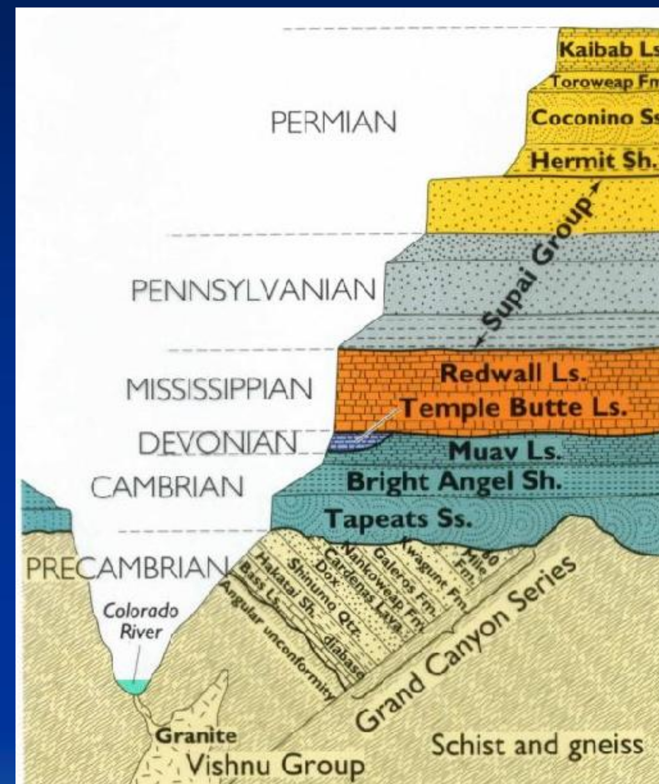
GEOLOGIC DATING LAB

Principles and Applications



Geology Laboratory - GEOL 101

Ray Rector - Instructor

Earth's Age and History

How Old Is the Earth?

How Can We Determine Earth's Geologic History?

Scientific Means of Dating Earth

Two Primary Means of Dating Rocks:

1) **Relative Dating**
   - ✓ Determines the temporal order of rock forming events
   - ✓ Does not give numeric ages
   - ✓ Use of stratigraphic principles and fossils

2) **Absolute Dating**
   - ✓ Determines the numeric age of rock forming events
   - ✓ Only appropriate for ages of igneous rocks and minerals
   - ✓ Primary method is the ***radiometric technique***
   - ✓ Used in conjunction with stratigraphic principles and fossils

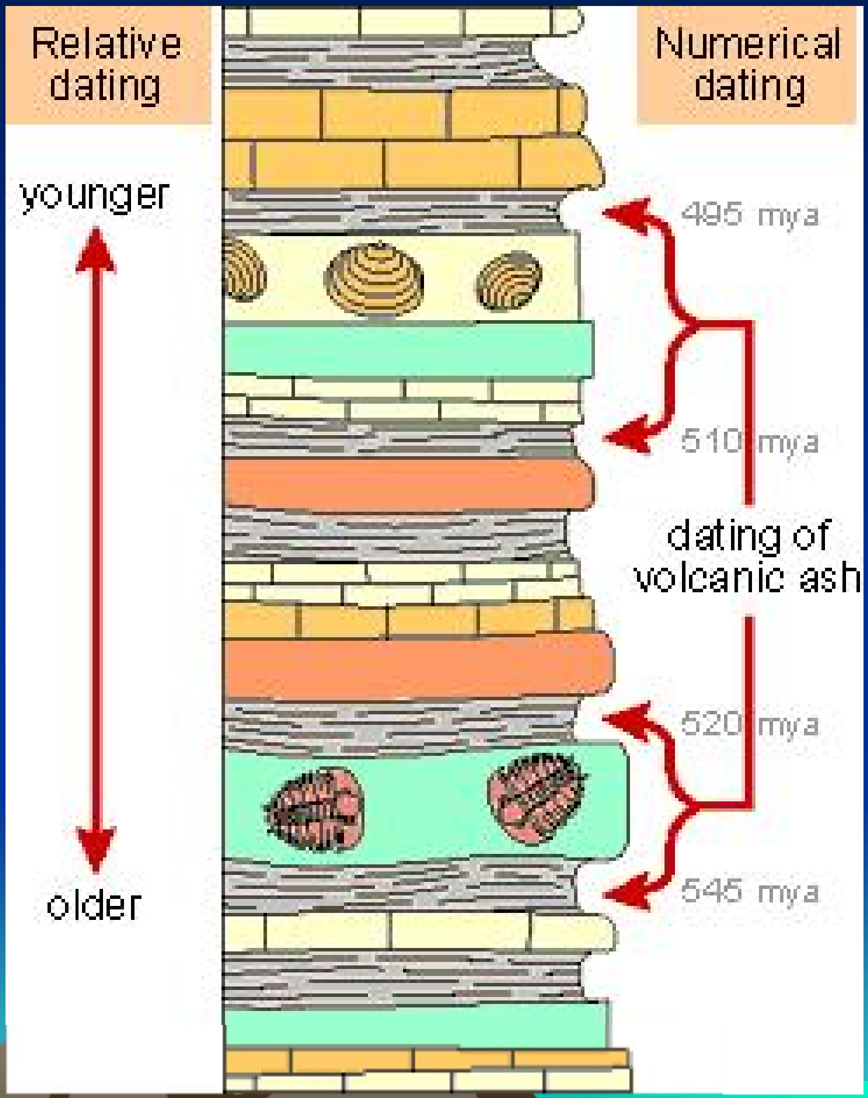
Relative Versus Absolute Dating

Relative Dating

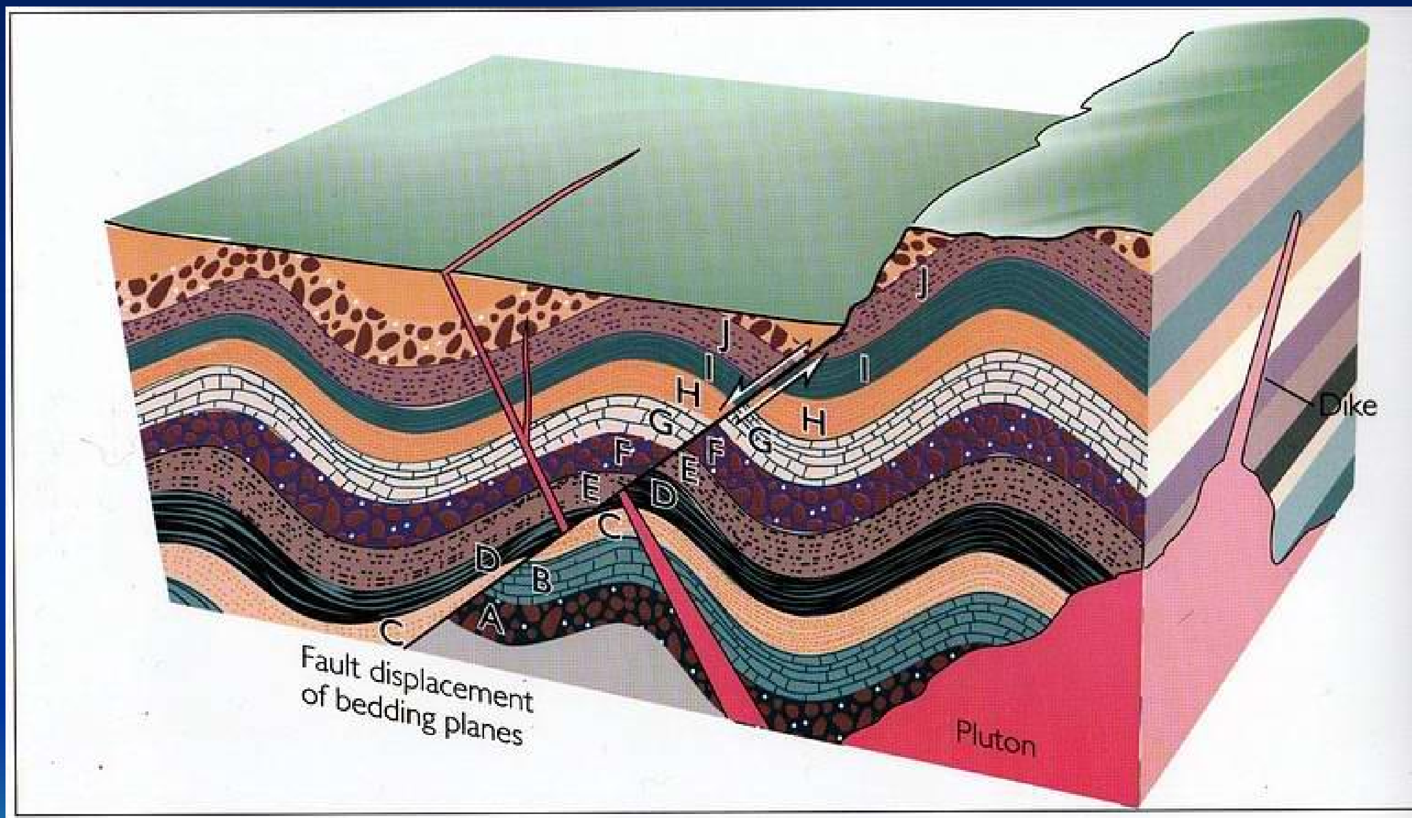
- Stratigraphic principles
- Fossil Succession
- Emphasis on Sed Rocks

Absolute Dating

- Radiometric techniques
- Emphasis on Igneous Bodies



How Can We Figure Out the Age Sequence of Geologic Events?



The Stratigraphic Principles

1. **Original Horizontality** - All sedimentary rocks are originally deposited horizontally. Sedimentary rocks that are no longer horizontal have been tilted from their original position.

2. **Lateral Continuity** - Sedimentary and volcanic rocks are laterally continuous over large areas.

3. **Superposition** - Oldest layer occurs at base of a layered sequence and is overlain by progressively younger rock layers.

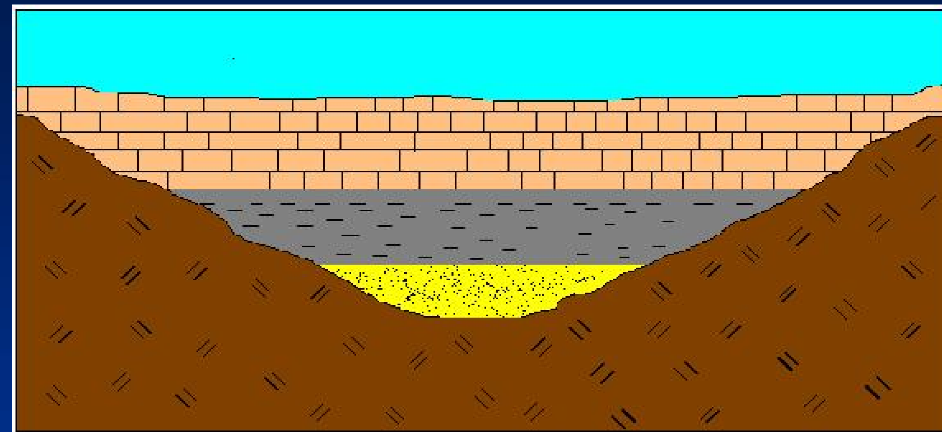
4. **Cross-Cutting Relations** - If a body or discontinuity cuts across a rock structure, it must have formed after that stratum.

5. **Law of Inclusions** - Rock fragments (in another rock) must be older than the rock containing the fragments.

6. **Law of Fossil Succession** - Unique fossil groups were succeeded by other fossil groups through time.

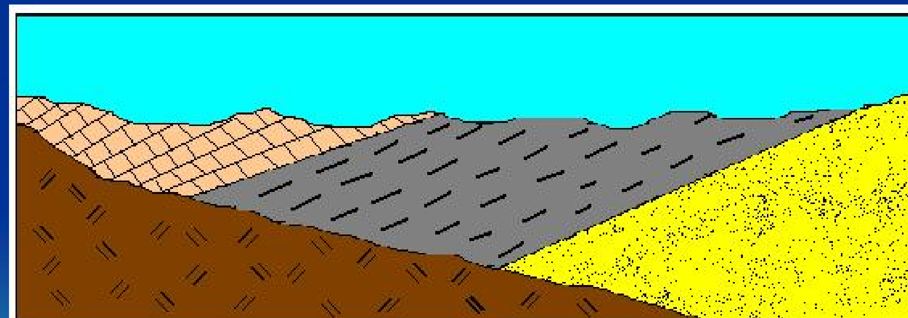
Principle of Original Horizontality

Sedimentary rock units originally deposit in horizontal layers



Original Horizontal Strata

Later events may cause the layers to become tilted or overturned

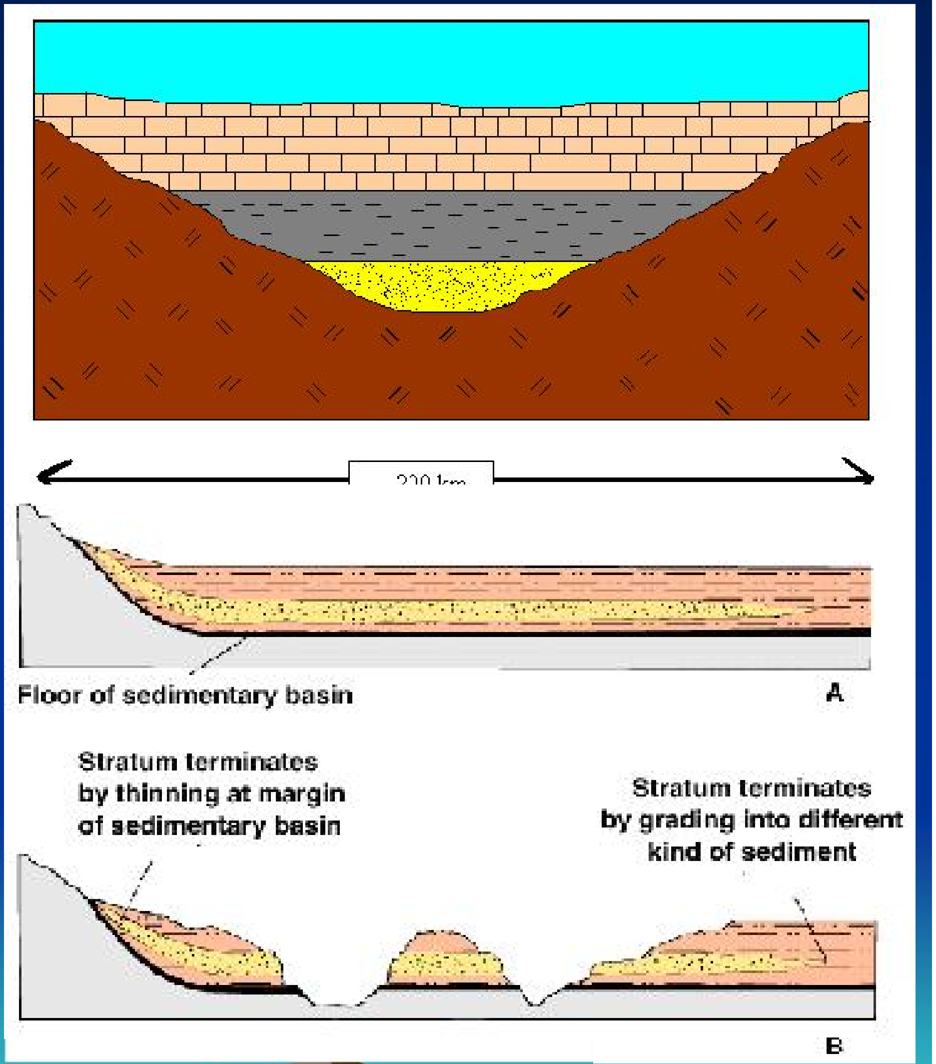


Tilted Strata

Principle of Lateral Continuity

Layers of sedimentary material initially extend laterally in all directions.

