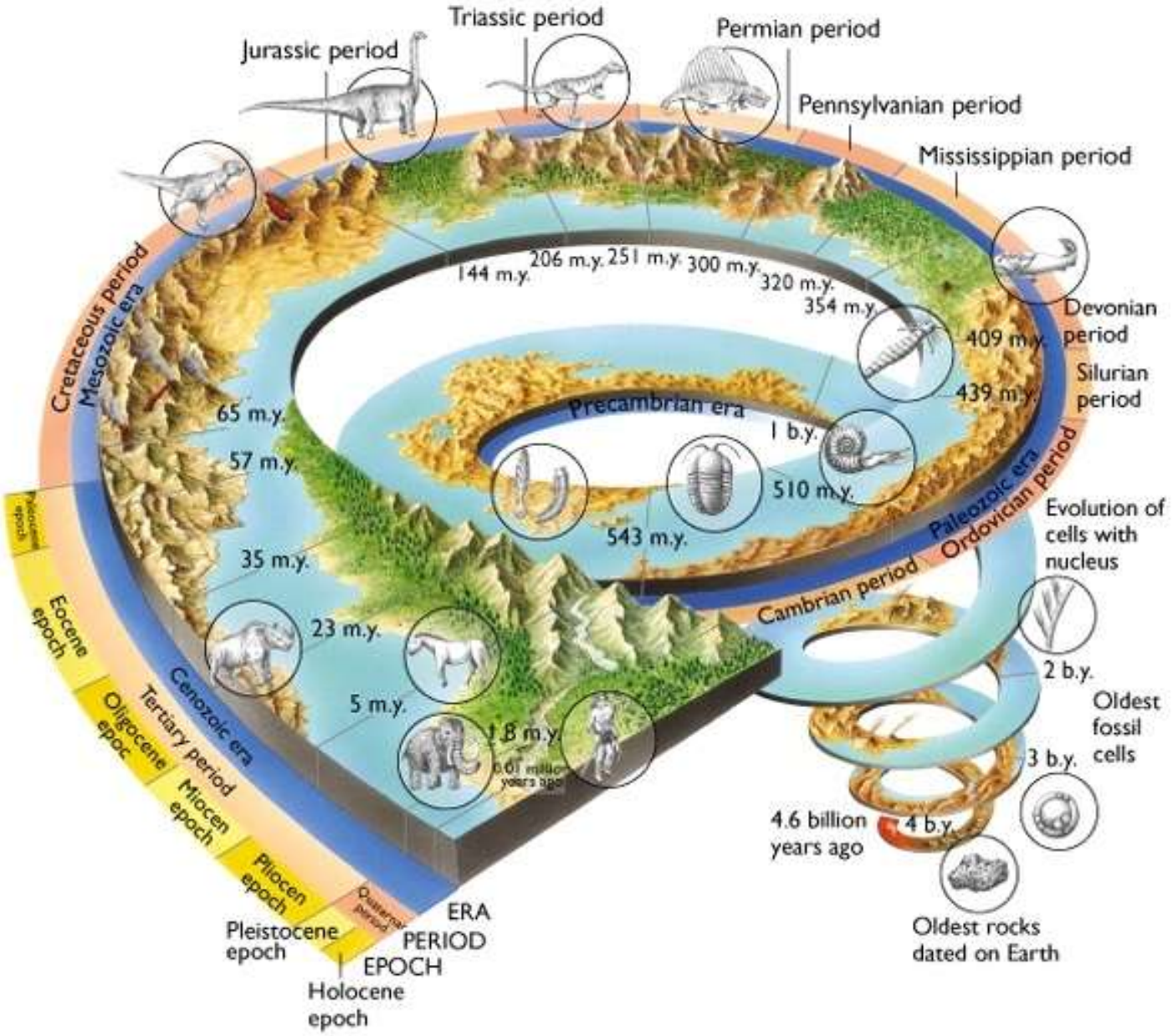


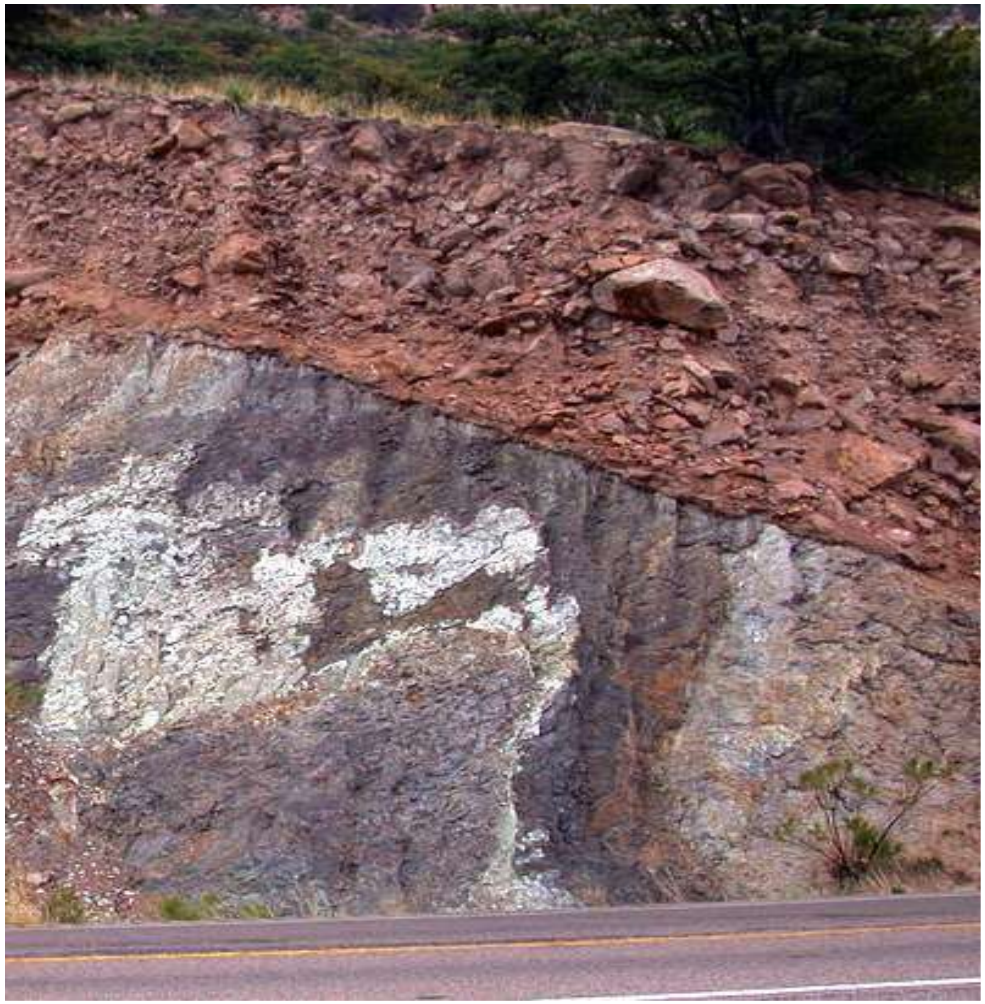
Lecture 10 – Constructing the geological timescale

Geologic Time

- Discovering the magnitude of the Earth's past was a momentous development in the history of humanity
- This discovery forever altered our perception of ourselves within nature and the universe

Geologic Time

- Understanding time permits assigning an age to…
  - Rocks
  - Fossils
  - Geologic structures
  - Landscapes
  - Tectonic events
  - Climate events



The geologic timescale

- **Relative dating**
  - Establishes the sequence of events without establishing exactly when they occurred
  - Logical principles are useful for defining relative age
- **~~Absolute~~ Numerical dating**
  - Establishes when an event took place or when a feature formed
  - Assigns a specific age in years

Group Question

Put the following sentences in order:

1. The driver crashed the truck into the ditch
2. A ditch was dug at the side of the road
3. The driver got into the truck
4. The driver got out of the truck

