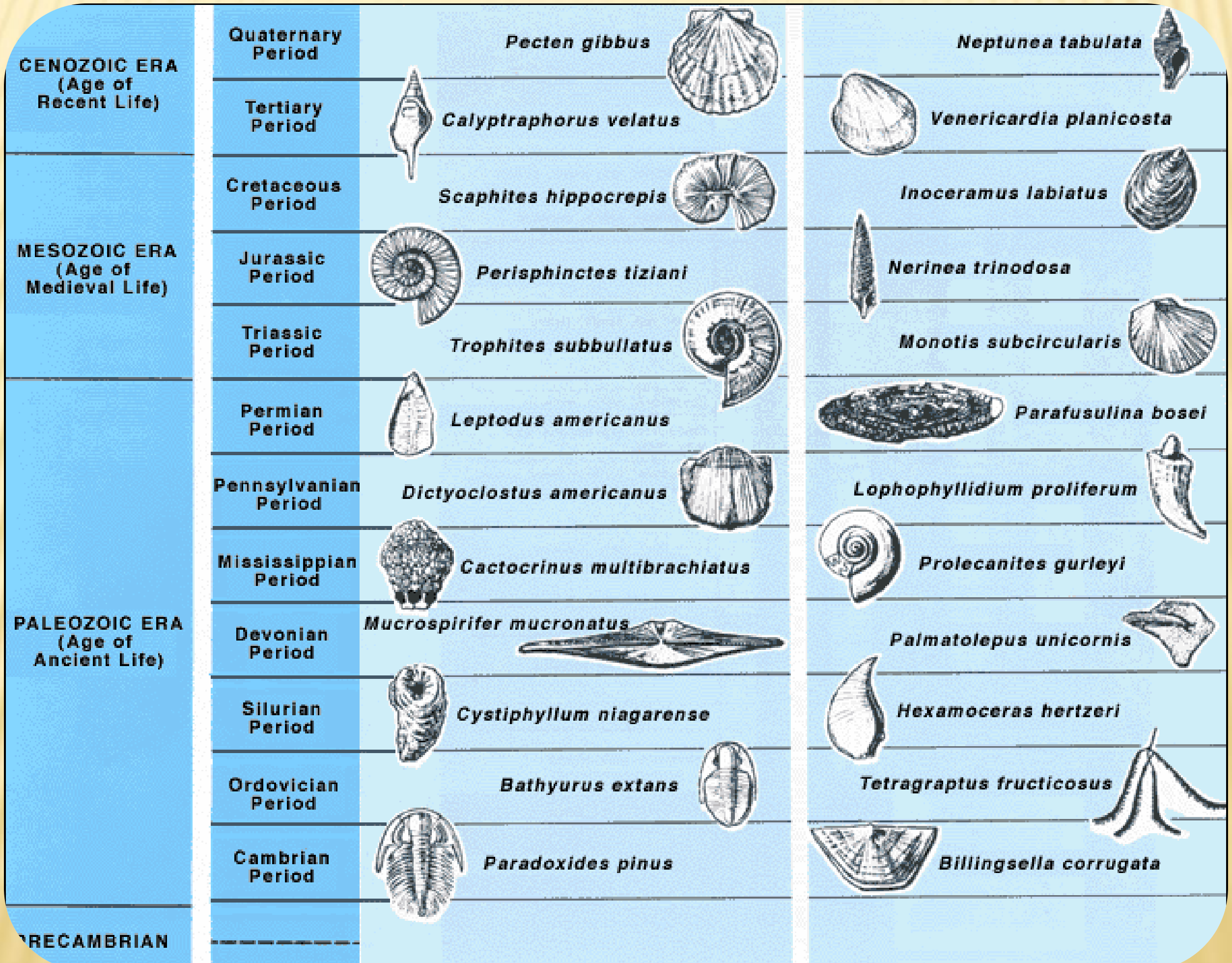
- They work on the premise that, although different sediments may look different depending on the conditions under which they were laid down, they may include the remains of the same species of fossil.

