Geologic Time

I. Principle of Uniformitarianism

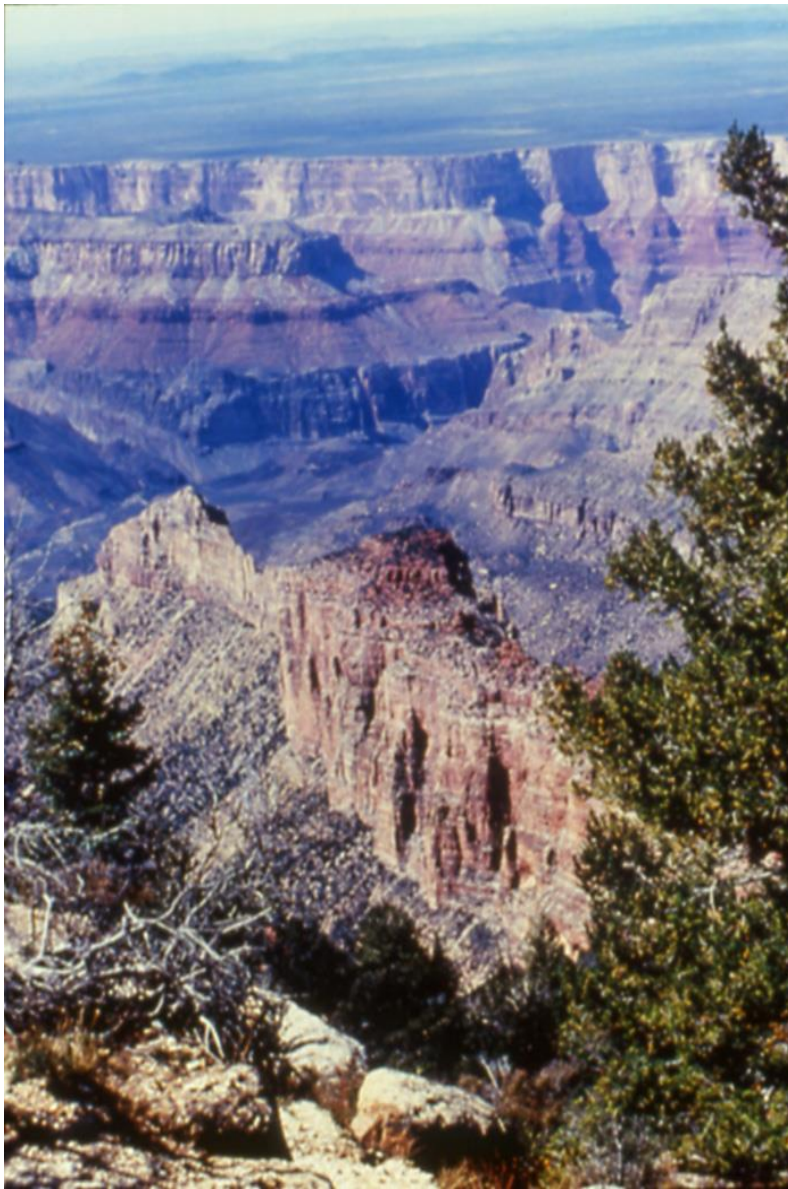
II. Determination of Relative Age

III. Absolute Age Determination

IV. Unconformity

V. Geologic Correlation

VI. The Geologic Time Scale& the Age of The Earth



(I) **Principle of Uniformitarianism**

"Present is key to past"

Current physical processes have also operated in geologic past

(proposed by James Hutton in 1700's).

1. Uniformity of law
2. Uniformity of methodology
3. Uniformity of kind
4. Uniformity of degree

Some exceptions:

- Bombardment of asteroids
- Formation of Komatiite
- Evolution of life

Catastrophism

consisted of epochs of paroxysmal and catastrophic action interposed between periods of comparative tranquility

Current consensus:

Earth's history is a slow, gradual process punctuated by occasional natural catastrophic events that have affected Earth and its inhabitants.

Types of Geologic Time

Relative Age vs. Absolute Age

- **Absolute Age**:

  age of rock (or geologic event) in years

- **Relative Age**:

age of one rock/event with respect to another (sequence of events)

Some exercises

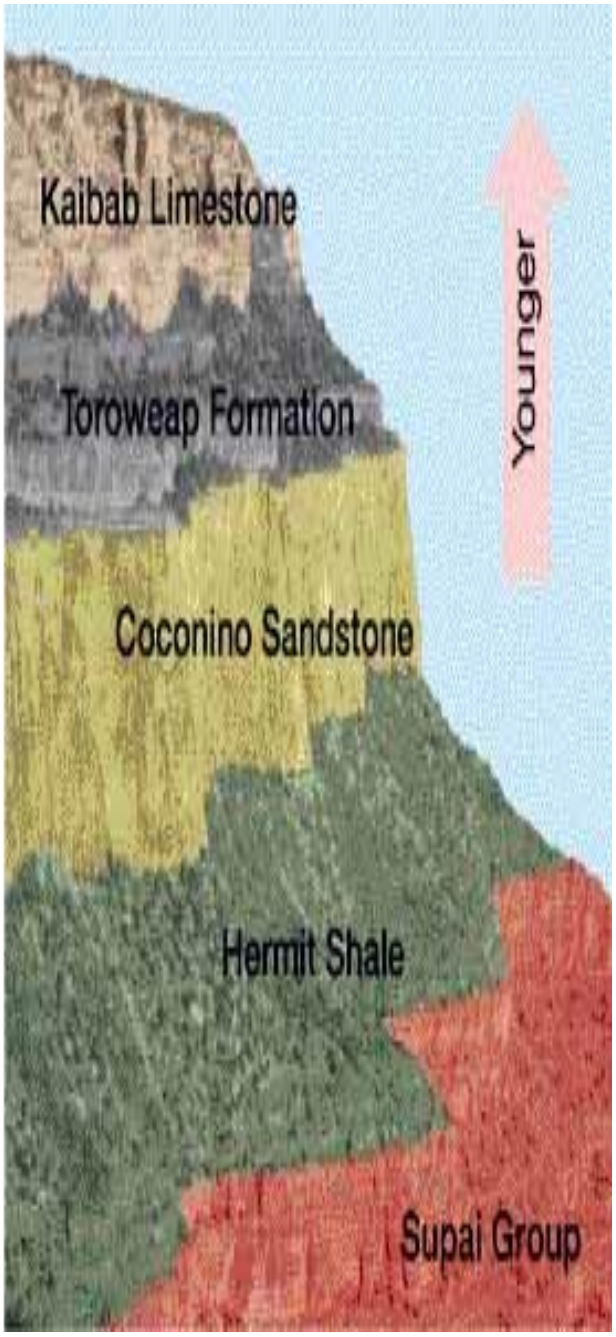
- The dinosaur was extinct at the **Cretaceous**
- The sediment was deposited at **100 years** ago
- The volcano was erupted at **7000 years** ago
- The fossil appeared in the **Ordovician** strata
- The last ice age terminated **5000 years before human civilization**

(II) Determination of Relative Age

by applying stratigraphic principles:

(A)Principle of Original Horizontality

: water-laid sediments are deposited in **horizontal layering (bedding).**



(B) Principle of Superposition

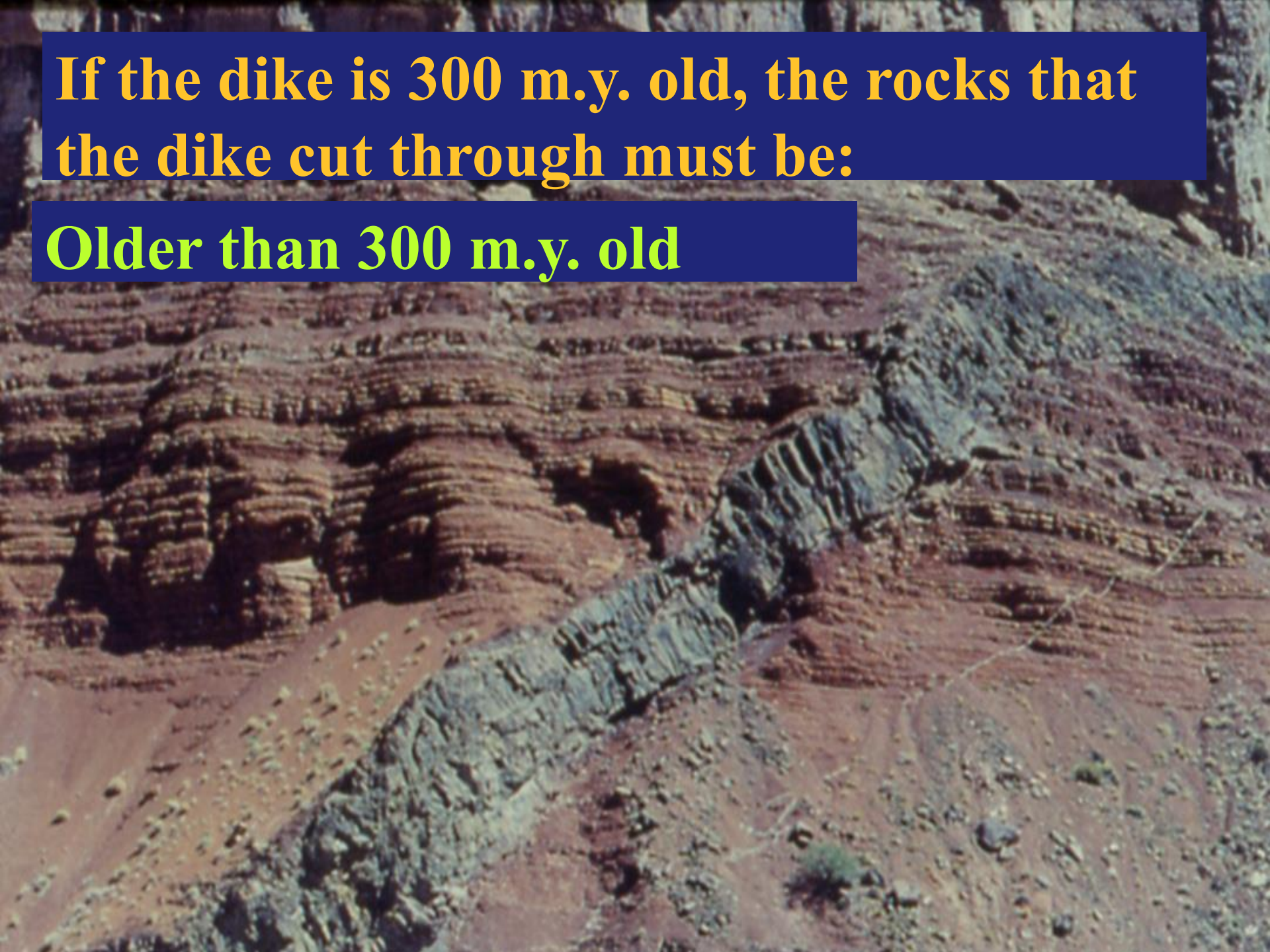
-moving upward through sequence of sedimentary rocks,