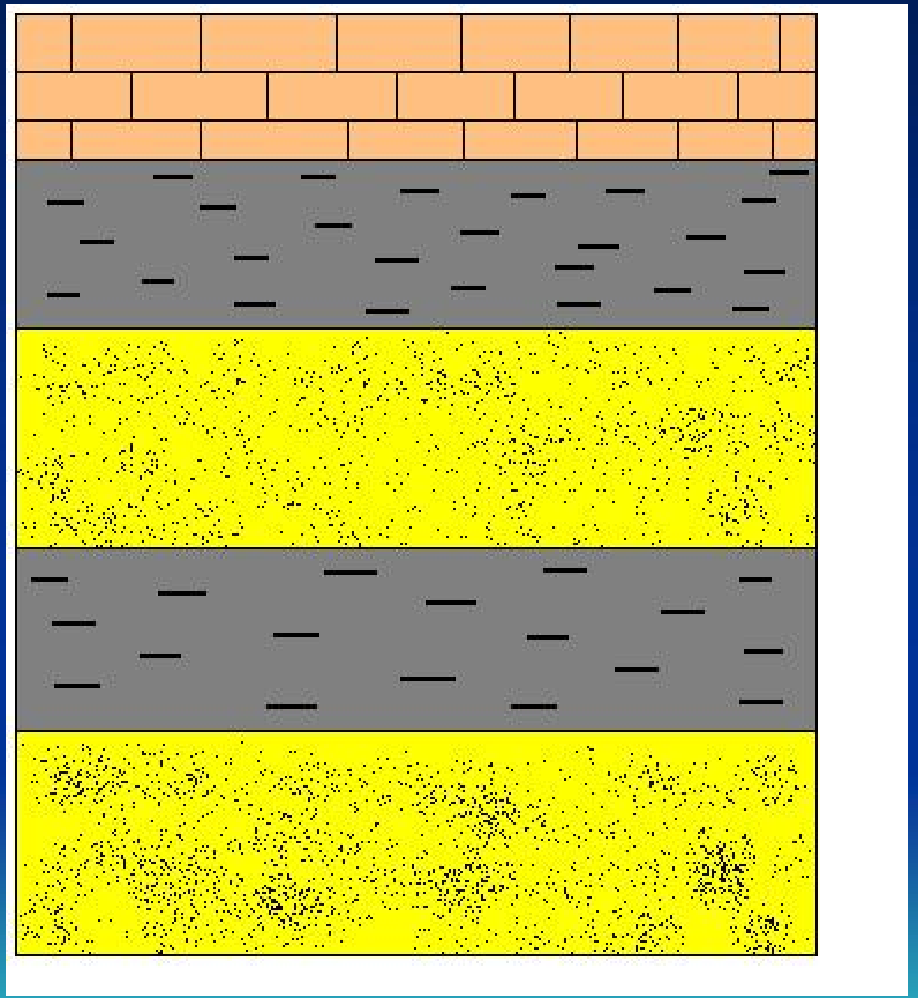
The layers eventually thin to zero and either terminate at the ends of the sedimentary basin or grade into other units.



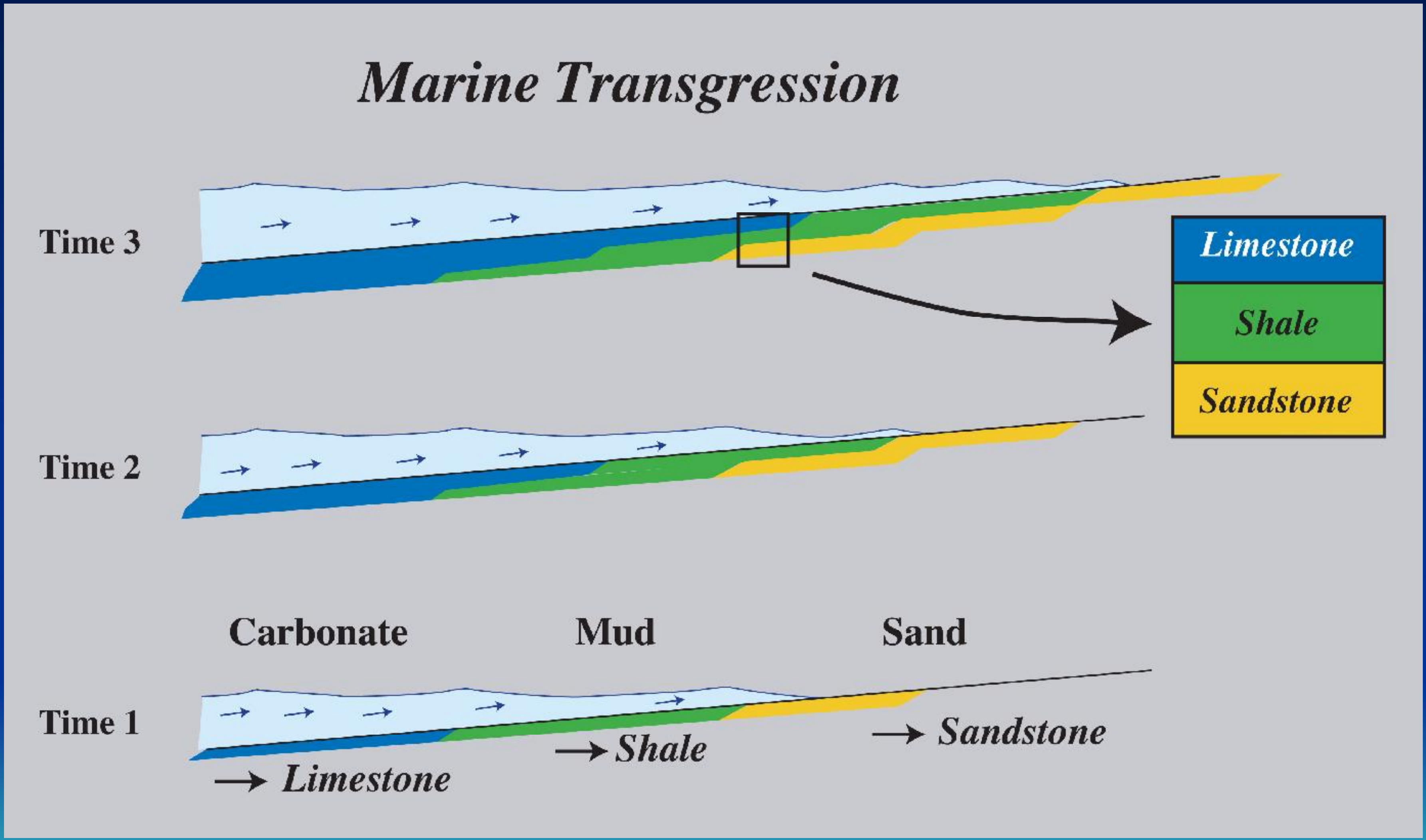
Principle of Superposition

In a vertical stack of layered rock units, the overlying unit is younger than the underlying unit.

The youngest rock layer is on top – the oldest layer is on the bottom.

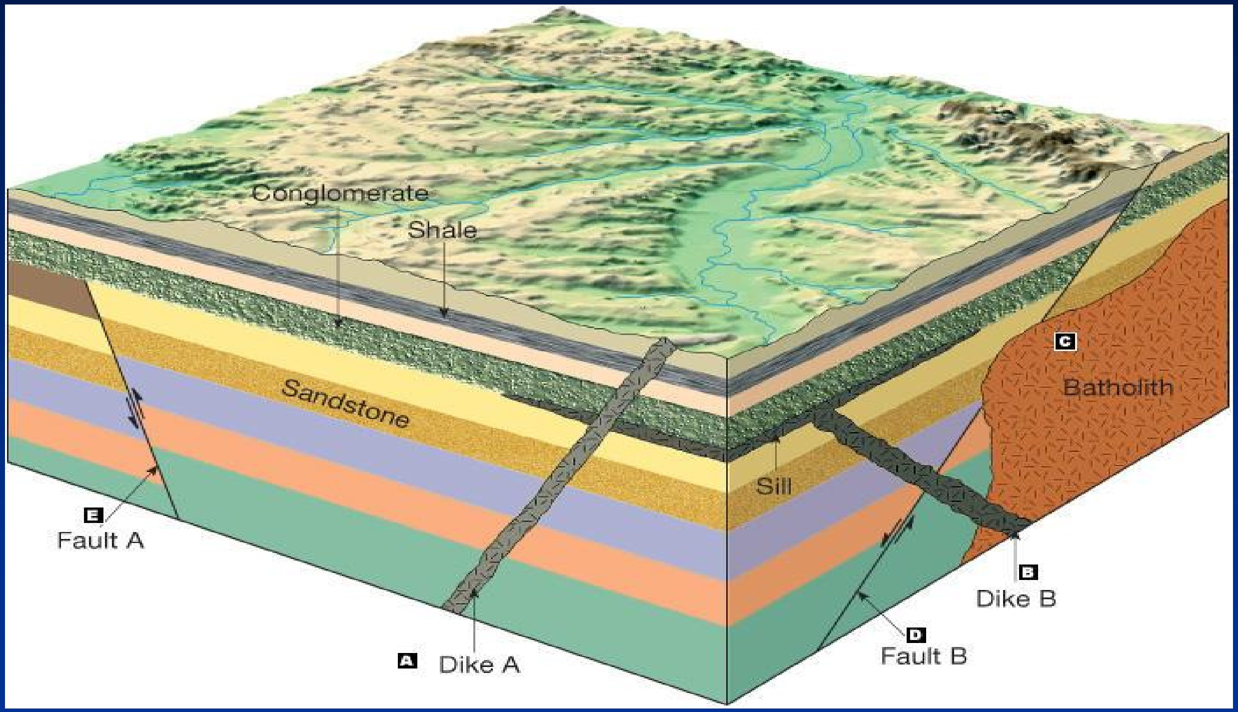


Marine Transgression



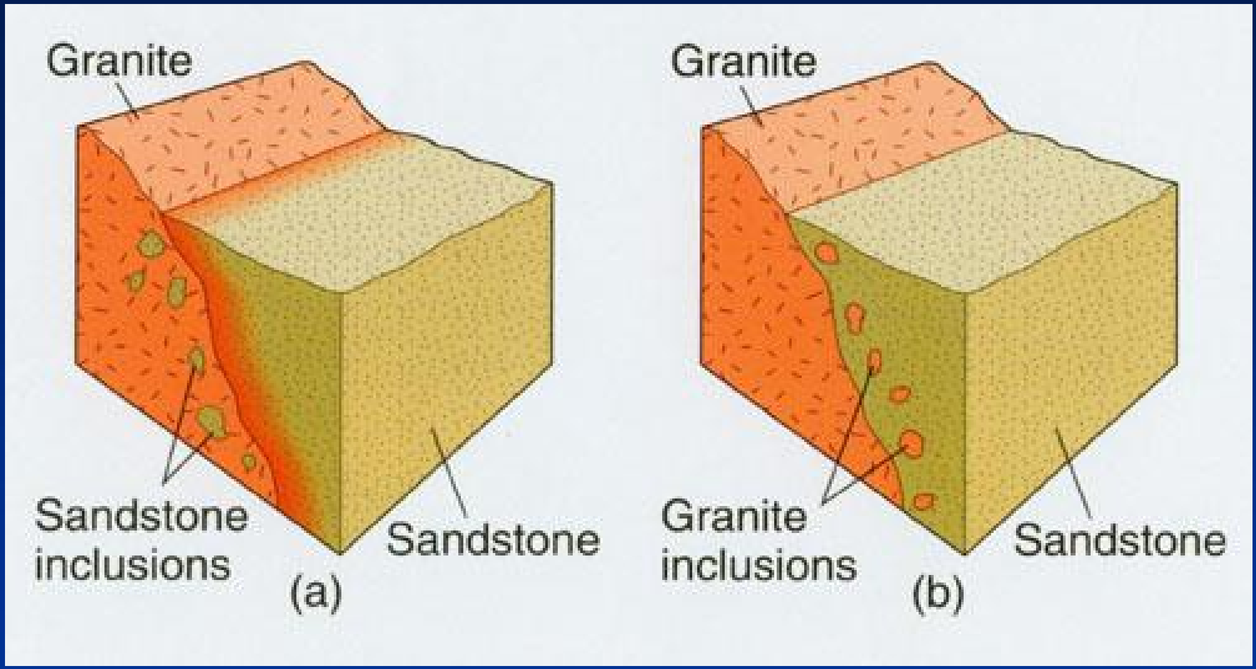
Different sedimentary lithologies can stack on top of each other over time dues to transgressions and regressions

Principle of Cross-Cutting Relations



The rock unit whose layer is being crosscut (disrupted or offset) is older than the rock unit or fault that is doing the crosscutting.

Principle of Inclusions



The rock unit that surrounds the inclusions must be younger than the inclusions.

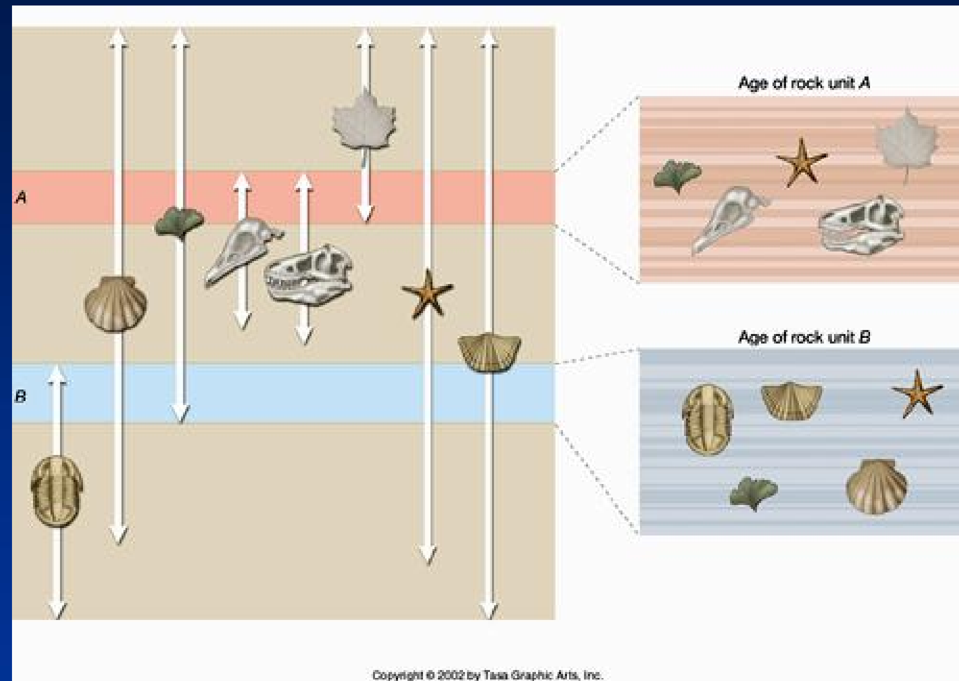
Principle of Fossil Succession

Key Idea:

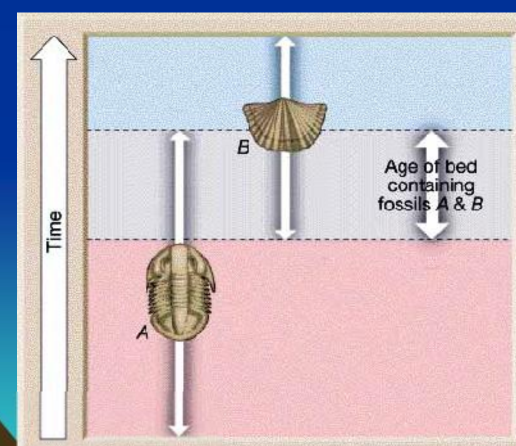
✓ Based on relative dating (law of superposition) and the use of age-specific (index) fossils species.