CORRELATION

- To be useful, an index fossil is produced by an organism that
- **is abundantly preserved in rocks,**
- **was geographically widespread,**
- **existed as a species or genus for only a relatively short time**, and
- **is easily identified in the field.**



EXAMPLES OF INDEX FOSSILS



CORRELATION

- Lithologic correlation: matching rocks of the same character from one place to another. Usually it is not as accurate as time correlation, but easier
- This doesn't require index fossils, but lithologic correlation may not correlate rocks deposited at the same time.
- Lithologic correlation requires the use of key beds/marker beds

CORRELATION

- A key bed/marker bed is a thin, widespread sedimentary layer that was deposited rapidly and synchronously over a wide area and is easily recognized

- Examples are the ash deposits from volcanic eruptions

CORRELATION

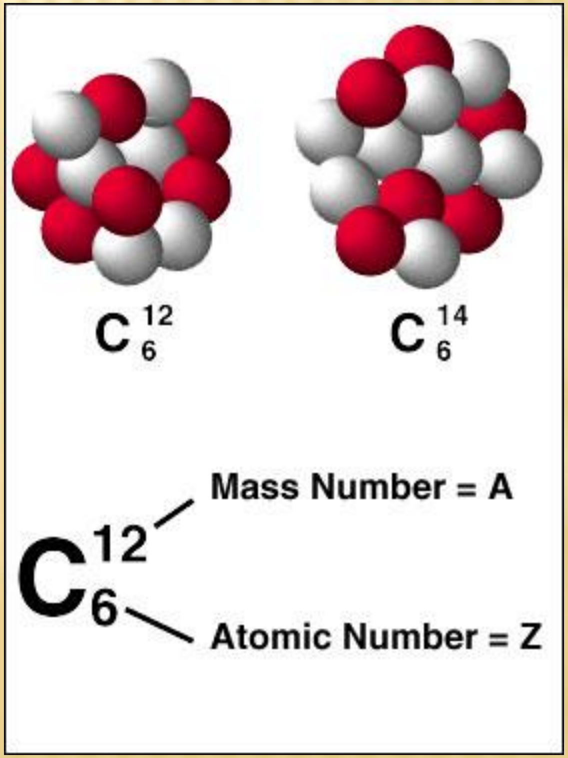
The K-T boundary layer which is marker bed found almost all over the world.The layer shows high concentration of the element iridium. iridium does not occur naturally on Earth in high concentrations, but it does occur in higher concentrations in certain types of meteorites. It points to a metorite impact 65 million years ago which was responsible for the extiction of the dinosaurs

ABSOLUTE GEOLOGIC TIME

- Natural Radioactivity of the elements present in rocks provides a way for measuring the absolute geologic time

•Elements having the same atomic number but different atomic mass are known as Isotopes