age becomes younger

(C) Principle of Cross-Cutting Relations

If an event cuts across rock layers,

the event is younger than the rock layers

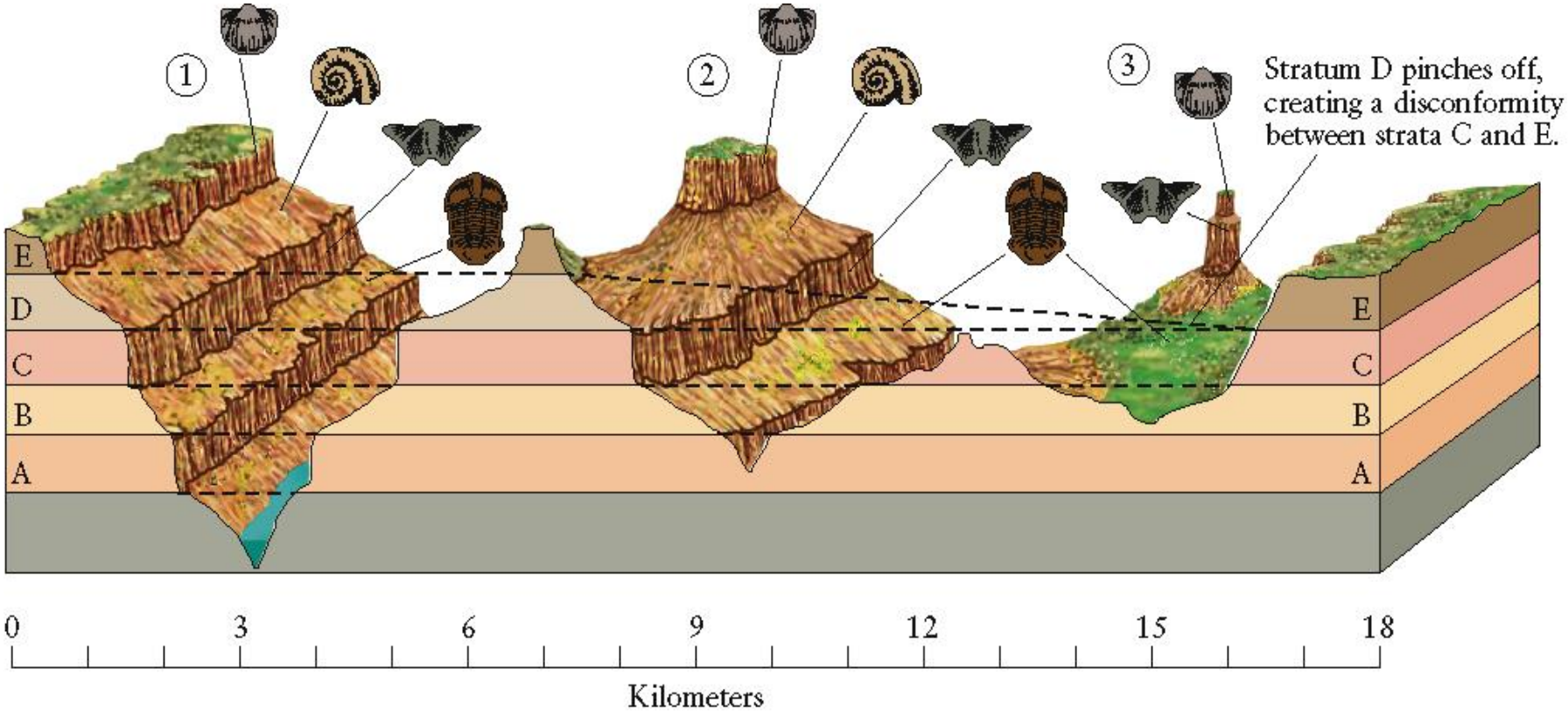


If the dike is 300 m.y. old, the rocks that the dike cut through must be:

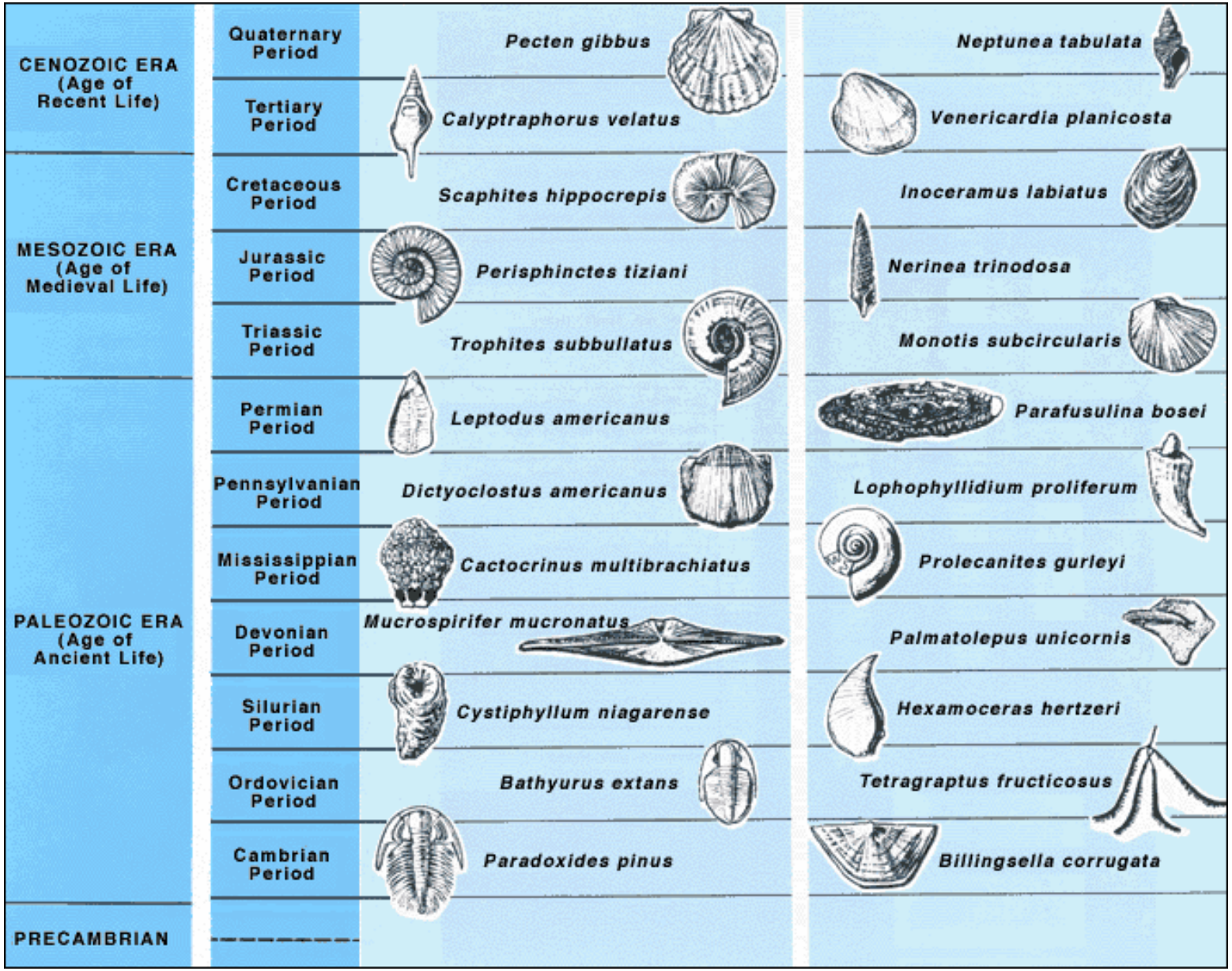
Older than 300 m.y. old

D) Principle of Fossil Succession

- fossils in sedimentary rocks evolved over geologic time. Groups of fossils in rock can represent interval of geologic time.