✓ Unique fossil species of a specific age range are temporally succeeded by other younger fossil species through time.

✓ A rock that contains a specific assemblage of index fossils must be the age of when those organisms (now fossils) were all alive.



Constraining the age (range) of an index fossil assemblage



Index Fossils

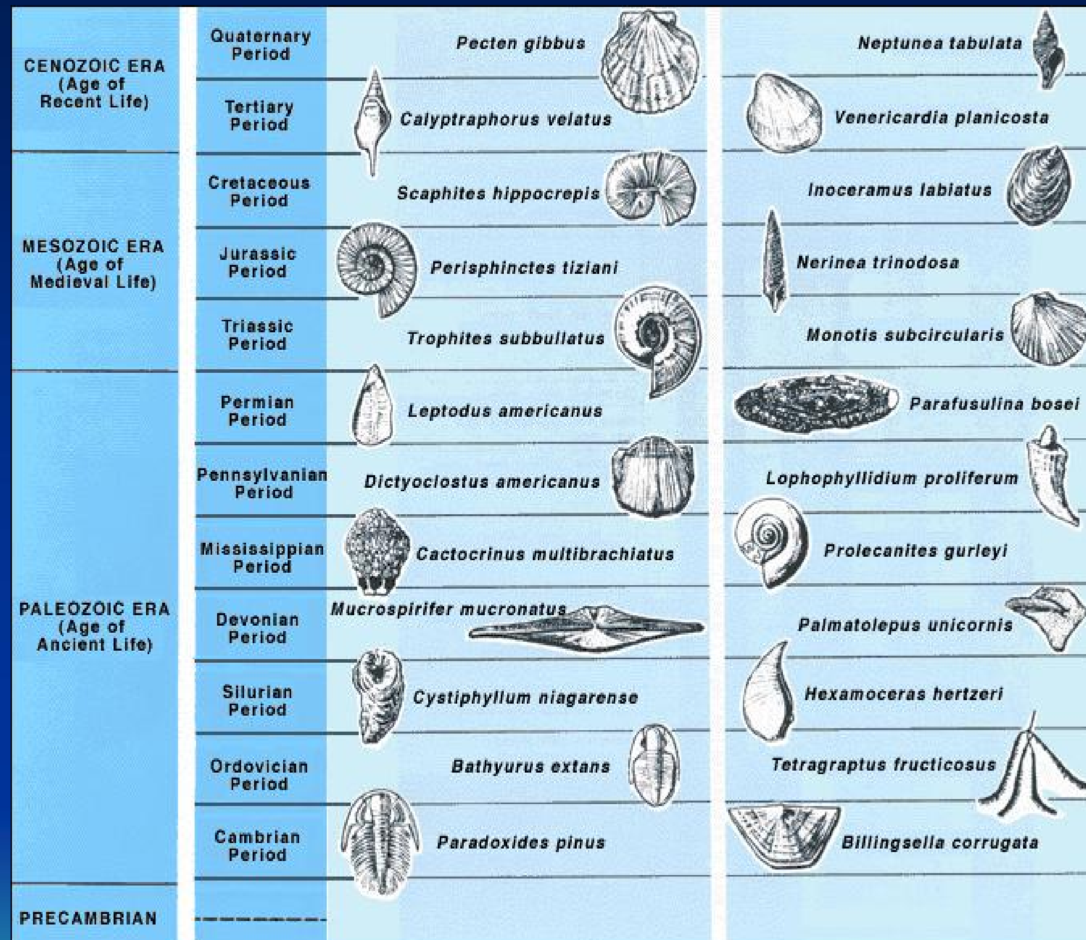
Criteria to be a Useful Index Fossil:

Must have:

1) Narrow time range age

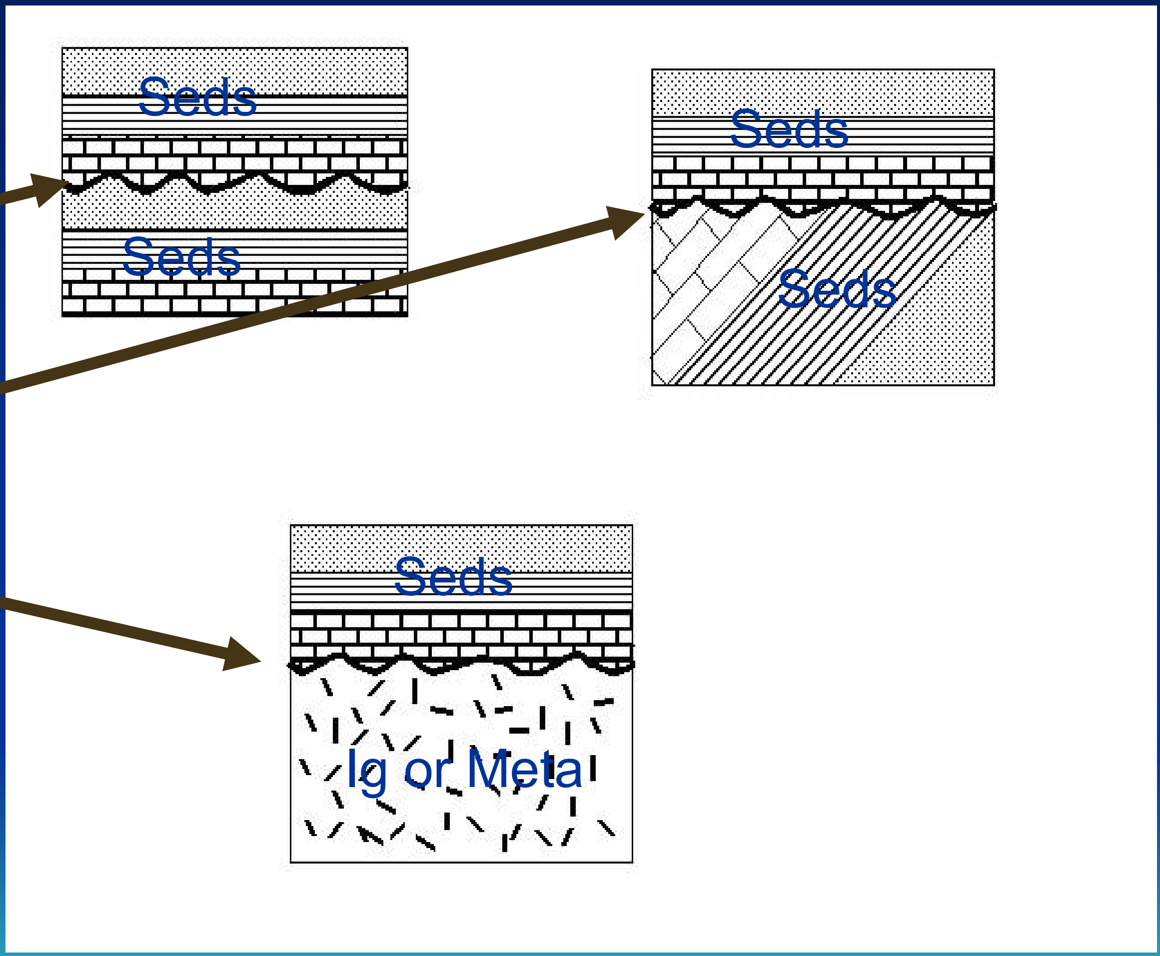
2) Worldwide distribution

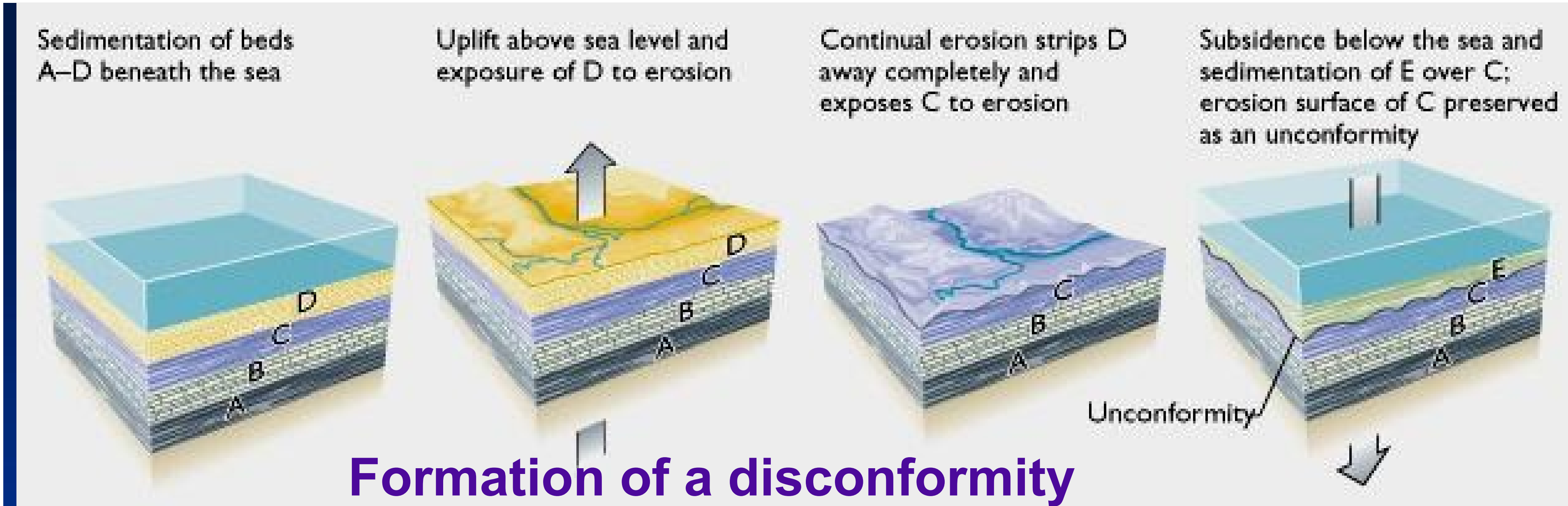
3) Preserve in a wide range of depositional settings