•The difference in mass is due to the difference in the number of neutrons

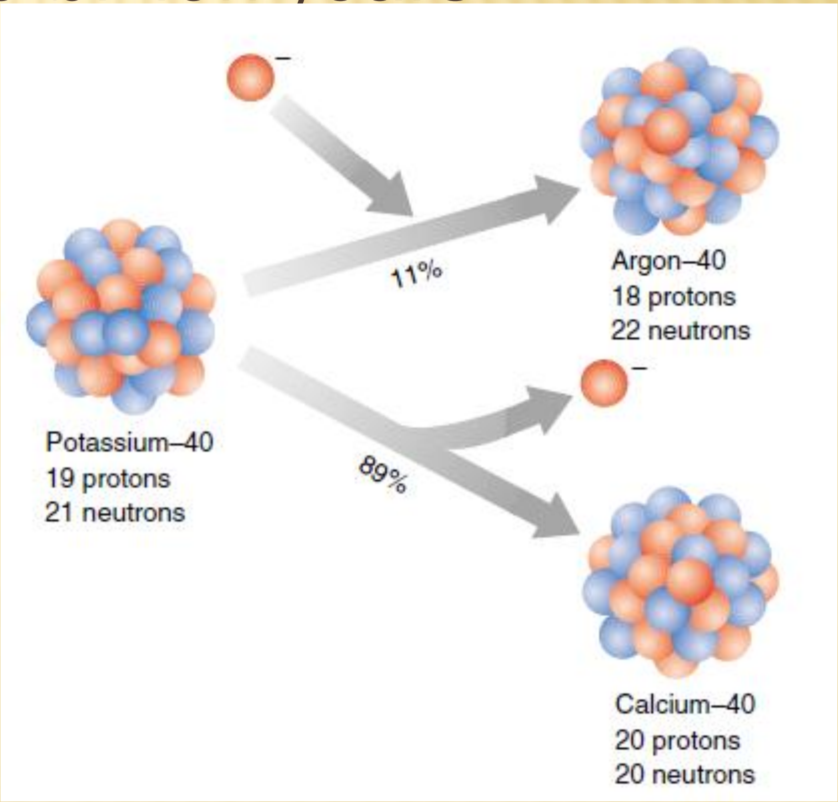


ABSOLUTE GEOLOGIC TIME

- Many isotopes are stable and do not change with time. For example potassium-39 remains unchanged even after 10 billion years

•Other isotopes are unstable or radioactive. Given time, their nuclei spontaneously break apart

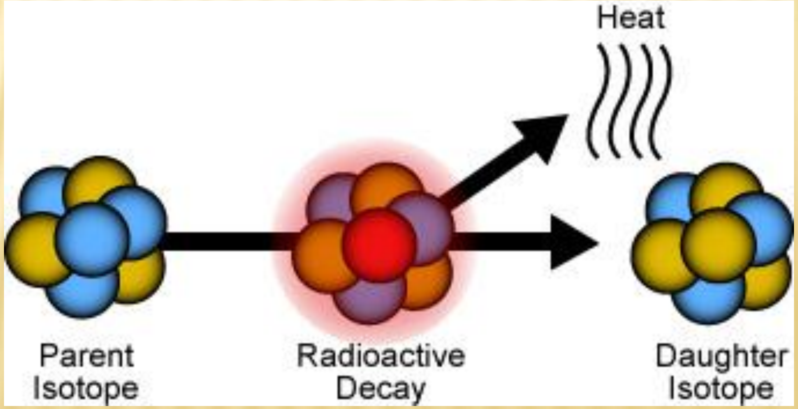
•Potassium-40 decomposes naturally to form two other isotopes, argon-40 and calcium-40



ABSOLUTE GEOLOGIC TIME

- A radioactive isotope such as potassium-40 is known as a parent isotope.

- An isotope created by radioactivity, such as argon-40 or calcium-40, is called a daughter isotope.