Index Fossils



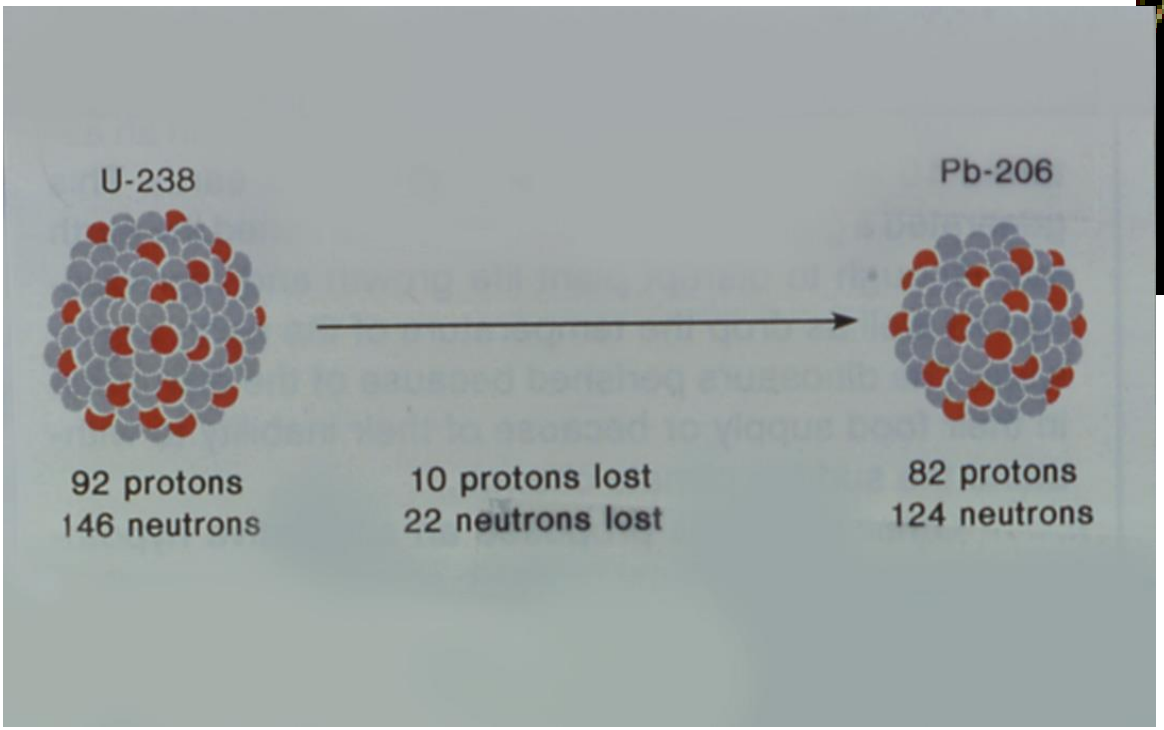
(III) Determination of absolute age by **radiometric dating**

Decay of Radioactive Isotopes

e.g., ^{238}U---------> ^{206}Pb

^{238}U: "parent"

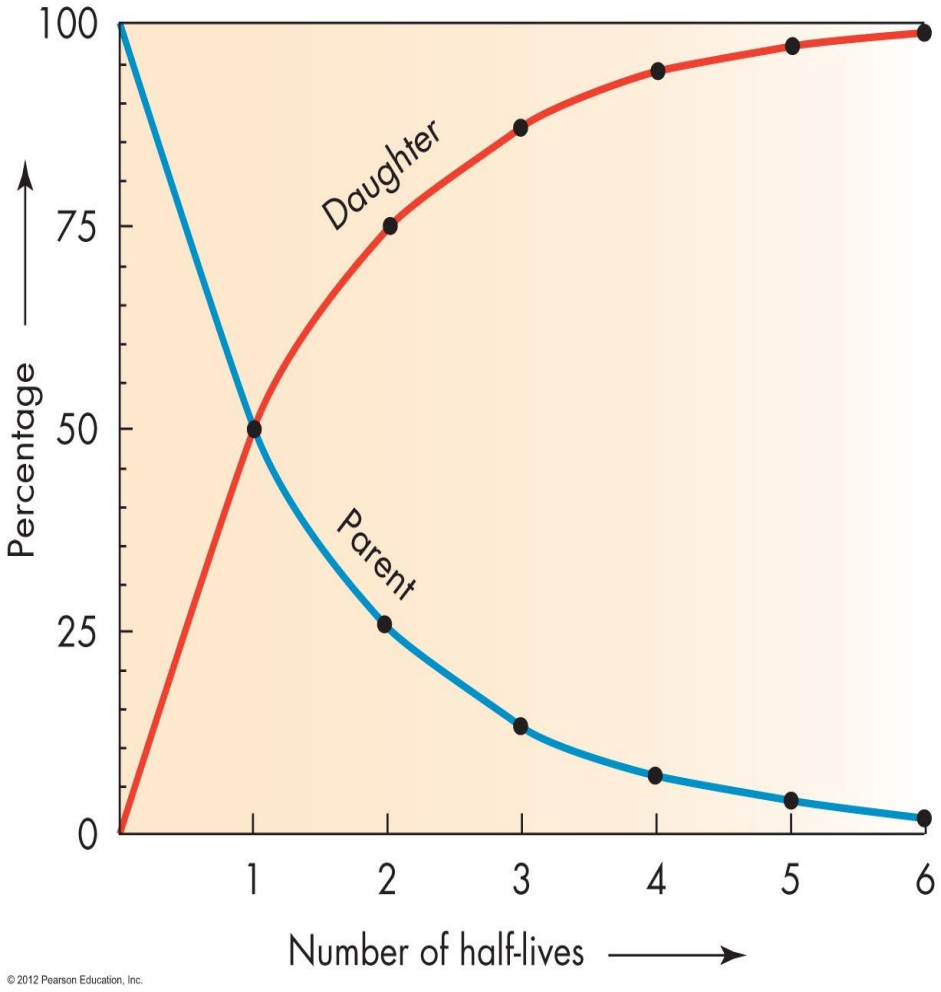
^{206}Pb : "daughter"



Rate of radioactive decay is given by **half life**

:the time required to reduce the number of parent atoms by one-half

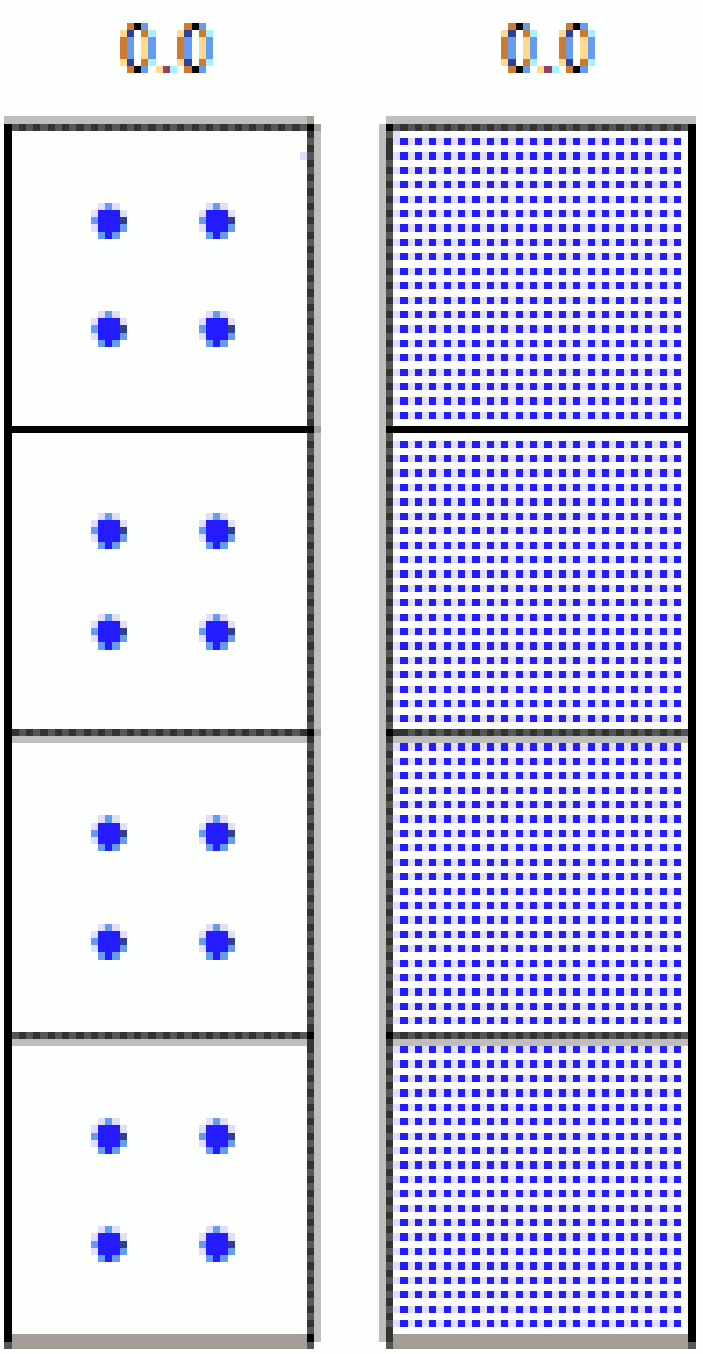
# of half-life	Parent remains
0	100%
1	50% (1/2)
2	25% (1/4)
3	12.5% (1/8)



Amount of parent left = $(1/2)^n$

n = number of half-lives passed

Half life simulation



Questions: What happens during half lifes when there is only one atom left?