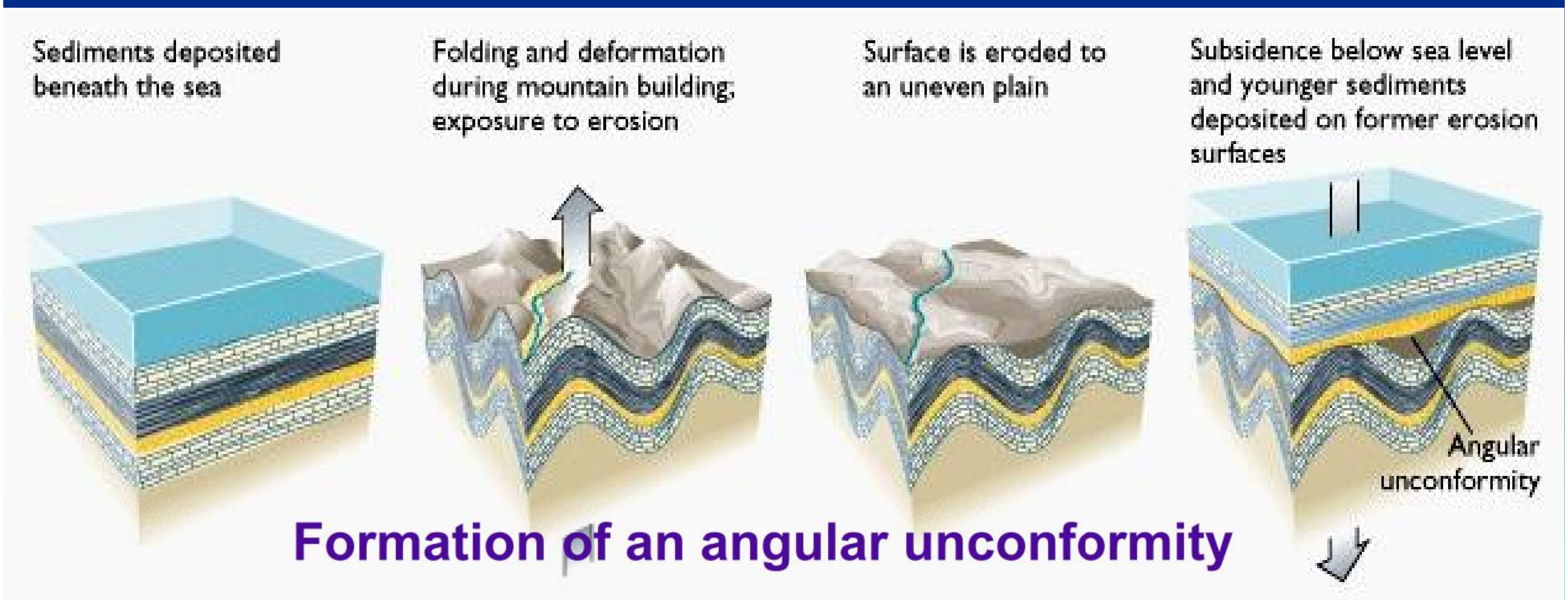
Three Types of Unconformities

1. Disconformity
2. Angular Unconformity
3. Nonconformity





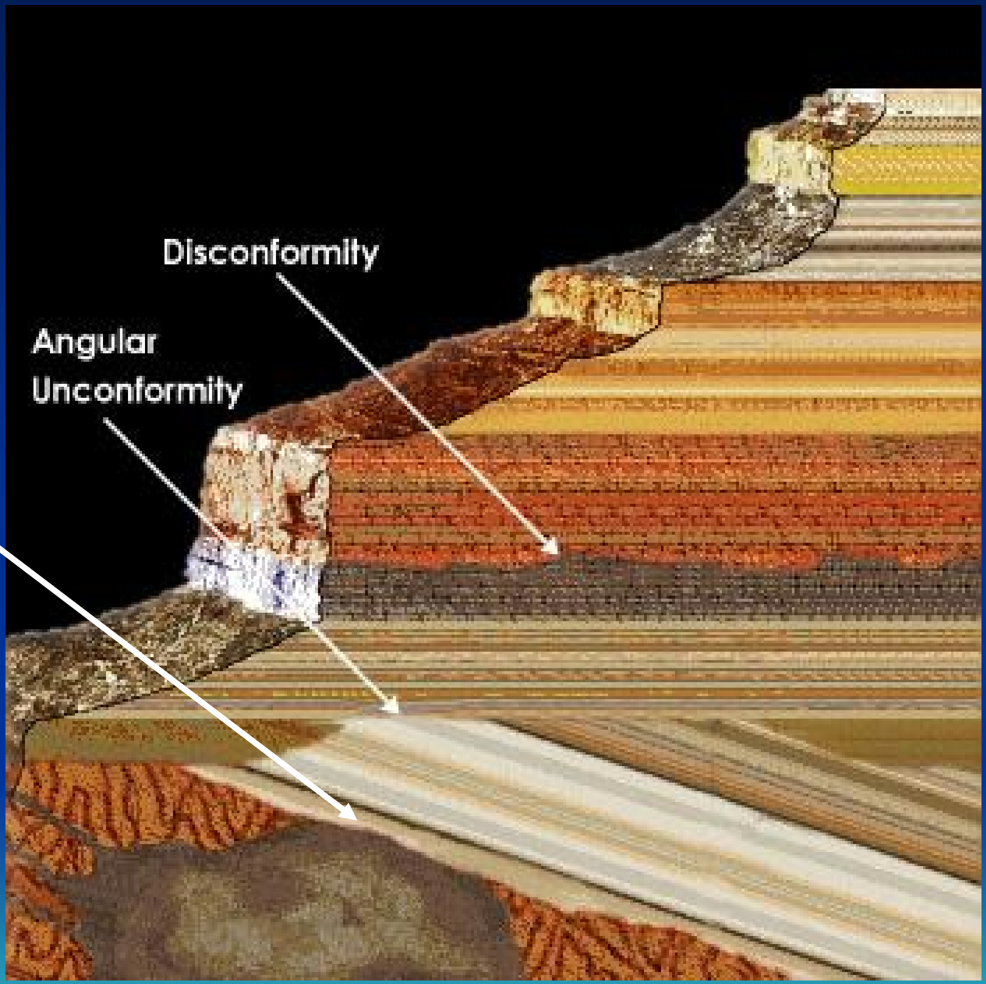
Formation of a disconformity



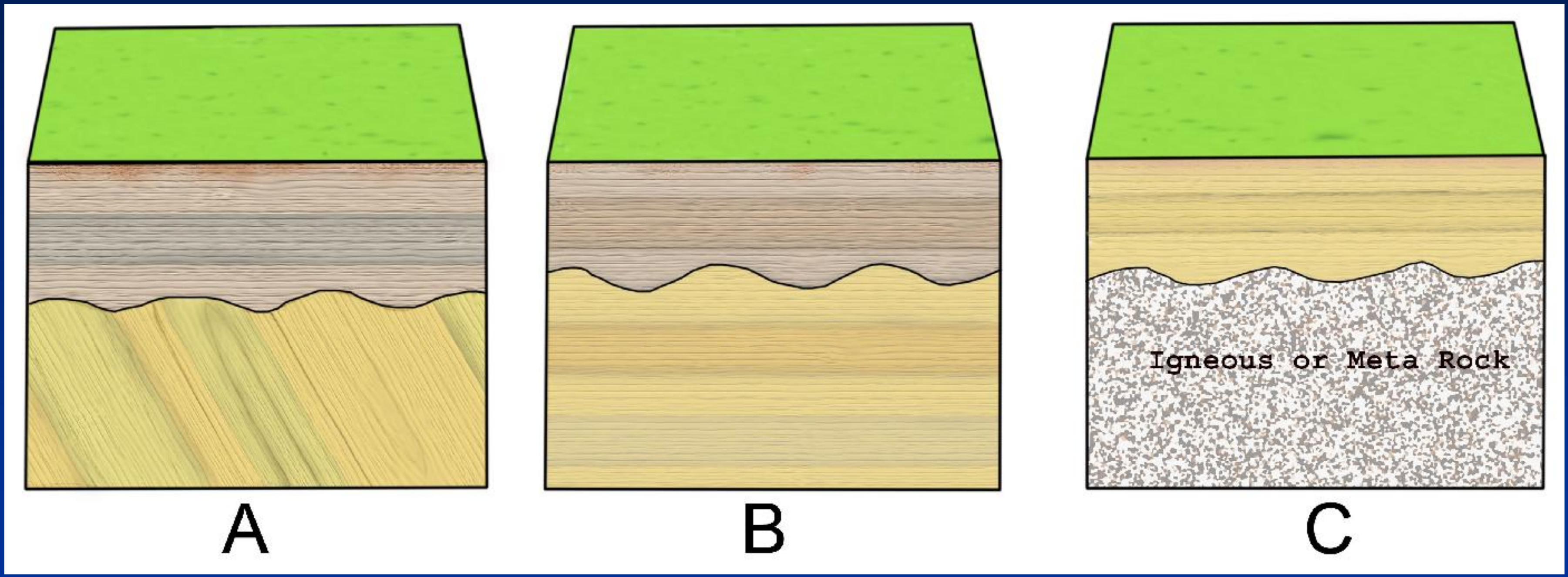
Formation of an angular unconformity

Three Types of Unconformities

1. Disconformity
2. Angular Unconformity
3. Nonconformity

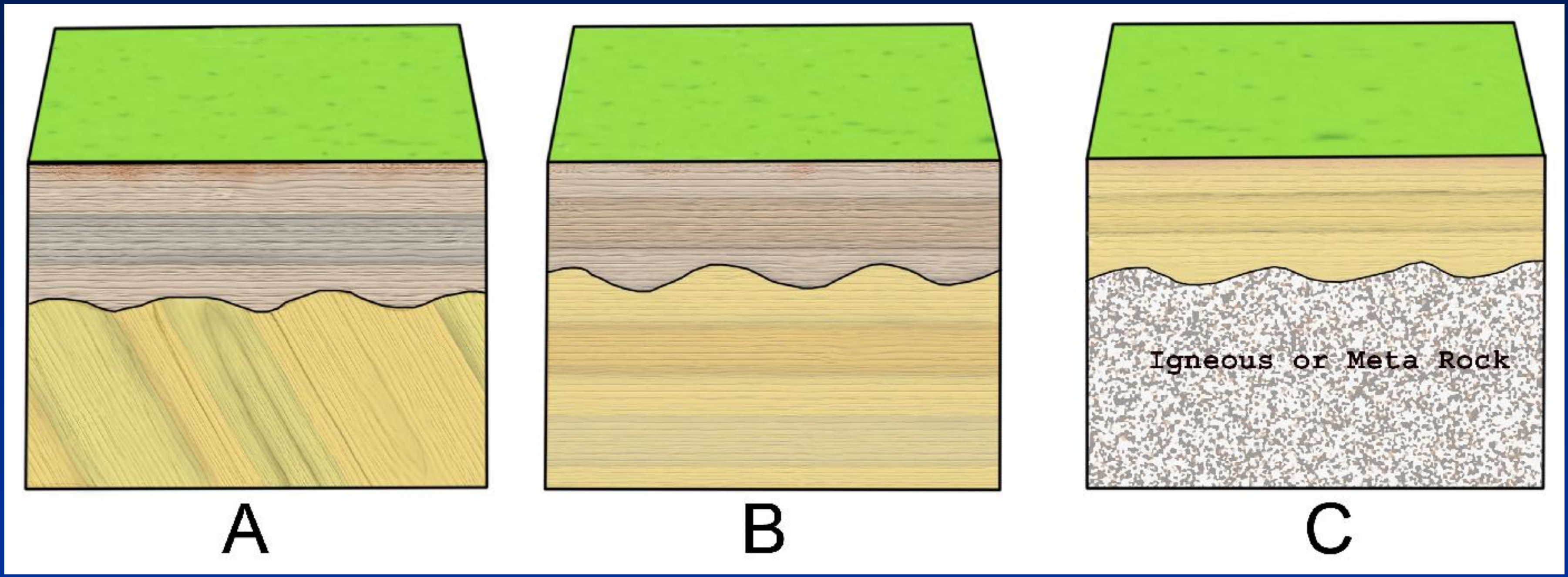


Name the Types of Unconformities



A? ______________ B? ______________ C? ______________

Name the Types of Unconformities



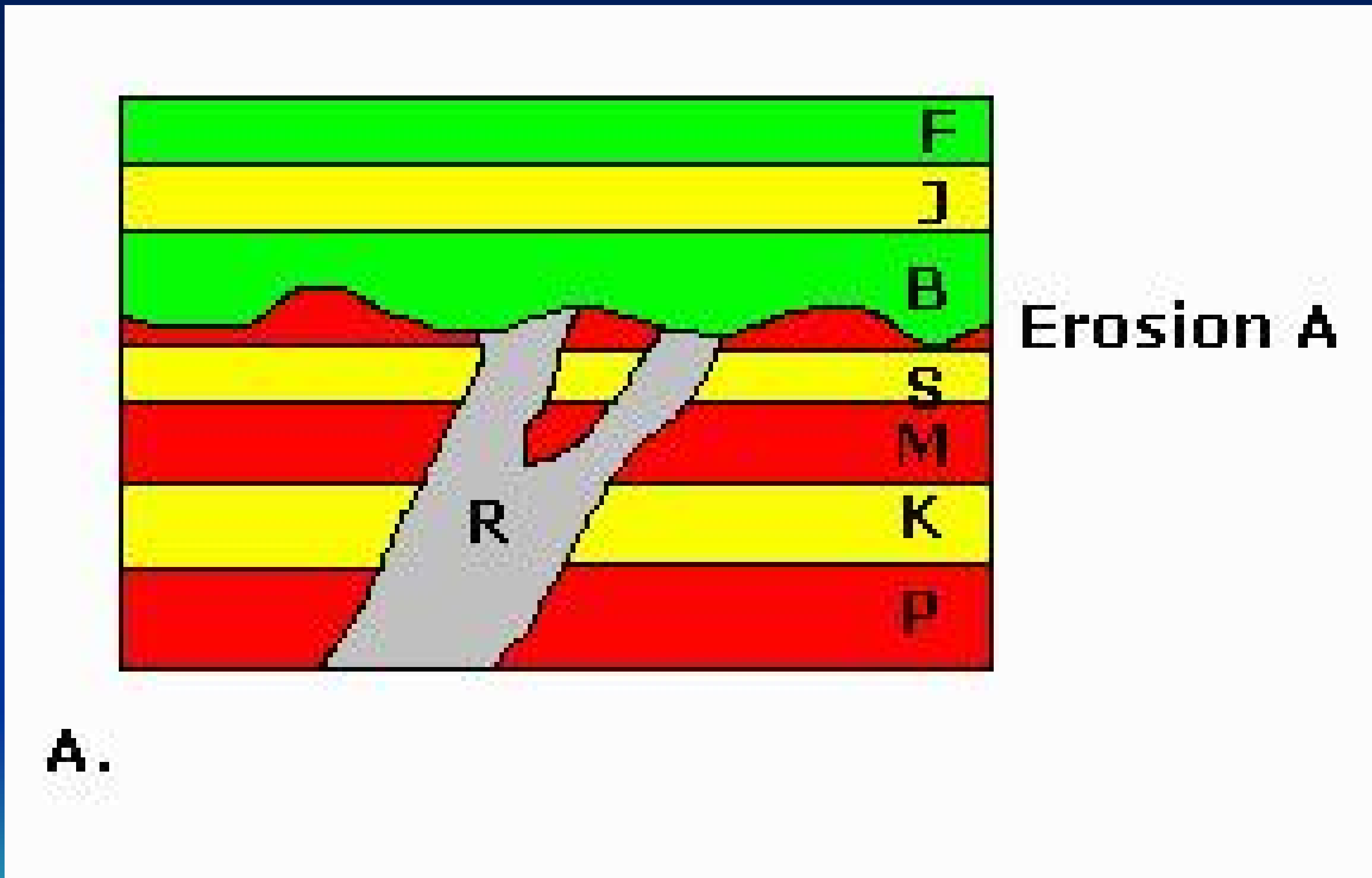
Angular Unconformity

Disconformity

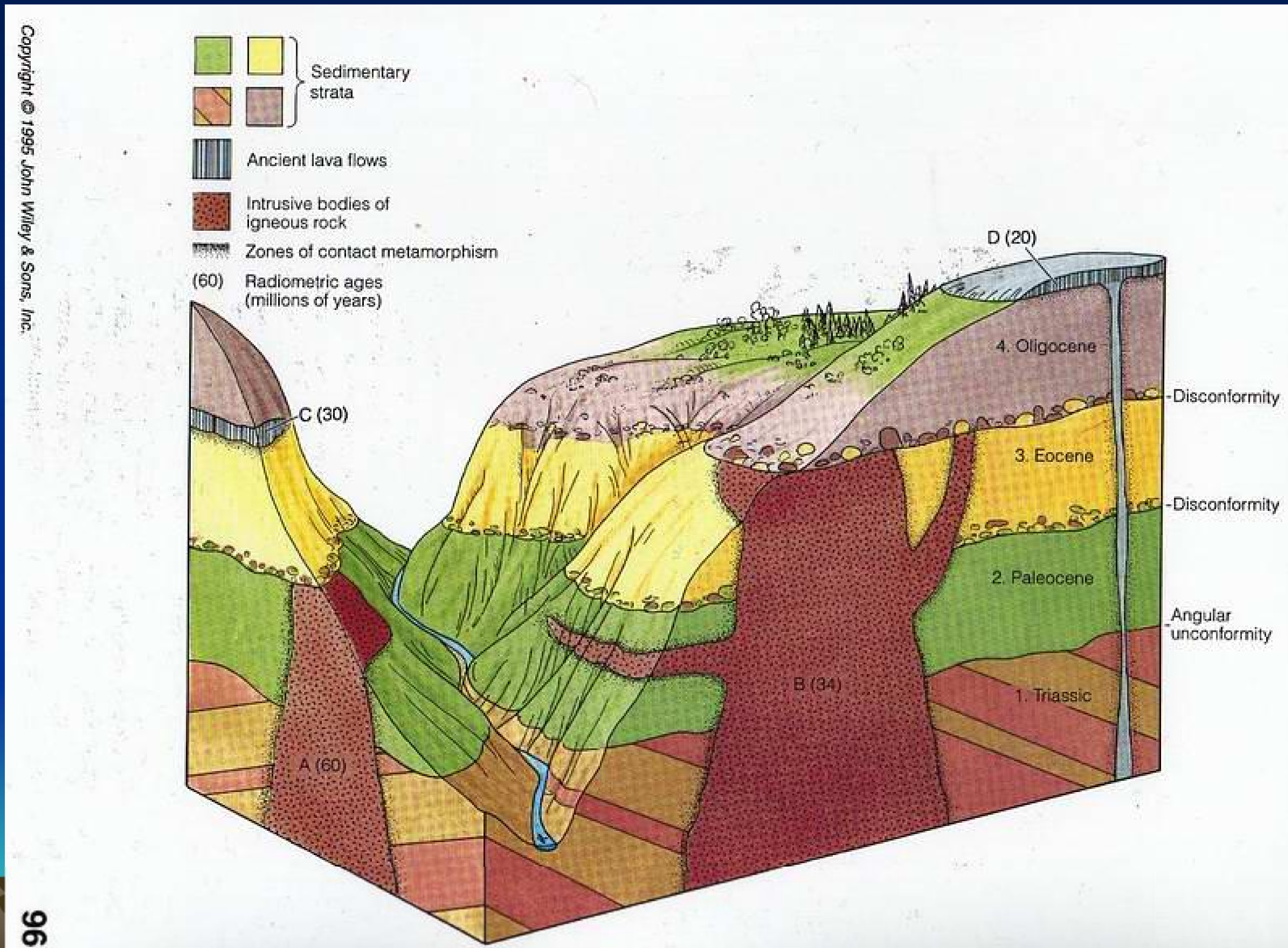
Nonconformity

Which Type of Unconformity?