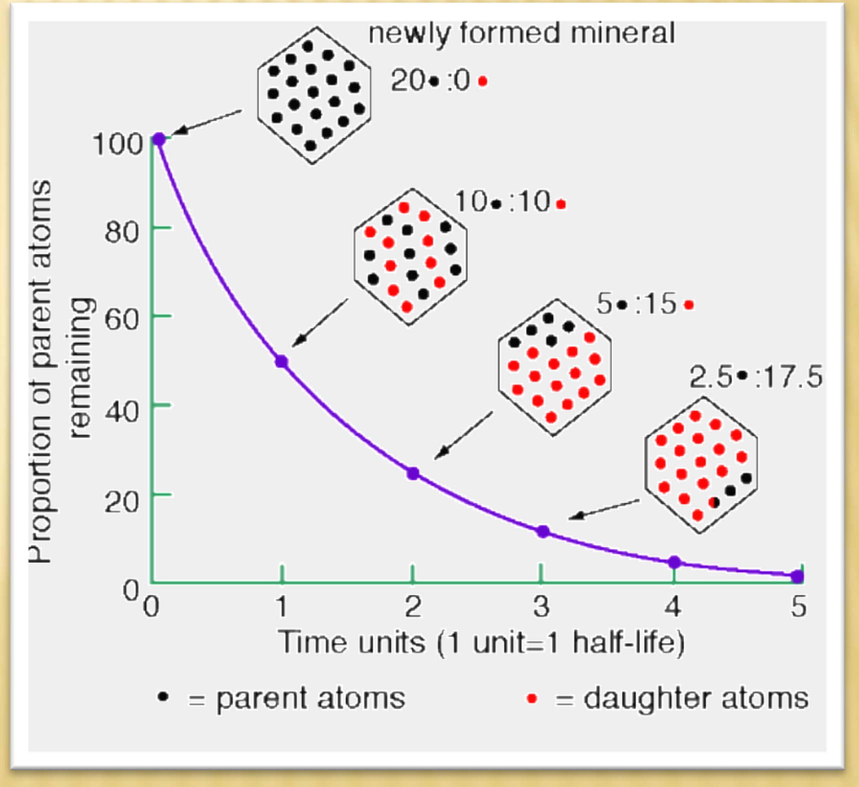


ABSOLUTE GEOLOGIC TIME

- The half-life is the time it takes for half of the atoms in a sample to decompose.

•The half-life of potassium- 40 is 1.3 billion years. Therefore, if 1 gram of potassium-40 were placed in a container, 0.5 gram would remain after 1.3 billion years, 0.25 gram after 2.6 billion years, and so on.

Each radioactive isotope has its own half-life; some half-lives are fractions of a second and others are measured in billions of years.



ABSOLUTE GEOLOGIC TIME

- Two aspects of radioactivity are essential to the calendars in rocks
- First, the half-life of a radioactive isotope is constant. It is easily measured in the laboratory and is unaffected by geologic processes. So radioactive decay occurs at a known, constant rate
- Secondly as a parent isotope decays, its daughter accumulates in the rock. The longer the rock exists, the more daughter isotope accumulates. The accumulation of a daughter isotope is similar to marking off days on a calendar

ABSOLUTE GEOLOGIC TIME

ISOTOPES		HALF-LIFE OF PARENT (YEARS)	EFFECTIVE DATING RANGE (YEARS)	MINERALS AND OTHER MATERIALS THAT CAN BE DATED
Parent	Daughter			
Carbon-14	Nitrogen-14	5730 ± 30	100–70,000	Anything that was once alive: wood, other plant matter, bone, flesh, or shells; also, carbon in carbon dioxide dissolved in ground water, deep layers of the ocean, or glacier ice
Potassium-40	Argon-40 Calcium-40	1.3 billion	50,000–4.6 billion	Muscovite Biotite Hornblende Whole volcanic rock
Uranium-238	Lead-206	4.5 billion	10 million–4.6 billion	Zircon Uraninite and pitchblende
Uranium-235	Lead-207	710 million		
Thorium-232	Lead-208	14 billion		
Rubidium-87	Strontium-87	47 billion	10 million–4.6 billion	Muscovite Biotite Potassium feldspar Whole metamorphic or igneous rock