Radioactive decay of an atom is statistical rather than deterministic, you cannot state precisely when an atom will decay. If there are a large number of atoms in a sample, however, the half-life can be used to effect a very accurate estimate of the amount of radioactivity that remains after a given time.

Age of rock is determined by knowing **half-life** of reaction + **amount of parent & daughter isotopes** in the system

The mathematical expression that relates radioactive decay to geologic time is

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

where

t is age of the sample,

D is number of atoms of the daughter isotope in the sample,

D_0 is number of atoms of the daughter isotope in the original composition,

N is number of atoms of the parent isotope in the sample at time t (the present), given by $N(t) = N_o e^{-\lambda t}$, and

λ is the decay constant of the parent isotope, equal to the inverse of the radioactive half-life of the parent isotope times the natural logarithm of 2.

TABLE 8.3 Radioactive Istopes Commonly Used for Determining Ages of Earth's Materials

Parent Isotope	Half-Life	Daughter Product	Effective Dating Range (years)
K-40 ^{40}K	1.3 billion years	^{40}Ar	100,000–4.6 billion
U-238 ^{238}U	4.5 billion years	^{206}Pb	10 million–4.6 billion
U-235 ^{235}U	713 million years	^{207}Pb	10 million–4.6 billion
Th-232 ^{232}Th	14.1 billion years	^{208}Pb	10 million–4.6 billion
Rb-87 ^{87}Rb	49 billion years	^{87}Sr	10 million–4.6 billion
C-14 ^{14}C	5,730 years	^{14}N	100–40,000

The effective dating range?

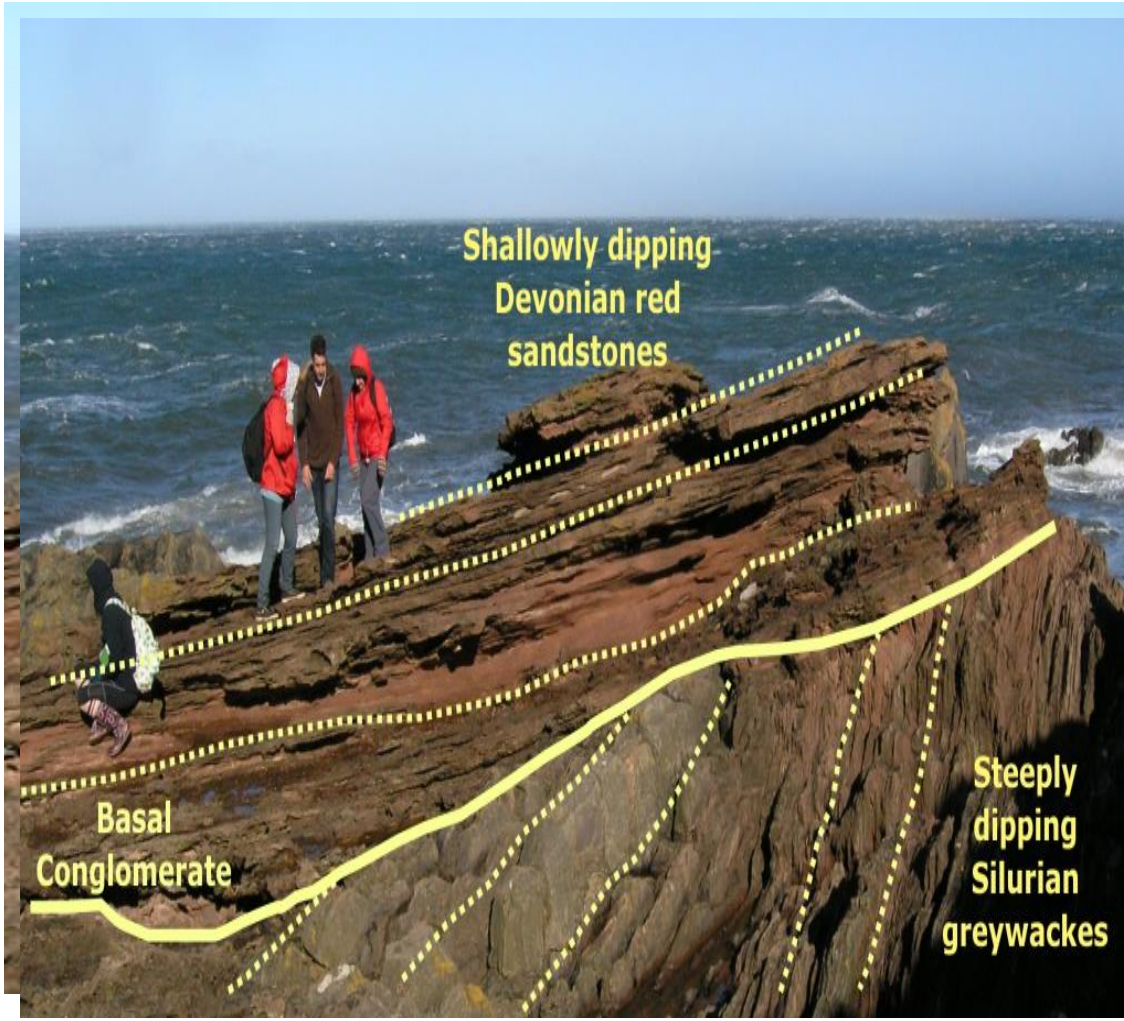
Some examples:

1. a dinosaur skull
2. a xenolith erupted from a volcano
3. a potassium feldspar
4. Lacustrine sediment from a plateau lake