A Very Simple Geologic Cross Section



3-D Geologic Cross Section



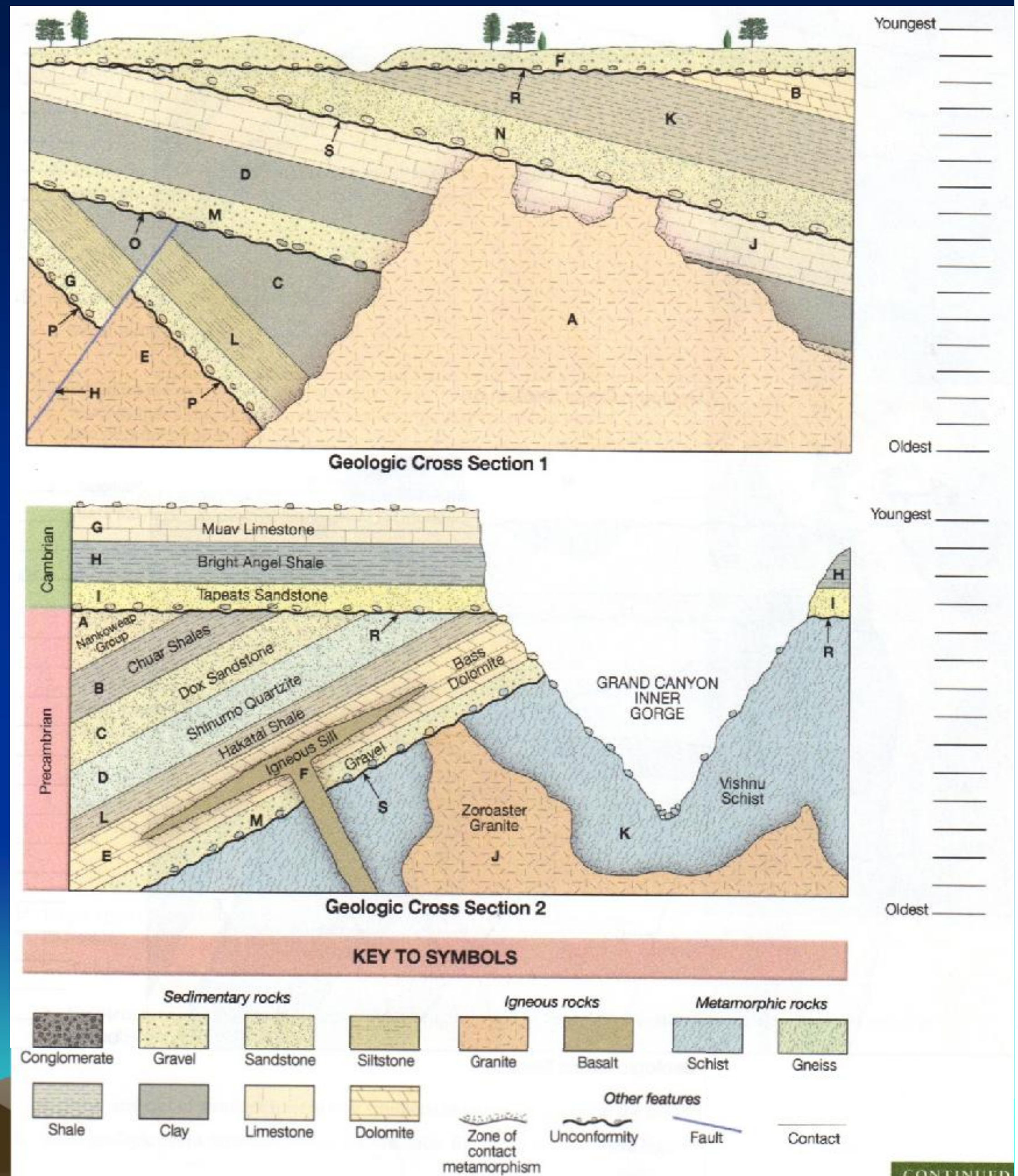
Application of Relative Dating Principles to a Geologic Cross Section

Procedure:

1) Identify all labeled rock formations and structures, including intrusions, faults, and unconformities

2) Use relative dating laws (*mainly the laws of superposition and cross-cutting*) to determine the relative age sequence for all stratigraphic elements – from oldest to youngest.

3) Determine what types of unconformities there are.



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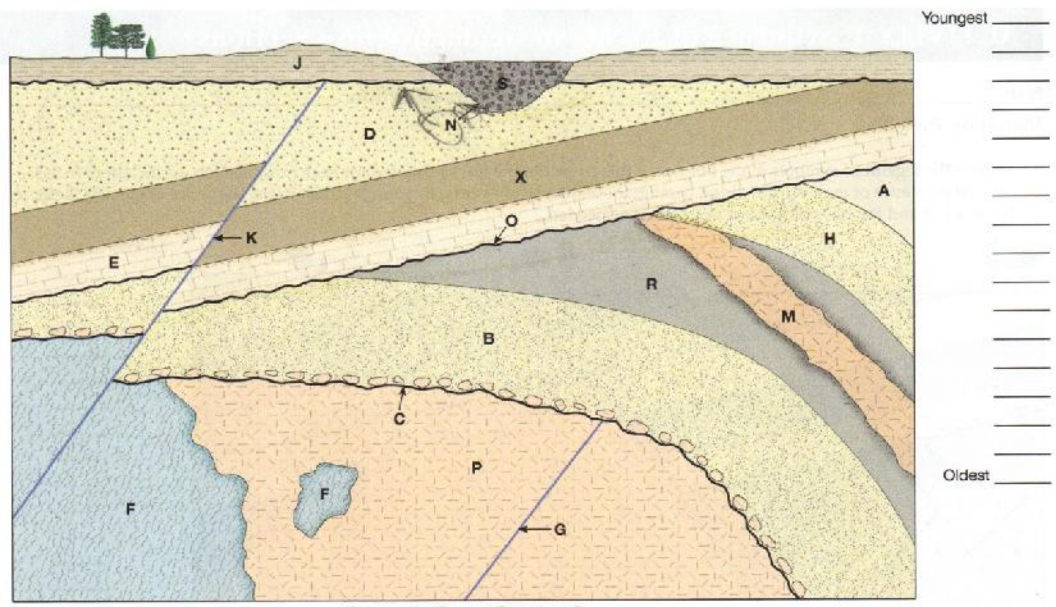
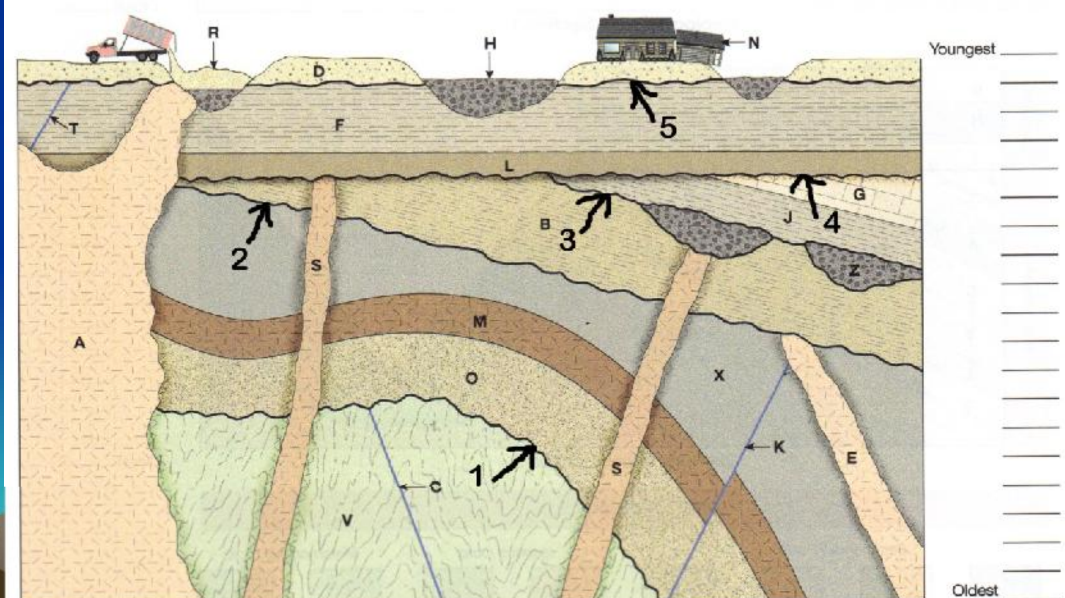
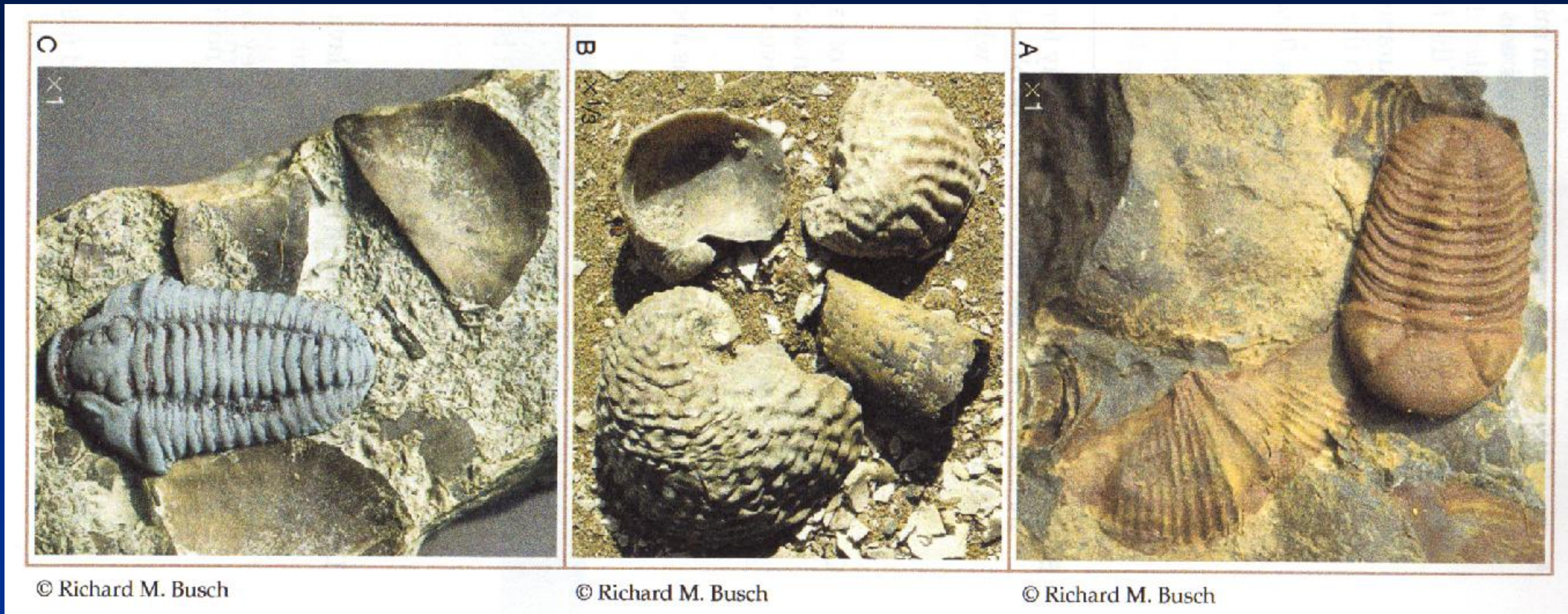


Geologic Cross Section 3



Geologic Cross Section 4

Application of Relative Dating Principles to Fossils



Index Fossils Present Age Range: (in million years

1. ________________________________ __________ mya to _________

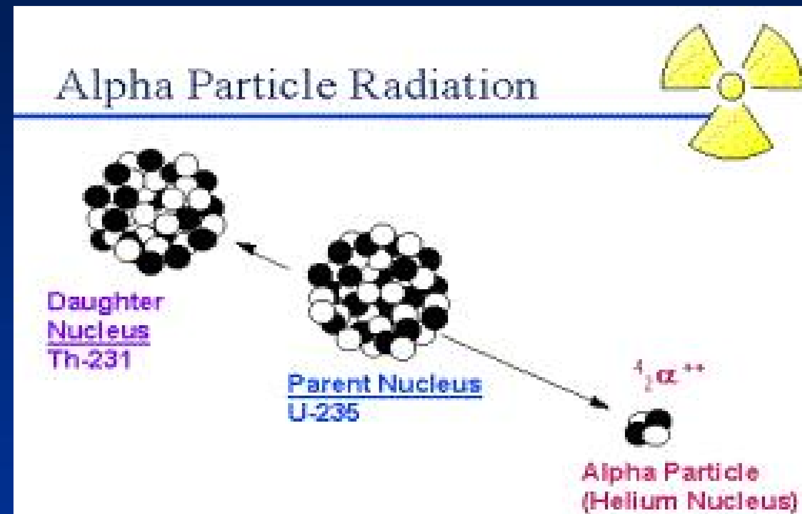
2. ________________________________ __________ mya to _________

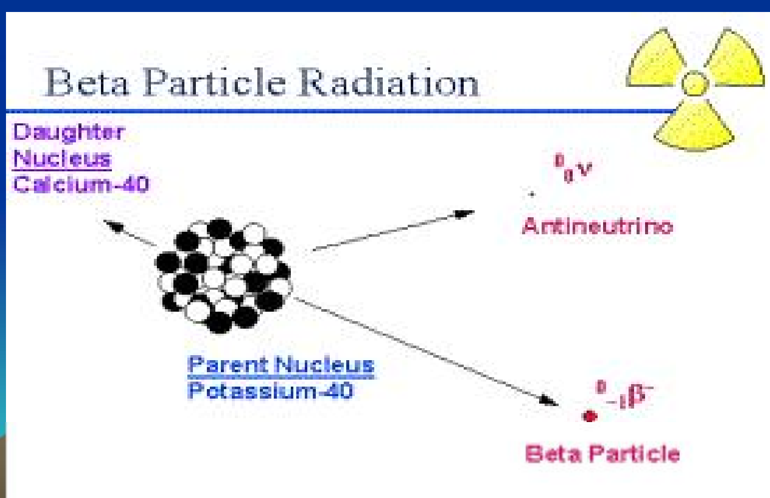
***Resolved* age of sample: __________ mya to _________ mya**