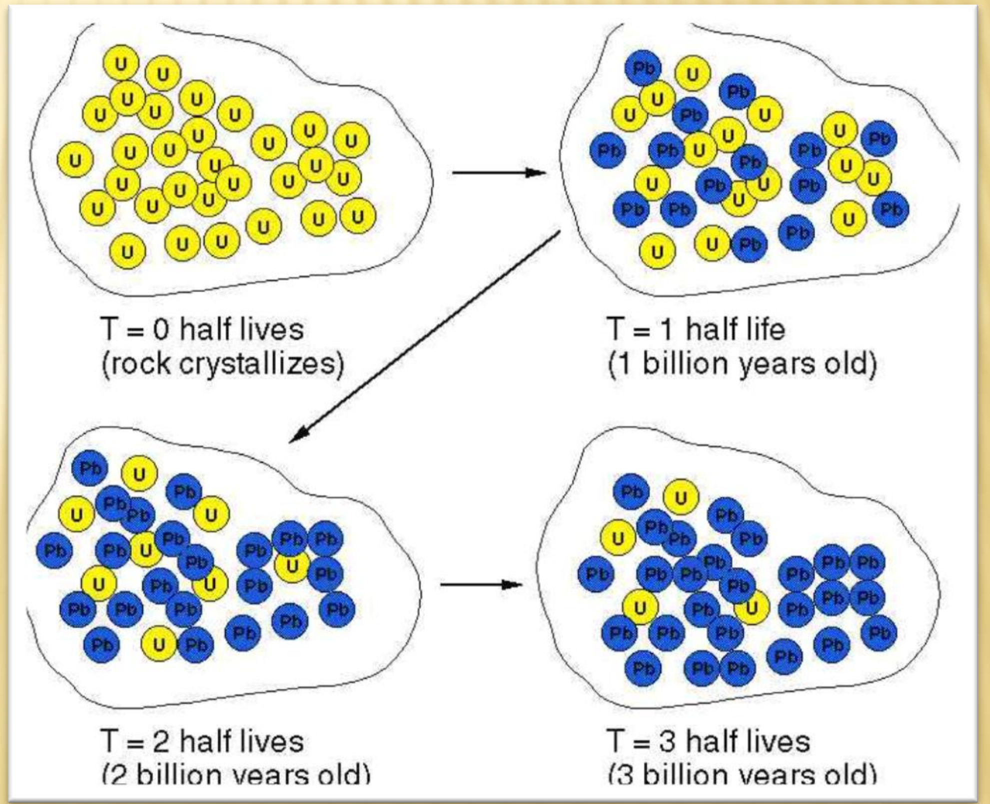
ABSOLUTE GEOLOGIC TIME

- Radiometric dating is the process of determining the ages of rocks, minerals, and fossils by measuring their parent and daughter isotopes

•At the end of one half-life, 50 percent of the parent atoms have decayed to daughter.

•At the end of two half-lives, the mixture is 25 percent parent and 75 percent daughter.

•To determine the age of a rock, a geologist measures the proportions of parent and daughter isotopes in a sample and compares the ratio.



THE GEOLOGICAL COLUMN AND TIME SCALE

•The largest time units are **eons**, which are divided into **eras**.

•Eras are subdivided, in turn, into **periods**, which are further subdivided into **epochs**

•The **Phanerozoic Eon** is finely and accurately subdivided because sedimentary rocks deposited at this time are often well preserved and they contain abundant well-preserved fossils

•In contrast, Precambrian rocks and time are only coarsely subdivided because fossils are scarce and poorly preserved and the rocks are often altered.

TIME UNITS OF THE GEOLOGIC TIME SCALE

Eon	Era	Period	Epoch	Boundary		Distinctive plants and animals
Phanerozoic Eon (*Phaneros* = "evident"; *Zoon* = "life")	Cenozoic Era	Quaternary	Recent or Holocene		"Age of Mammals"	Humans
		Quaternary	Pleistocene	2		
		Tertiary: Neogene	Pliocene	5		Mammals develop and become dominant
		Tertiary: Neogene	Miocene	24		
		Tertiary: Paleogene	Oligocene	37		
		Tertiary: Paleogene	Eocene	58		
		Tertiary: Paleogene	Paleocene	66		Extinction of dinosaurs and many other species
	Mesozoic Era	Cretaceous		144	"Age of Reptiles"	First flowering plants, greatest development of dinosaurs
		Jurassic		208		First birds and mammals, abundant dinosaurs
		Triassic		245		First dinosaurs
	Paleozoic Era	Permian		286	"Age of Amphibians"	Extinction of trilobites and many other marine animals
		Carboniferous: Pennsylvanian		320		Great coal forests; abundant insects, first reptiles
		Carboniferous: Mississippian		360		Large primitive trees
		Devonian		408	"Age of Fishes"	First amphibians
		Silurian		438		First land plant fossils
		Ordovician		505	"Age of Marine Invertebrates"	First fish
		Cambrian		538		First organisms with shells, trilobites dominant
Proterozoic	2500	Sometimes collectively called Precambrian				First multicelled organisms
Archean	3800					First one-celled organisms
Hadean	4600+					Approximate age of oldest rocks; Origin of the Earth