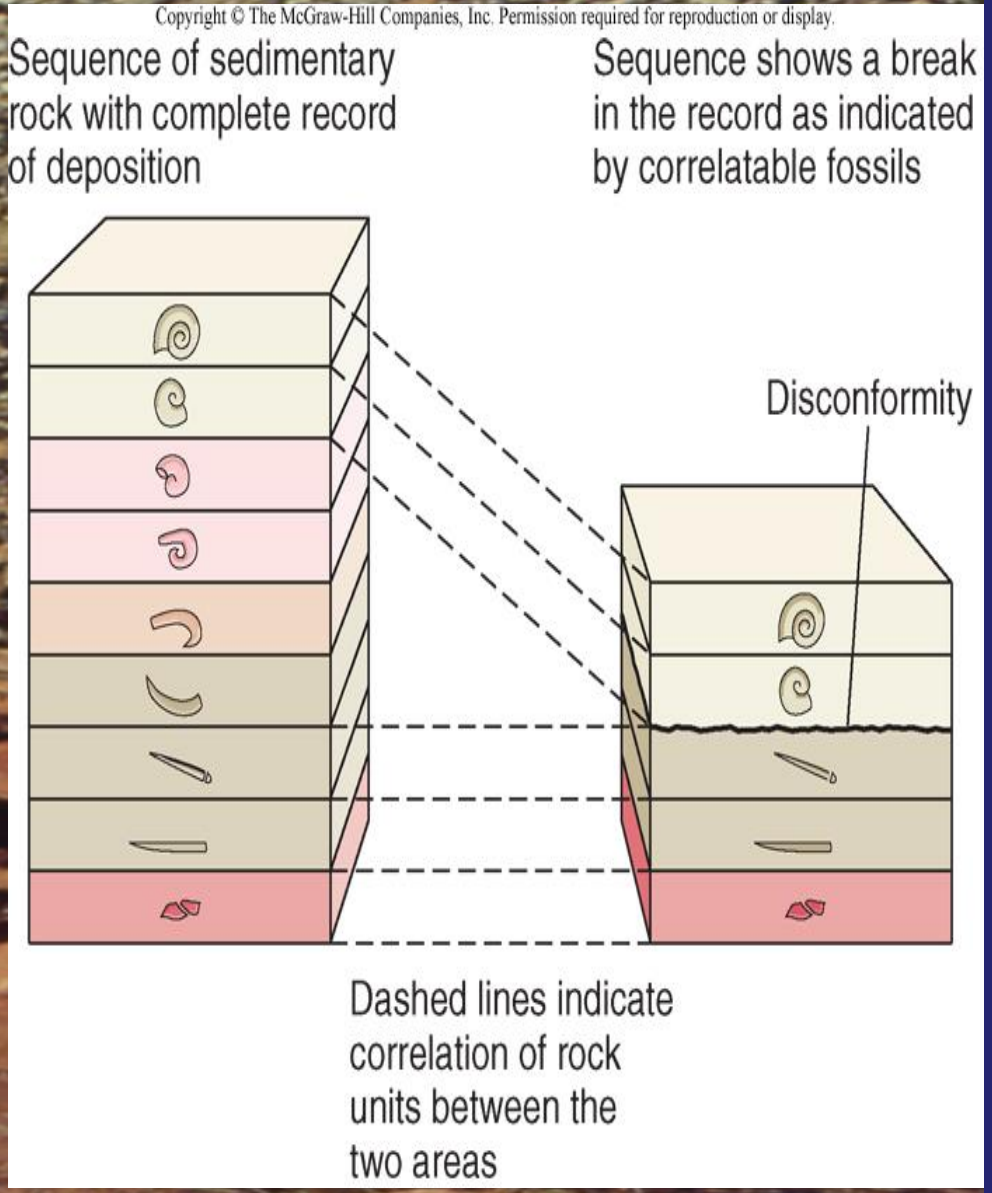
(IV) Unconformity

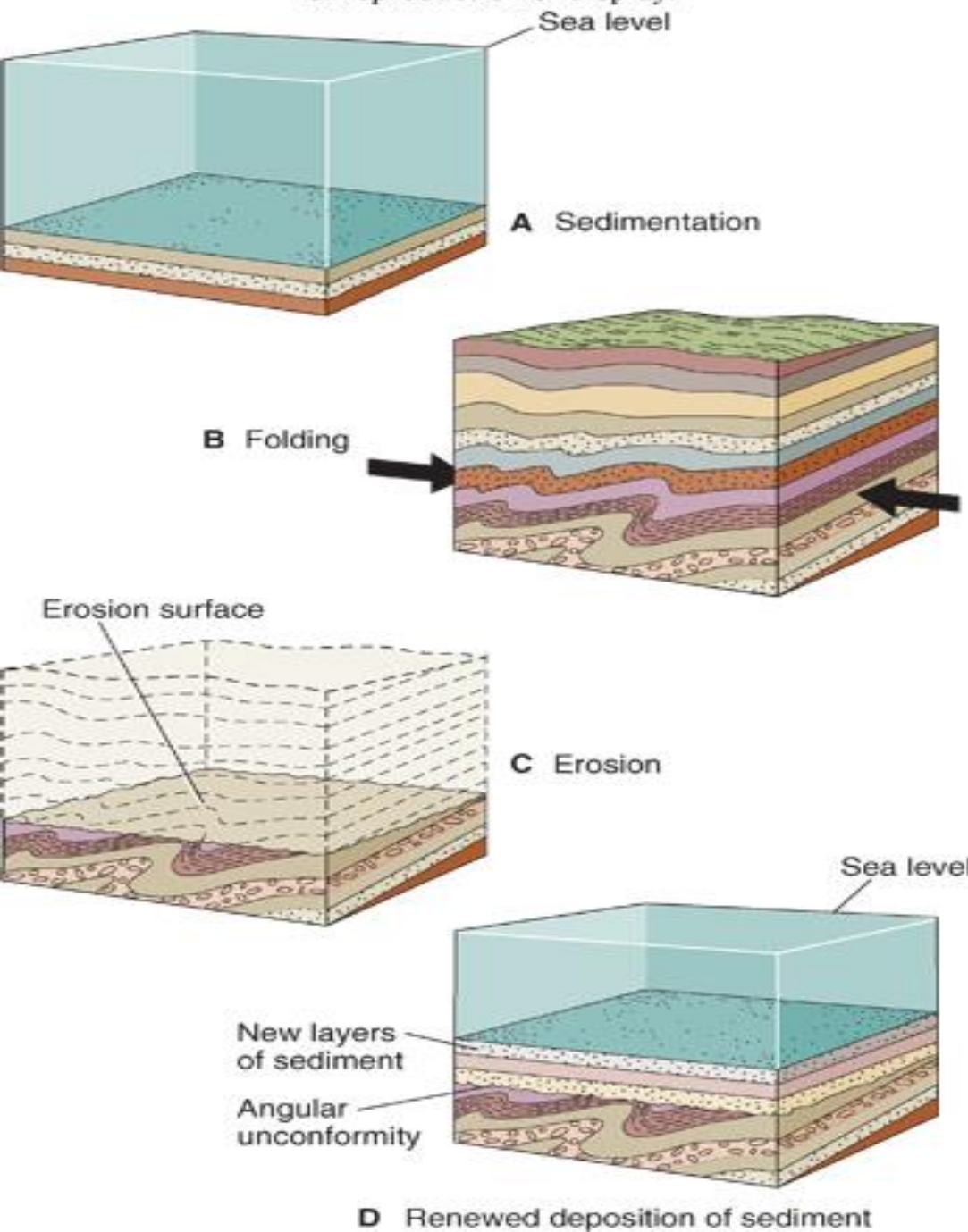
: A break or gap in the rock records

- Disconformity
- Angular Unconformity
- Nonconformity

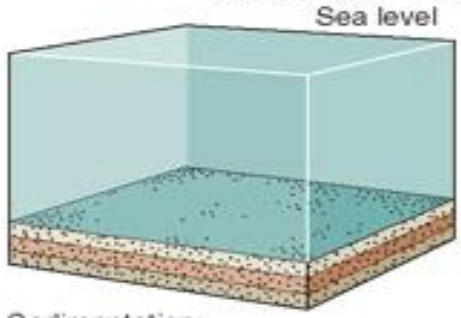


Disconformity

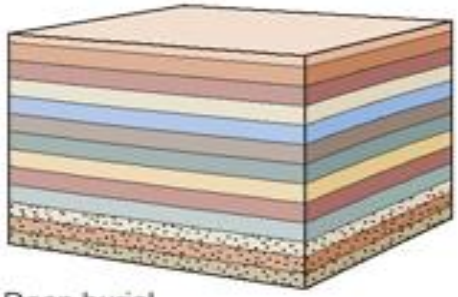




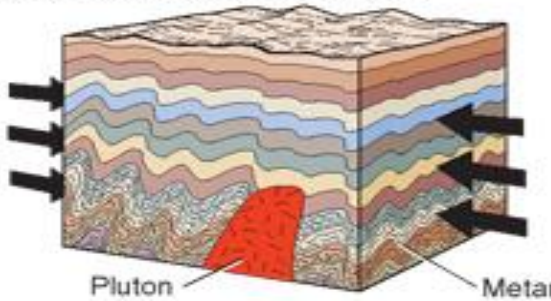
Angular Unconformity



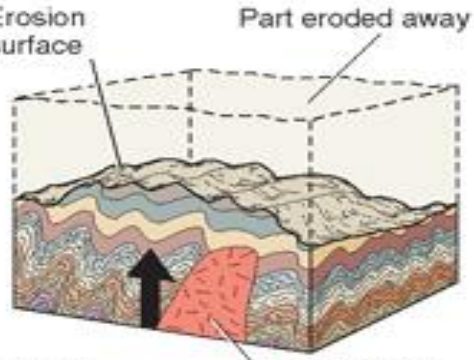
A Sedimentation



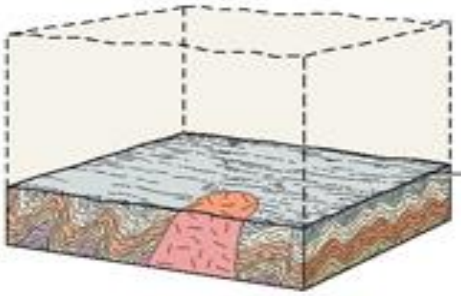
B Deep burial



C During mountain-building episode: Intense deformation, intrusion of a pluton, and metamorphism of lower rocks