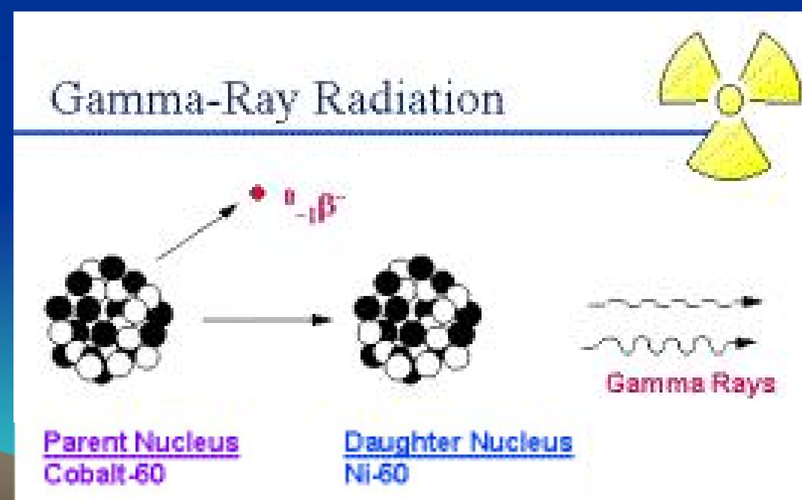
Spontaneous Radioactive Decay

Three Types of Radioactive Decay

1) Alpha Emission
2) Beta Emission
   - Beta minus
   - Beta plus
3) Gamma Emission

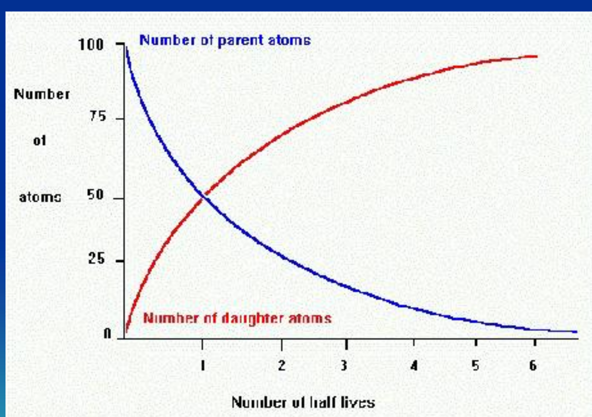


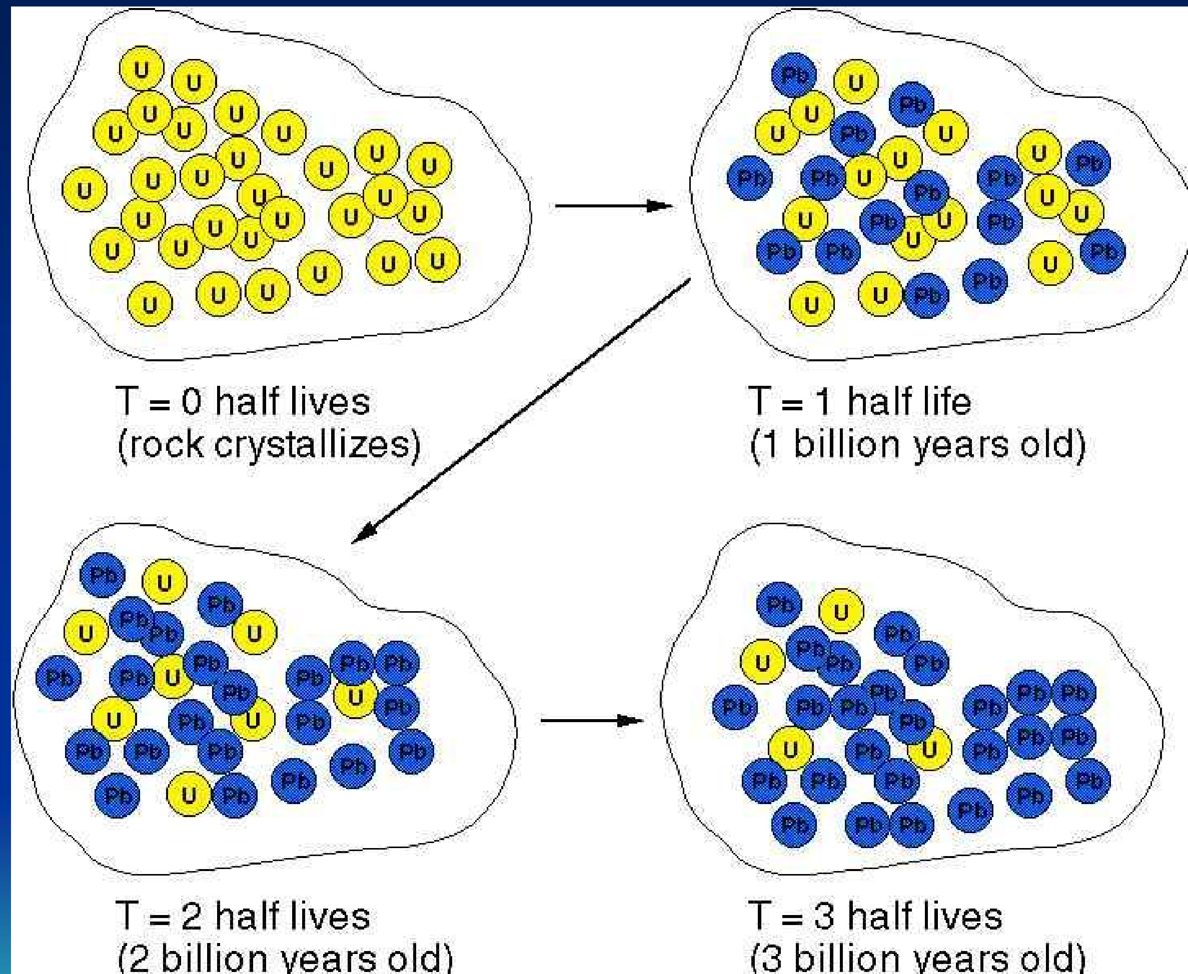




Radiometric Dating of Minerals

Zircons Crystals

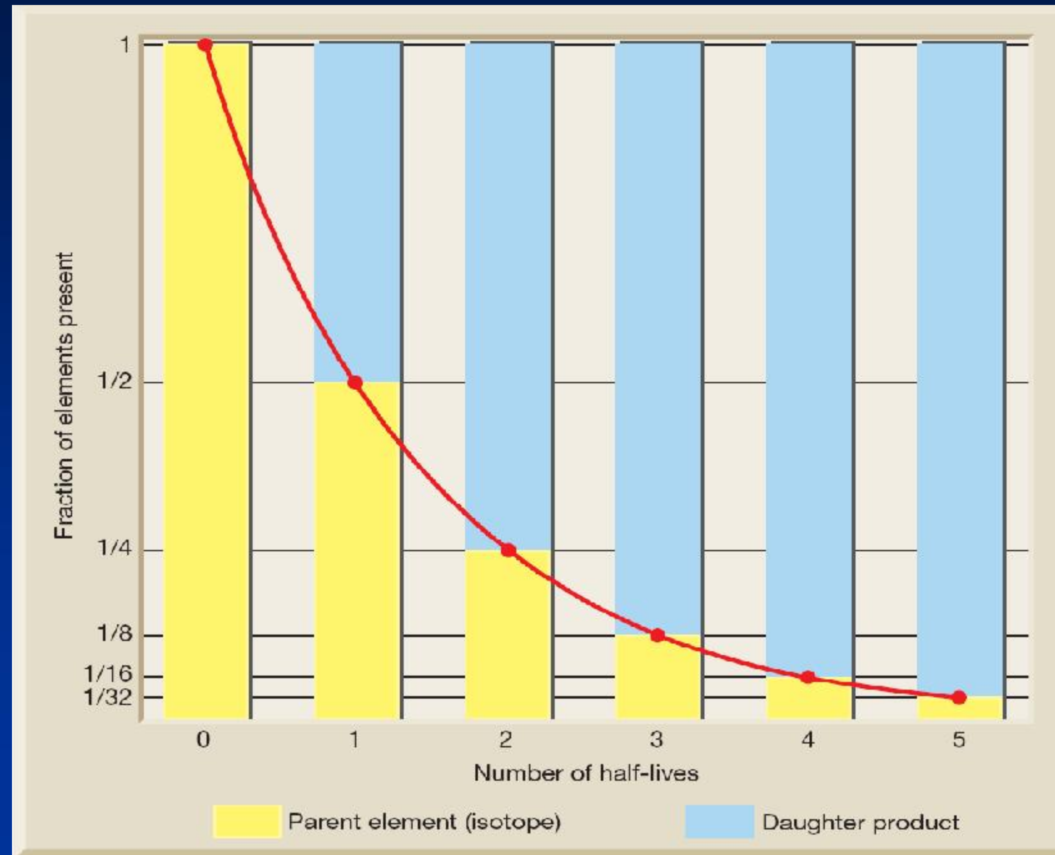


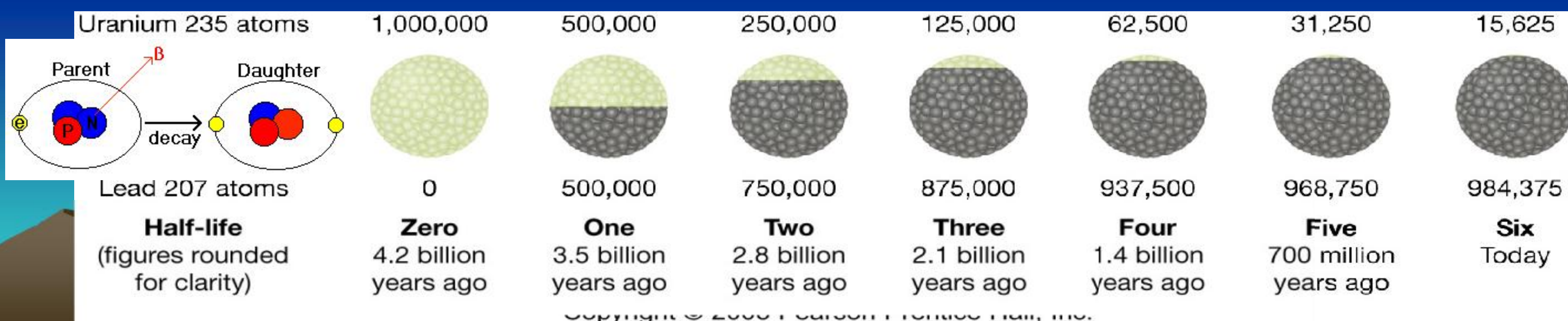


Principles of Radiometric Decay

The Principles

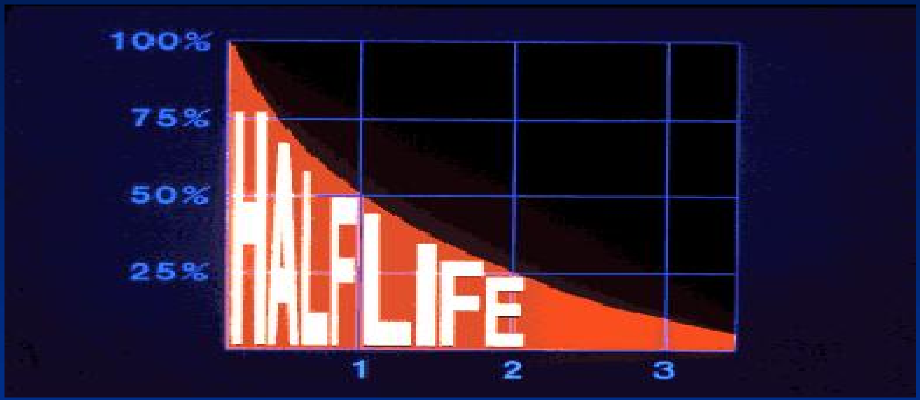
- ✓ Spontaneous decay of unstable parent element into a its unique stable daughter element
- ✓ The half-life of each parent-daughter pair is a constant
- ✓ Age of an igneous rock is determined by measuring the ratio of rock's parent-daughter material

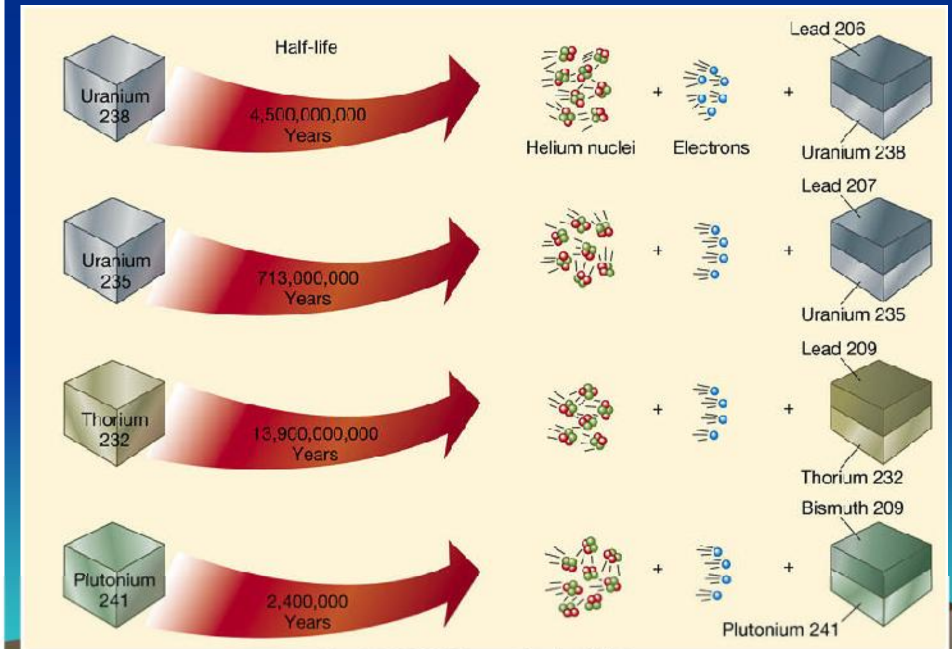




Radiometric Half-Lives

Radioactive Parent/Daughter Pairs and Associated Half-Lives





Parent Isotope	Stable Daughter Product	Currently Accepted Half-Life Values
Uranium-238	Lead-206	4.5 billion years
Uranium-235	Lead-207	713 million years
Thorium-232	Lead-208	14.0 billion years
Rubidium-87	Strontium-87	48.8 billion years
Potassium-40	Argon-40	1.25 billion years
Samarium-147	Neodymium-143	106 billion years

Isotopic Decay Sequence

Unstable Parent

Radioactive Decay Sequence of Uranium-238 Parent Isotope into Lead-206 Daughter Isotope