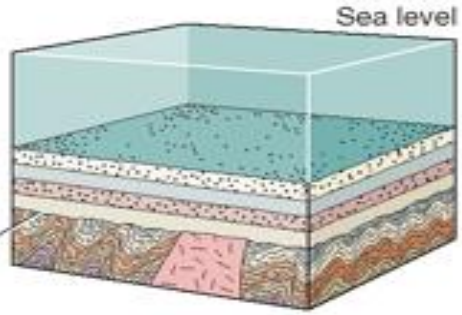


D Uplift accompanied by erosion



E Continued erosion

Nonconformity



F Renewed deposition

G

Photo by C. C. Plummer

(IV) Unconformity

: A break or gap in the rock records

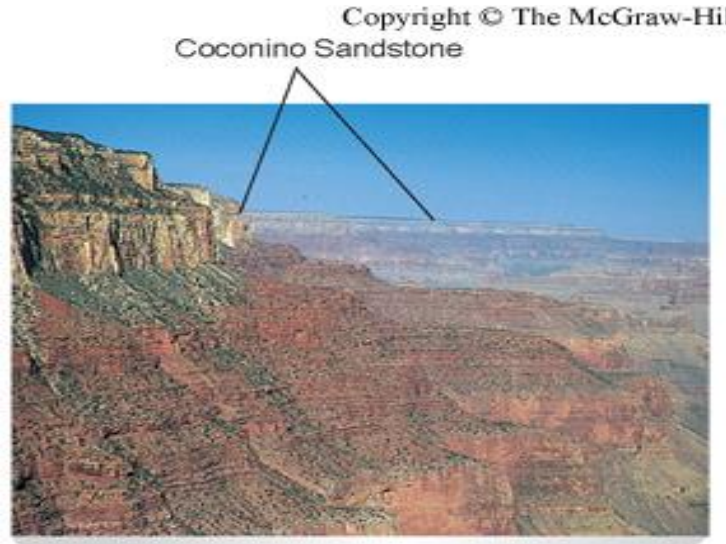
-- Disconformity

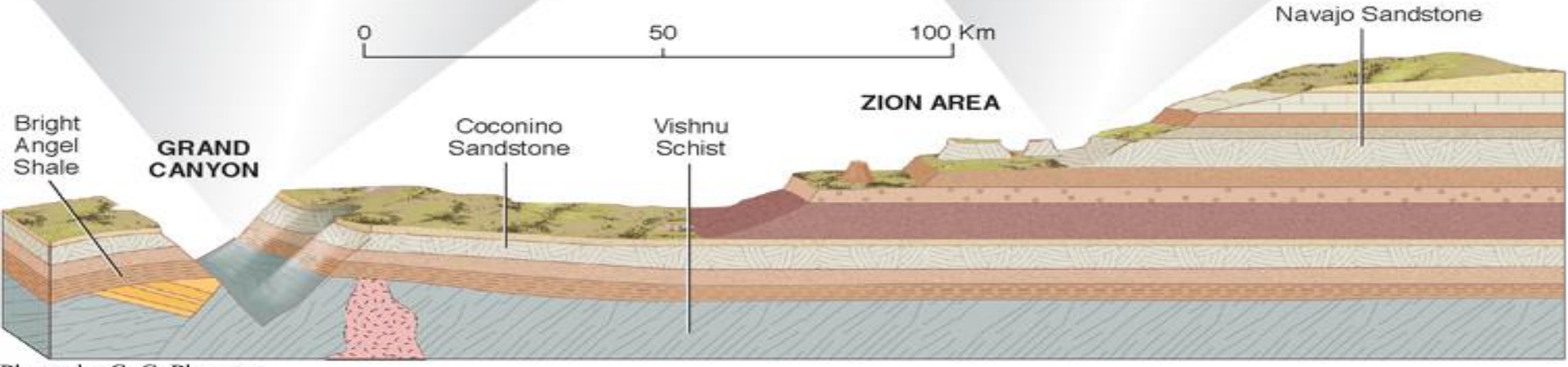
-- Angular Unconformity

-- Nonconformity

(V) Geologic Correlation
-- Physical Criteria

e. g., rock types, texture, structures





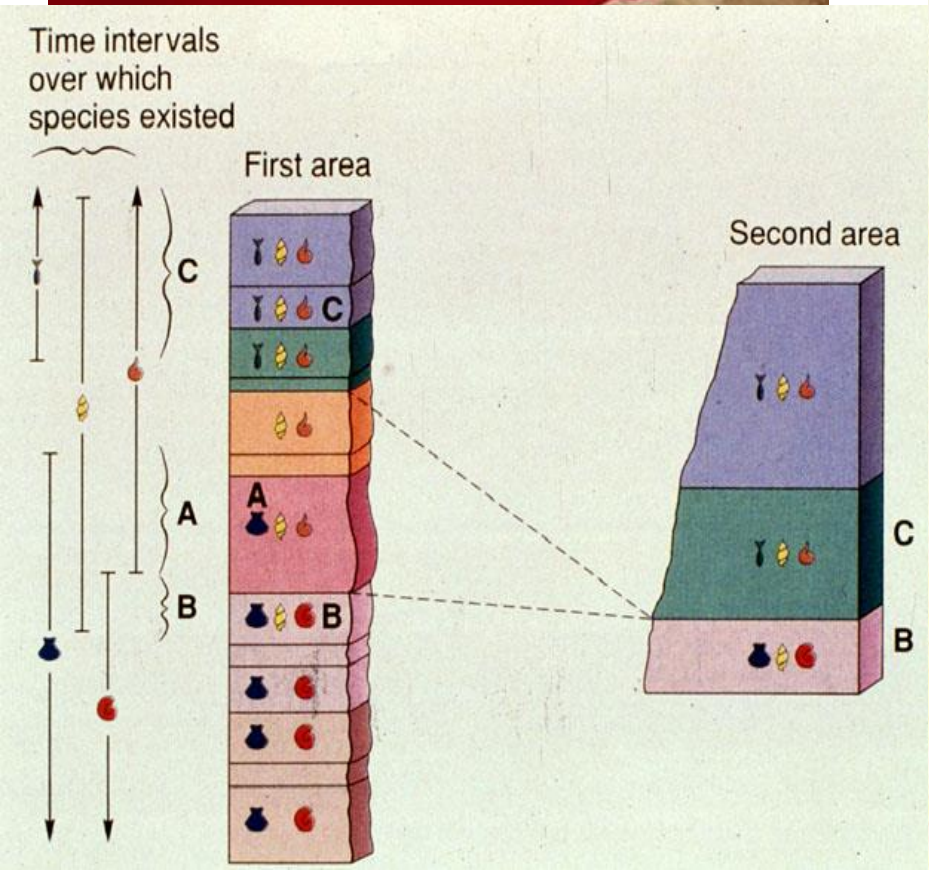
Photos by C. C. Plummer

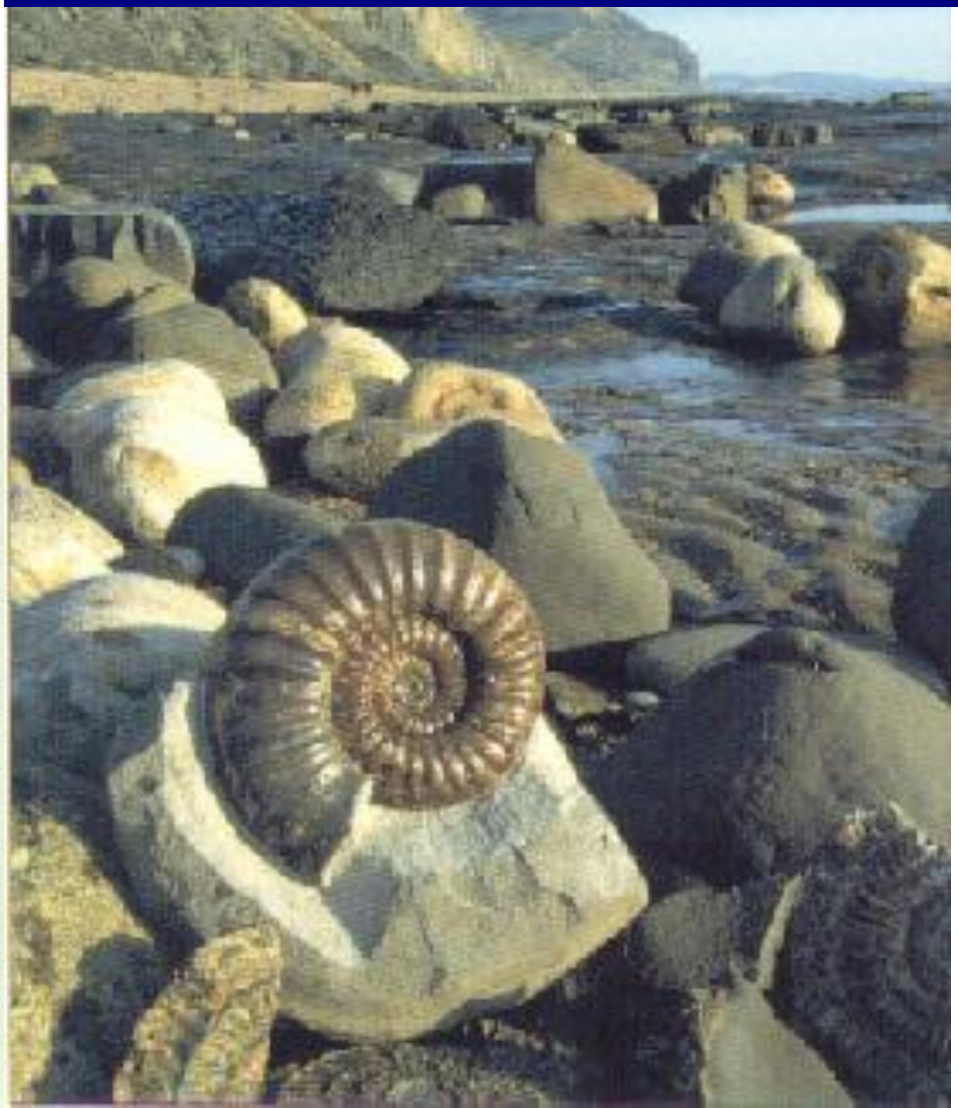
Geologic Correlation

-- Physical Criteria

-- **Fossils**

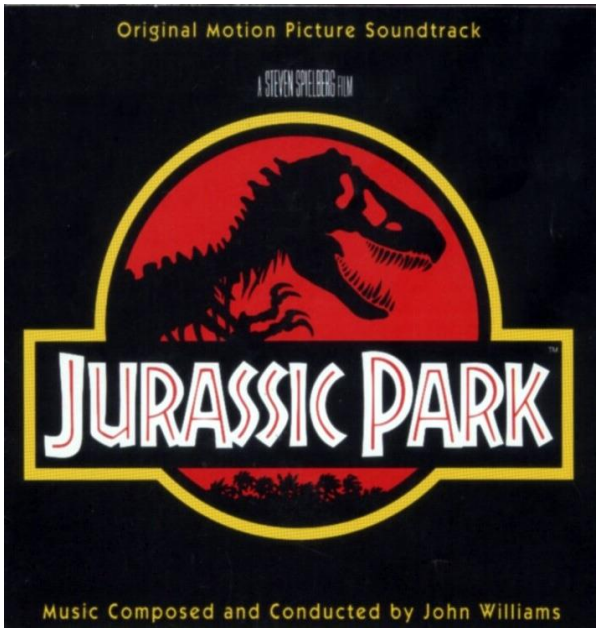
Fossil records: more reliable than physical criteria for **large scale correlation**





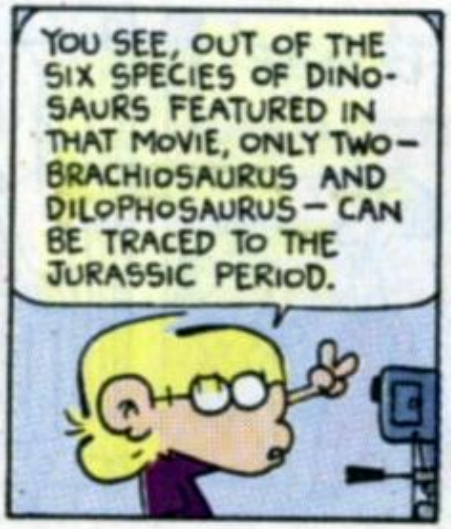
(VI) The Standard Geologic Time Scale

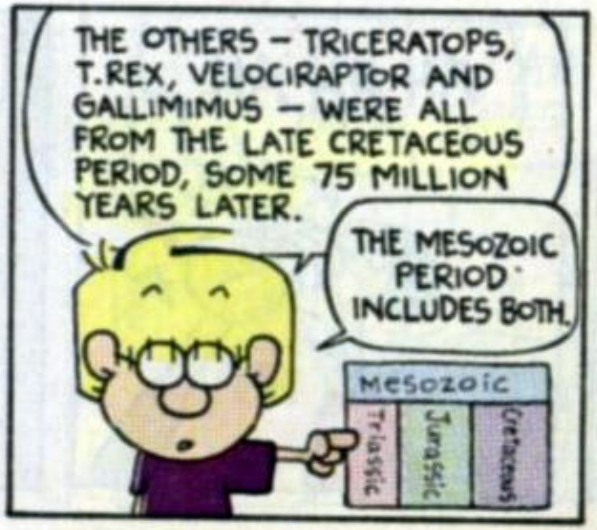
: Based on presence or absence of characteristic life forms



FoxTrot

BILL AMEND

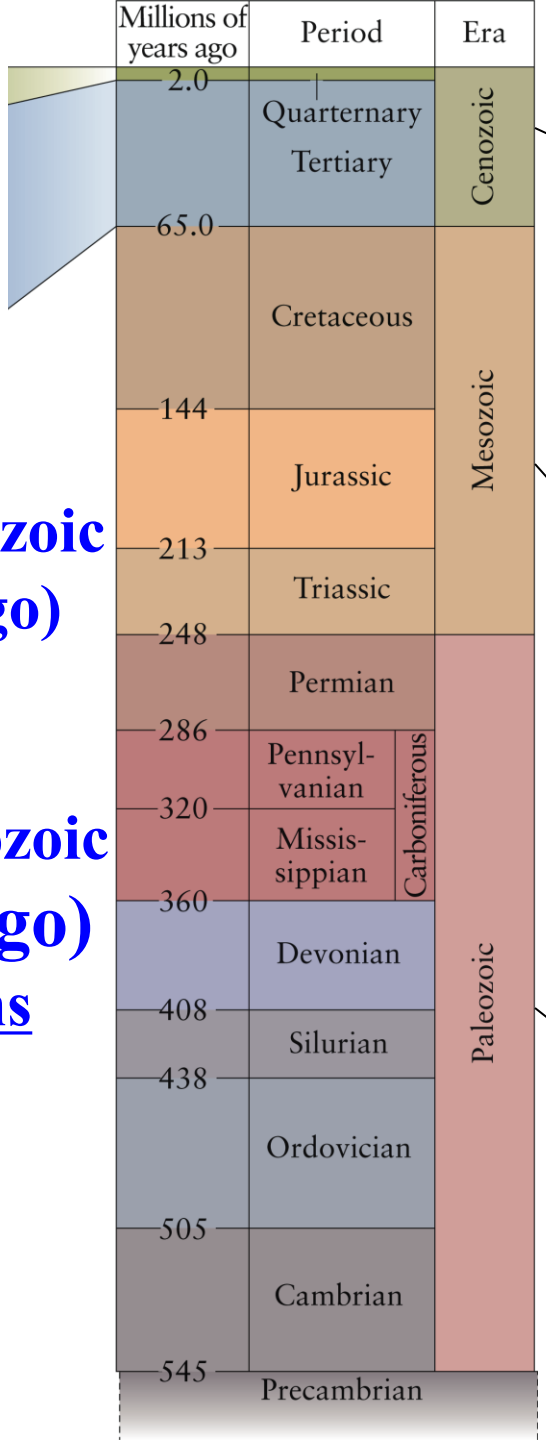


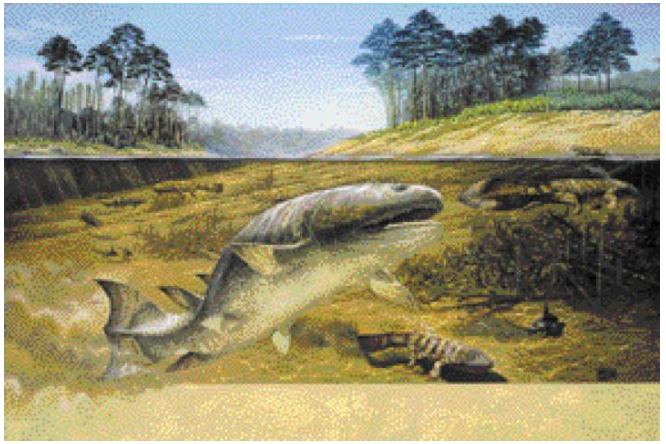


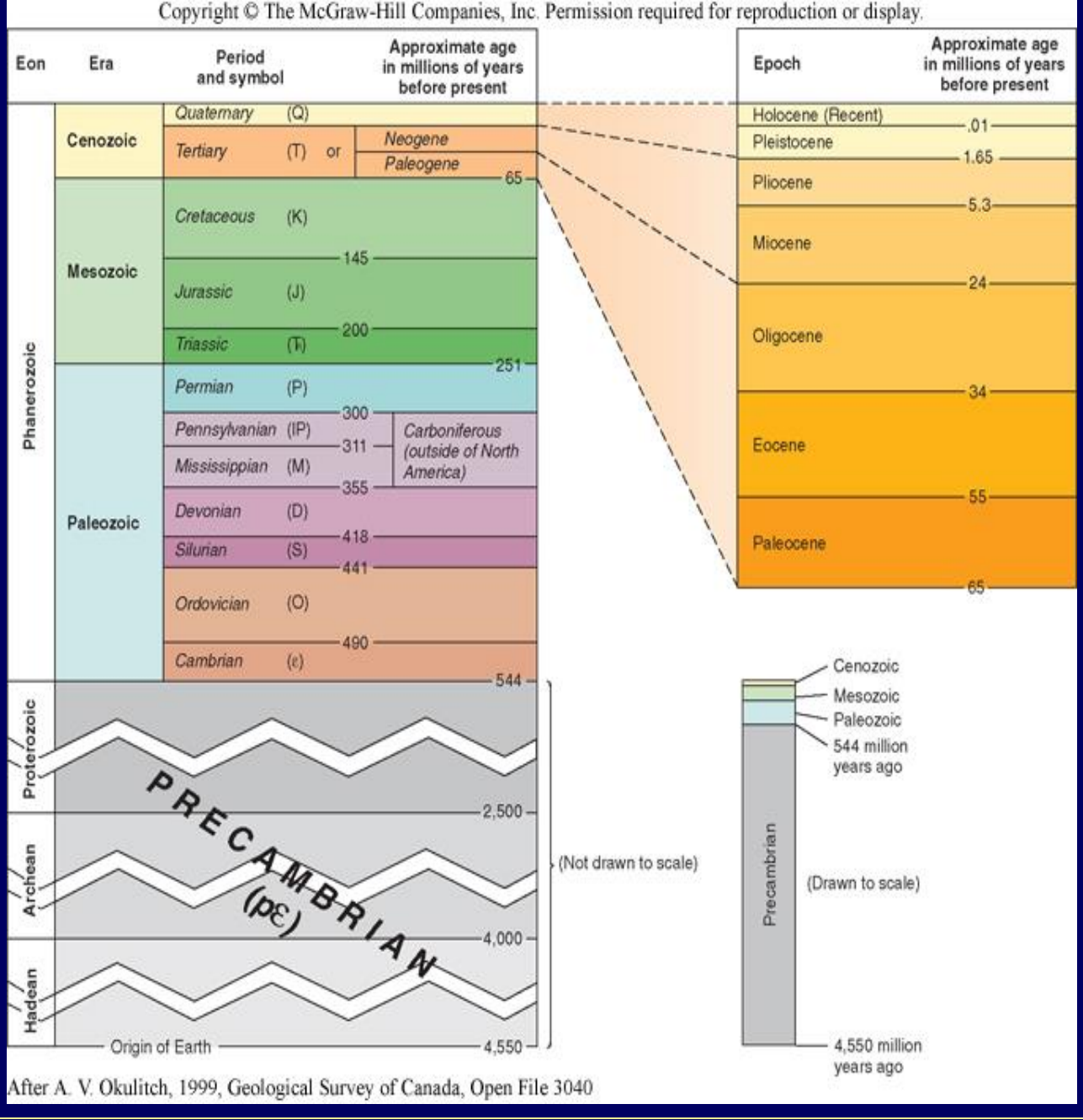
Mesozoic/Cenozoic
(~ 65 M. Y. ago)