238 U 4.468E+9 yr 238.05078	a --> 4.270 MeV	234 Th 24.10 da 234.04359	B- --> 6.420 MeV	234 Pa 6.70 hr 234.04330	B- --> 2.197 MeV	234 U 2.455E+5 yr 234.04094	a --> 4.859 MeV
230 Th 7.538E+4 yr 230.03312	a --> 4.770 MeV	226 Ra 1600 yr 226.02540	a --> 4.871 MeV	222 Rn 3.8235 da 222.01757	a --> 5.590 MeV	218 Po 3.10 min 218.00896	a --> 6.115 MeV
214 Pb 26.8 min 213.99979	B- --> 1.024 MeV	214 Bi 19.9 min 213.99869	a --> 3.272 MeV	210 Tl 1.30 min 209.99006	B- --> 5.484 MeV	210 Pb 22.3 yr 209.98417	a --> 5.484 MeV
206 Hg 8.15 min 205.97749	B- --> 1.308 MeV	206 Tl 4.199 min 205.97609	B- --> 1.533 MeV	206 Pb 24.1% 205.97444 Stable **Daughter**			

- Half-life of U-238/Pb-206 system is 4.5 billion years

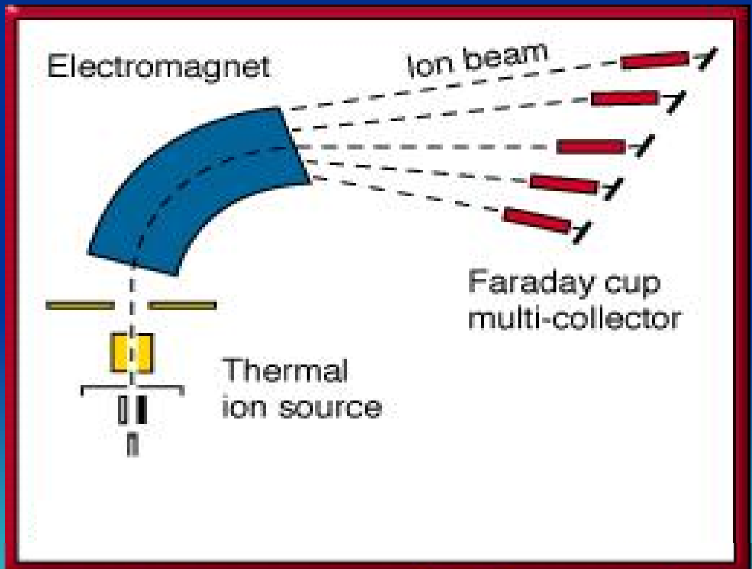
Radiometric Dating Method

Analysis of Parent/Daughter Isotopic Compositions in Rocks

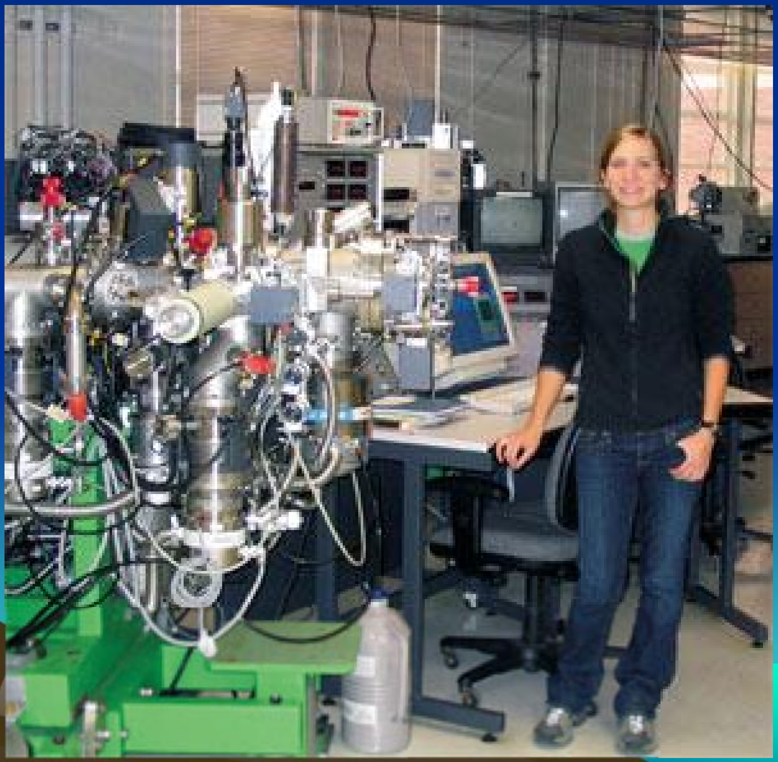
✓Parent and daughter elements are isolated and refined from host mineral using conventional wet chemistry methods.

✓Geochronologists determine the isotopic abundances of each paired parent and daughter element using a mass spectrometer.

✓ Isotopic abundance data are then used to determine rock age using the decay formula.



Mass Spectrometer



Radiometric Dating Method

Radioactive Decay of Parent Isotope into a Daughter Isotope

The mathematical expression that relates radioactive decay to geologic time is called the ***age equation***:

More simply, all you need to do is multiply the number of elapsed half-lives of the parent-daughter's isotopic system in the mineral (or whole rock) by the system's half-life decay constant:

$$t = \frac{1}{\lambda} \ln\left(1 + \frac{D}{P}\right)$$

where t is the age of the rock or mineral specimen,
D is the number of atoms of a daughter product today,
P is the number of atoms of the parent isotope today,
ln is the natural lograithm (logarithm to base e), and
λ is the appropriate decay constant.

(The decay constant for each parent isotope is related to its half-life, $t^{1/2}$ by the following expression: $t^{1/2} = \frac{\ln 2}{\lambda}$

Age Formula: ***# of half-lives elapsed x half-life constant***

Radiometric Dates of Earth Rocks

The Earths Oldest Rocks

Description	Technique	Age (in billions of years)
Amitsoq gneisses (western Greenland)	Rb-Sr isochron	3.70 +- 0.12
Amitsoq gneisses (western Greenland)	207Pb-206Pb isochron	3.80 +- 0.12
Amitsoq gneisses (western Greenland) (zircons)	U-Pb discordia	3.65 +- 0.05
Amitsoq gneisses (western Greenland) (zircons)	Th-Pb discordia	3.65 +- 0.08
Amitsoq gneisses (western Greenland) (zircons)	Lu-Hf isochron	3.55 +- 0.22
Sand River gneisses (South Africa)	Rb-Sr isochron	3.79 +- 0.06

Radiometric Dates of Moon Rocks

Oldest Moon Rocks

Mission	Technique	Age (in billions of years)
Apollo 17	Rb-Sr isochron	4.55 +- 0.1
Apollo 17	Rb-Sr isochron	4.60 +- 0.1
Apollo 17	Rb-Sr isochron	4.49
Apollo 17	Rb-Sr isochron	4.43 +- 0.05
Apollo 17	Sm-Nd isochron	4.23 +- 0.05
Apollo 17	Sm-Nd isochron	4.34 +- 0.05
Apollo 16	40Ar/39Ar	4.47
Apollo 16	40Ar/39Ar	4.42

Radiometric Dates of Meteorites

Meteorites

Description	Technique	Age (in billions of years)
Juvinas (achondrite)	Mineral isochron	4.60 +- 0.07
Colomera (silicon inclusion, iron met.)	Mineral isochron	4.61 +- 0.04
Carbonaceous chondrites	Whole-rock isochron	4.69 +- 0.14
Bronzite chondrites	Whole-rock isochron	4.69 +- 0.14
Krahenberg (amphoterite)	Mineral isochron	4.70 +- 0.1
Norton County (achondrite)	Mineral isochron	4.7 +- .1

Radio-Isotopic Dating Activity

Applied to Stratigraphy in Conjunction with Relative Dating

Procedure:

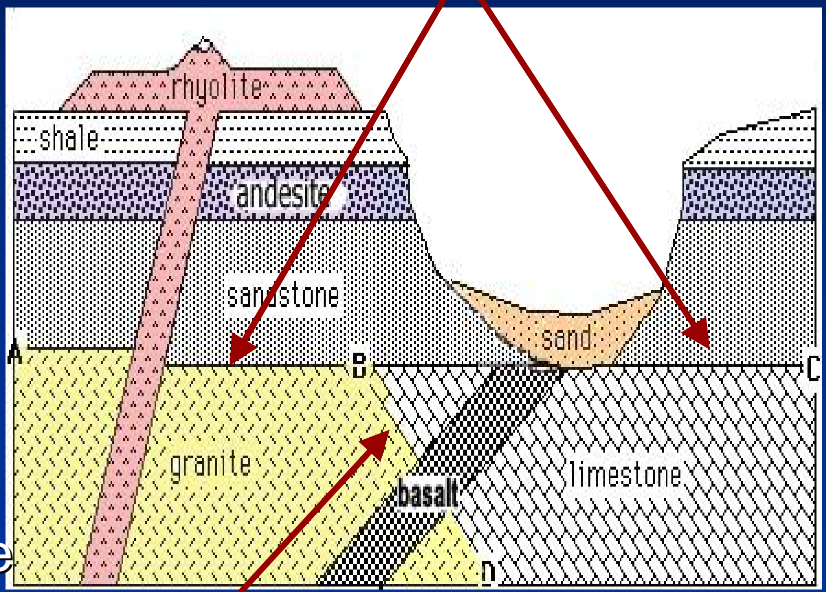
1) Use relative dating laws to determine the relative age sequence for all stratigraphic elements – from oldest to youngest.

2) Identify all igneous units and determine their absolute ages using the radio-isotopic method