Paleozoic/Mesozoic
(~ 250 M. Y. ago)

Mass extinctions







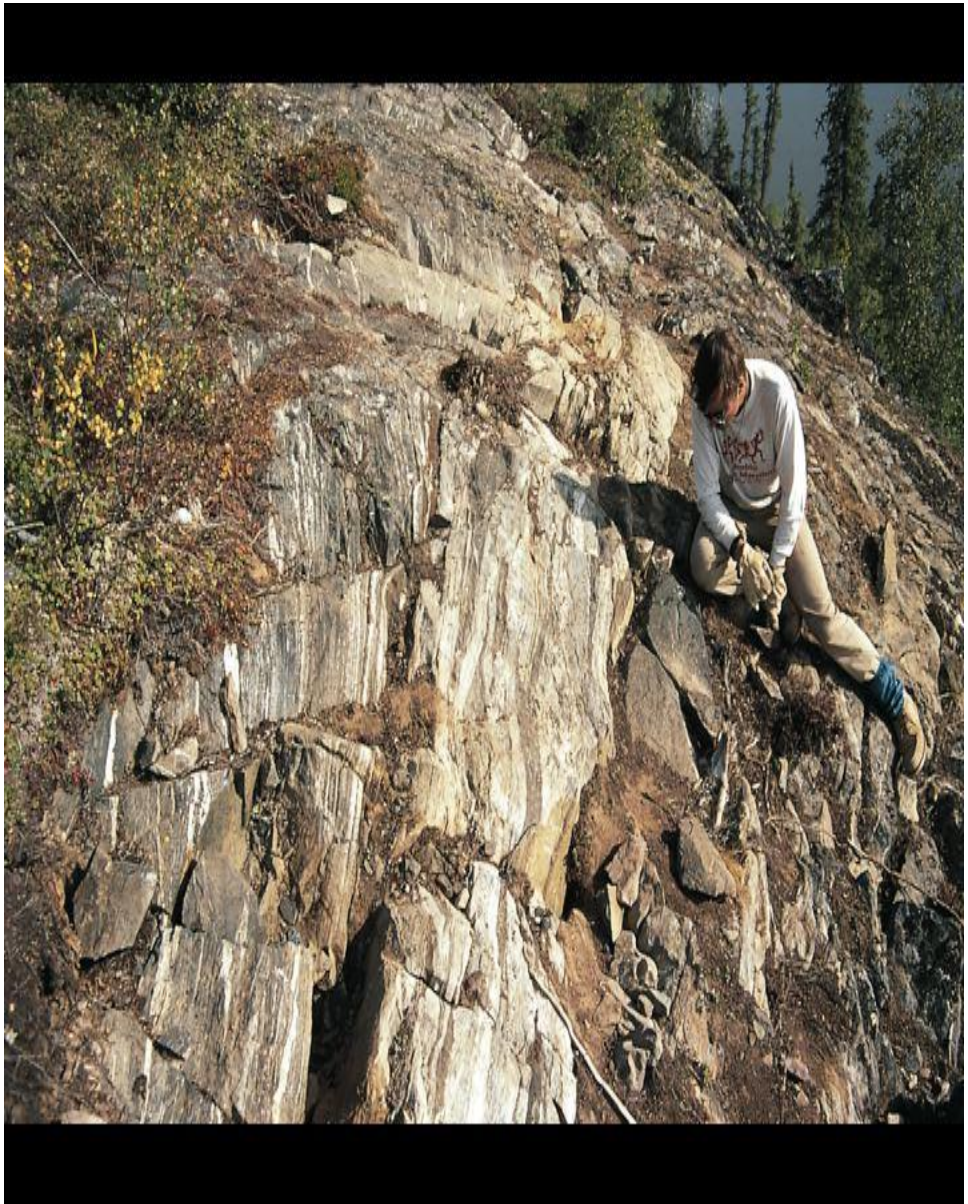
Precambrian: ~ 90% of geologic time !

The Age of Earth

Oldest dated Earth minerals: 4.4 billion years old

from some Zircon in a quartzite from West Australia

→ Earth must be older than 4.4 b.y. old



Meteroites: 4.5 b.y. to 4.6 b.y. old

Most rocks from the Moon: 4.6 b.y.

How old is the Earth?

- Oldest dated earth material: 4.4 billion years old

- Oldest rocks from the Moon: 4.6 b.y.

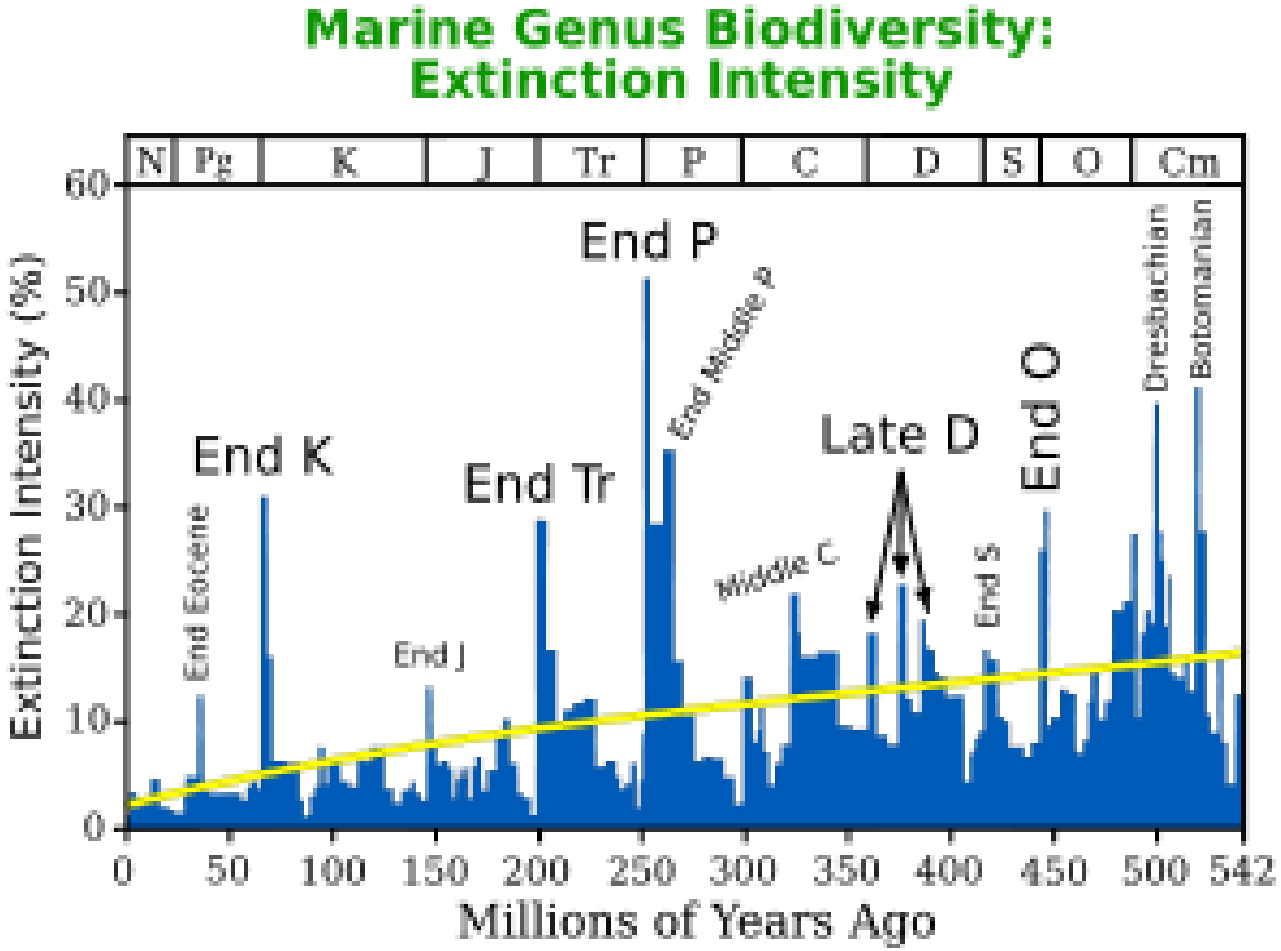
- Meteorites: 4.5 to 4.6 b.y.

Assuming age of the Earth

= Age of other planetary materials in the solar system

--> Age of the Earth = 4.5 b.y. to 4.6 b. y. old
(i.e., 4500 – 4600 m.y. old)

The Great Dying
Video by National Geography



The Great Dying
Video by National Geography