3) Write absolute ages on the relative date list

4) Use relative and

Unconformity A - C



Unconformity B - D

Youngest ________

____

____

____

____

____

____

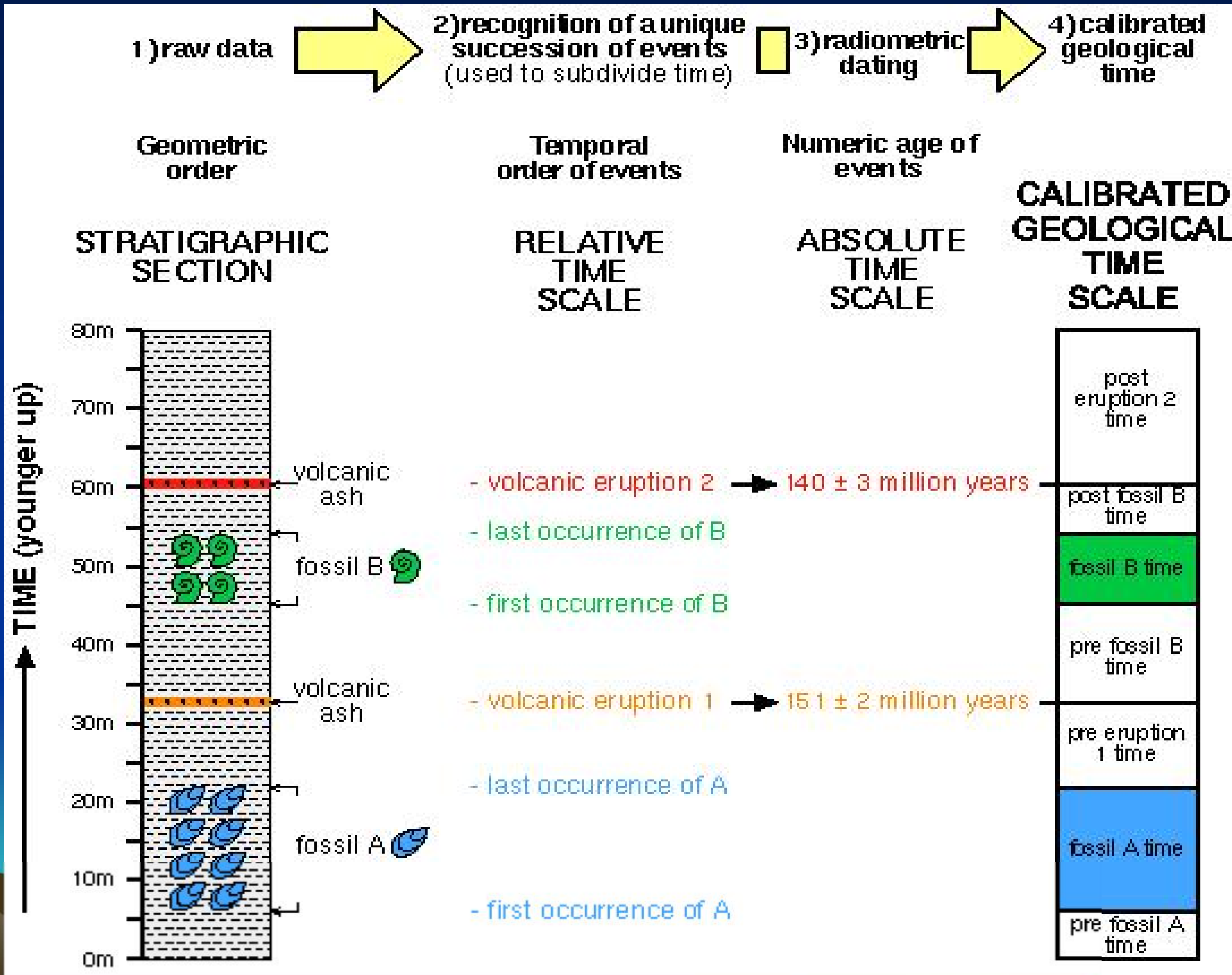
____

____

Oldest ________

Note: There are four igneous rock units

Combined Use of Relative and Absolute Dating



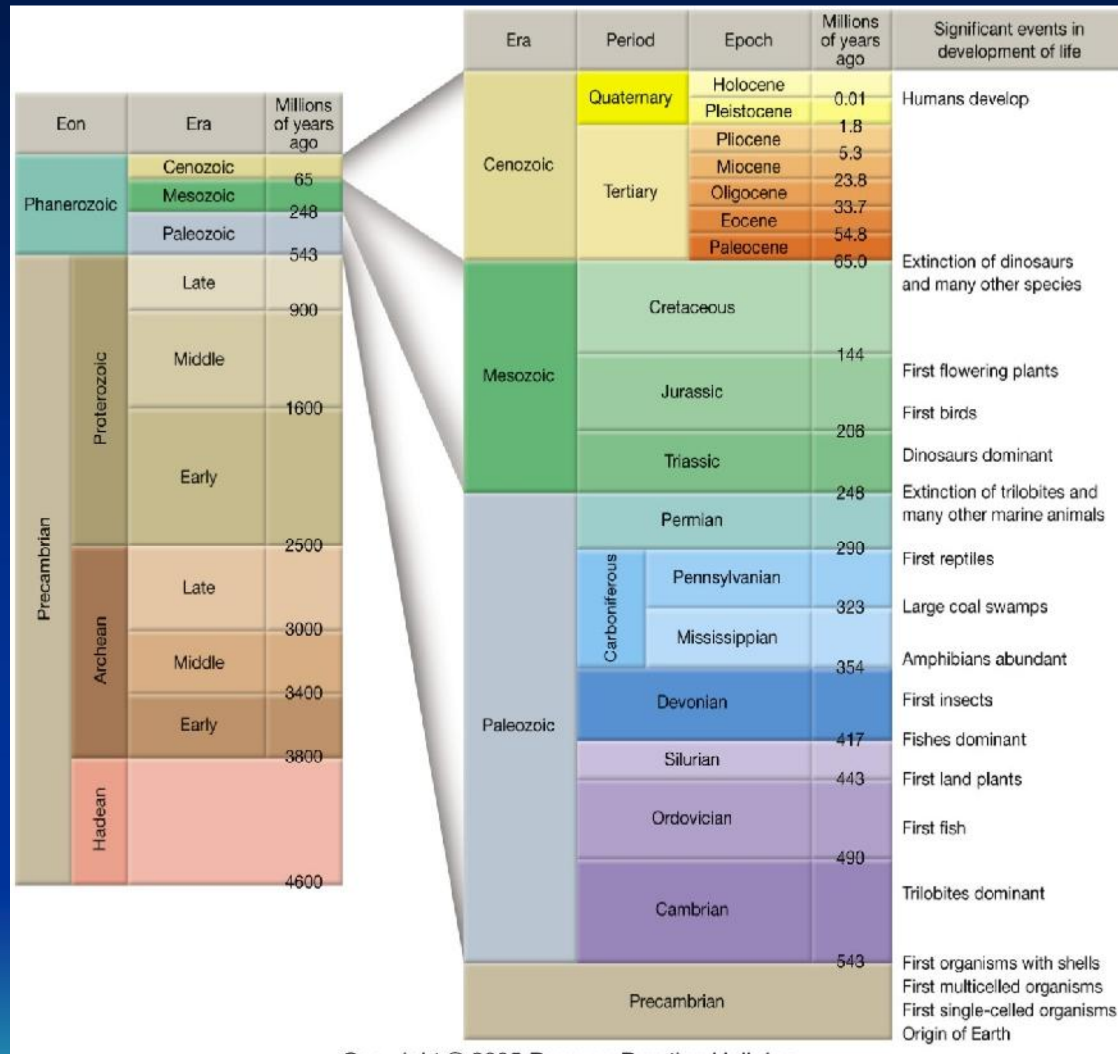
THE GEOLOGICAL TIMESCALE

Key Ideas:

Originally based on relative dating and the use of age-specific (index) fossils

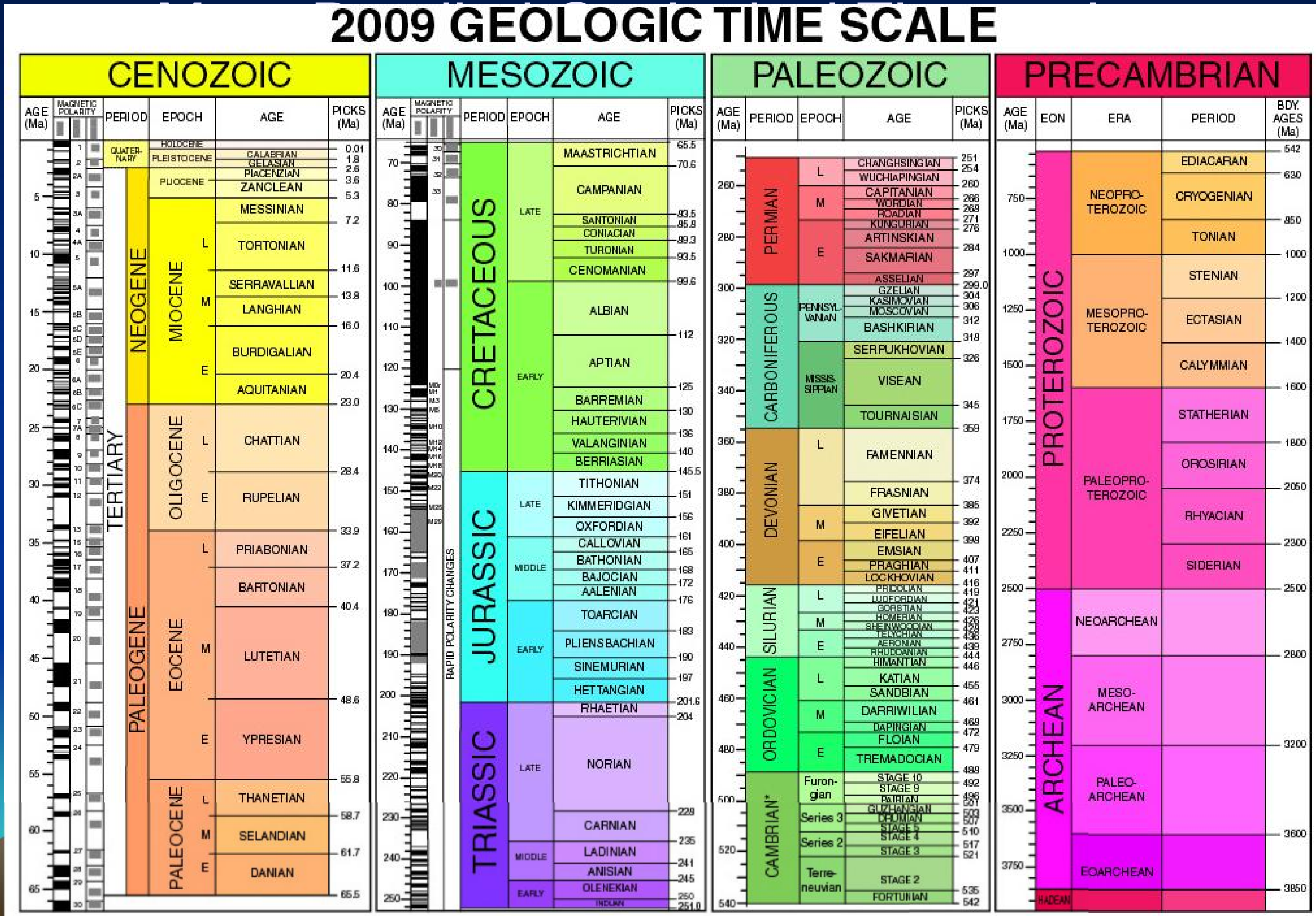
✓ Periods separated by major mass extinction events

✓ Numeric ages derived from radiometric analysis of igneous rocks found within the stratigraphic record

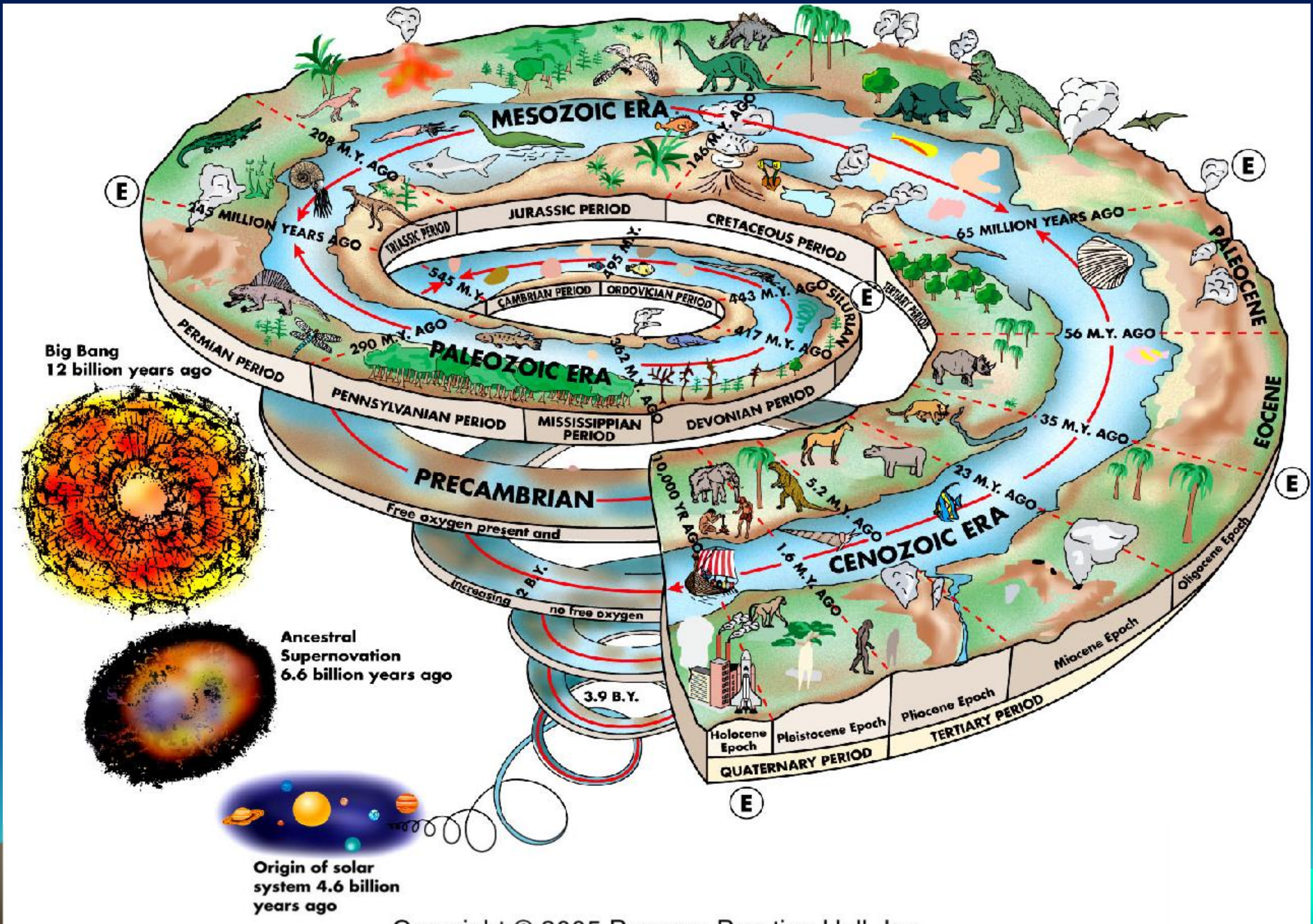


Note: You will need to memorize the basic geo-timescale for the final exam.

THE COMPLETE GEOLOGICAL TIMESCALE



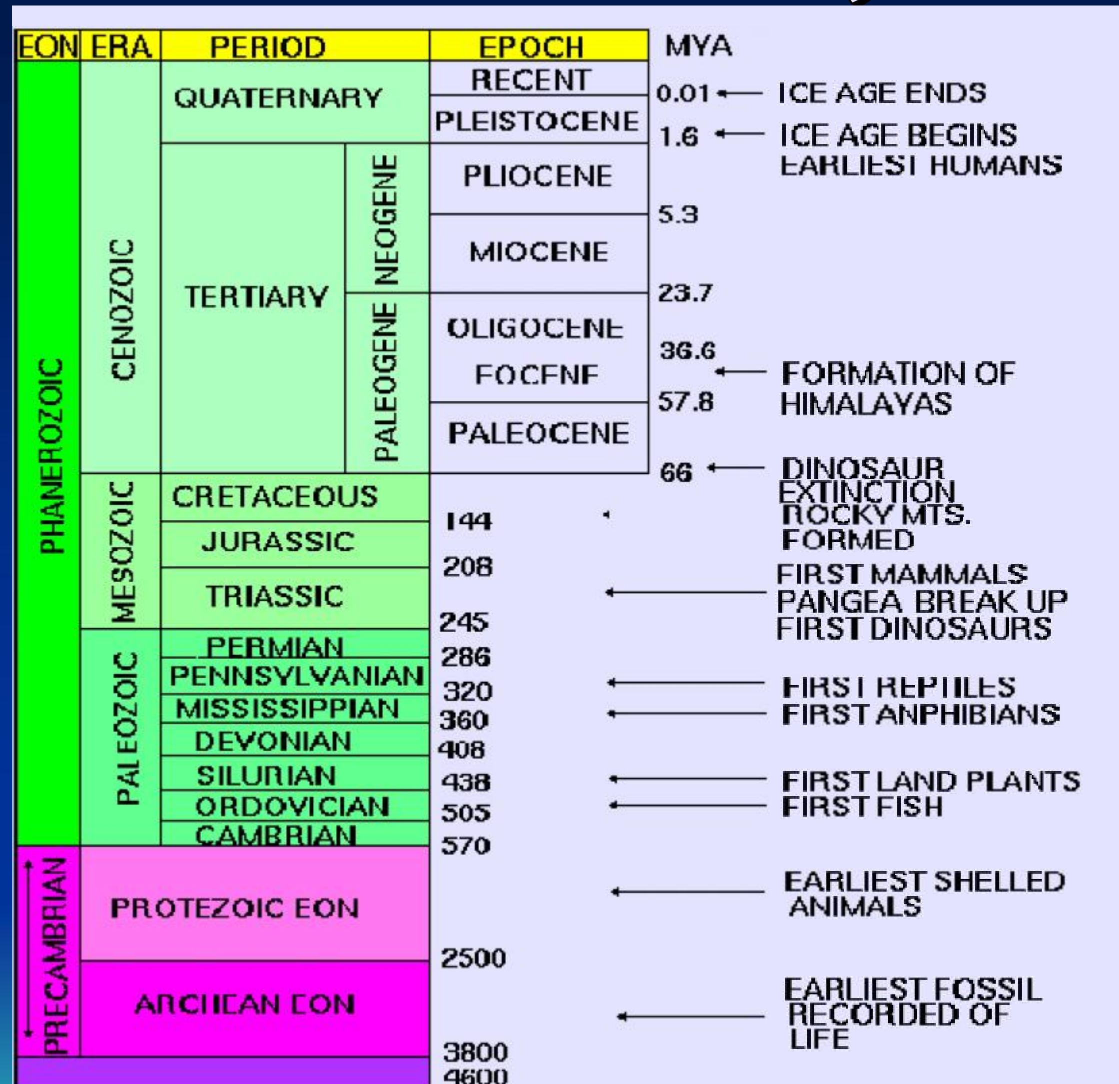
The Twisted Geological Timescale



THE GEOLOGICAL TIMESCALE QUIZ

Need to Memorize:

1) The 2 Eons
2) The 5 Eras
3) The 12 Periods
4) The 7 Epochs
5) The Age of Earth
6) Age of Beginning of Paleozoic Period
7) Age of Beginning of Mesozoic Period
8) Age of Beginning of Cenozoic Period



Note: You will need to memorize this basic geo-timescale for the final exam.

Head's-Up for Next Week's Lab

Earthquakes

Next Week's Lab Activities

1) Measure Epicenter and Magnitude
2) Ground Motion Experiment
3) Measure Fault Displacement

Preparation

Recommended Pre-Lab Web Activities (Click on Link)

1) Learn About Earthquakes - USGS Site
2) Virtual Earthqauke!
3) World ocean bottom features and Tectonic plate boundaries

EARTHQUAKE TOPICS

What are Earthquakes?

Where and How do Earthquake Form?

How are Earthquakes Measured?

What are the Effects of Earthquakes?

Can we Predict Earthquakes?

How can we Prepare for an Earthquake?