A) 3, 2, 1, 4

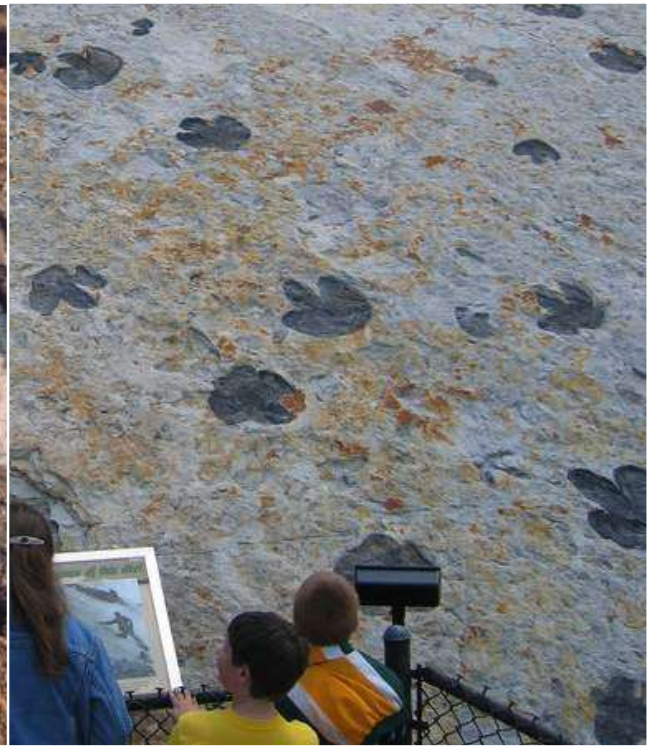
B) 3, 1, 2, 4

C) 2, 3, 1, 4

Principle of uniformitarianism

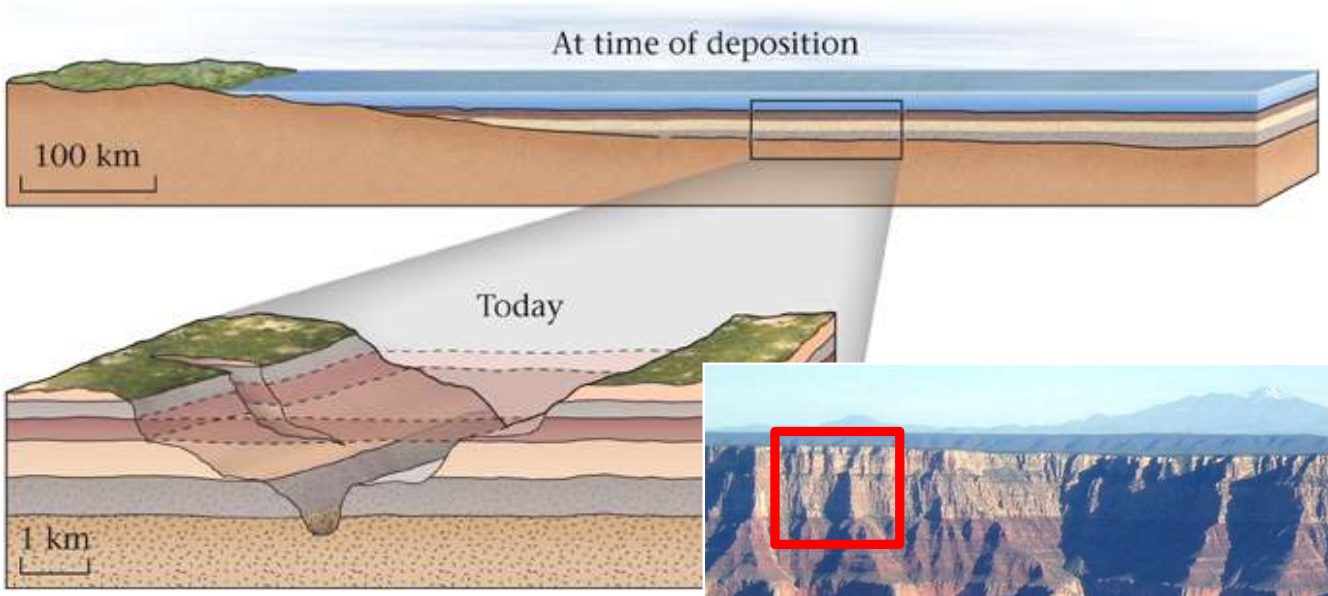
- **<u>The present is the key to the past</u>**





Principles of original horizontality and continuity

- Strata often form laterally extensive horizontal sheets
- Flat-lying rock layers are unlikely to have been disturbed



Principles of original horizontality and continuity

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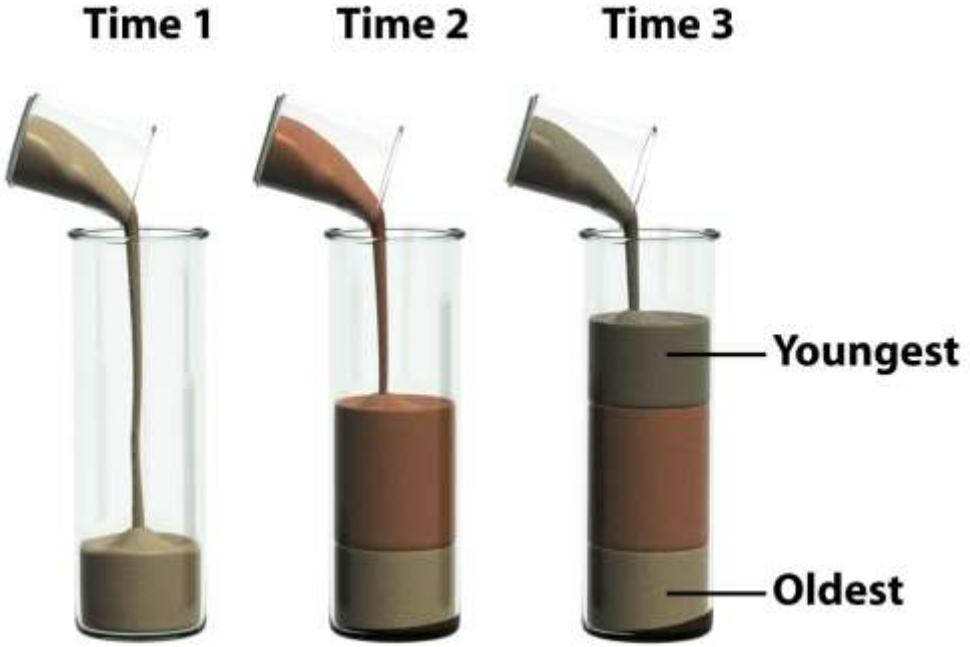
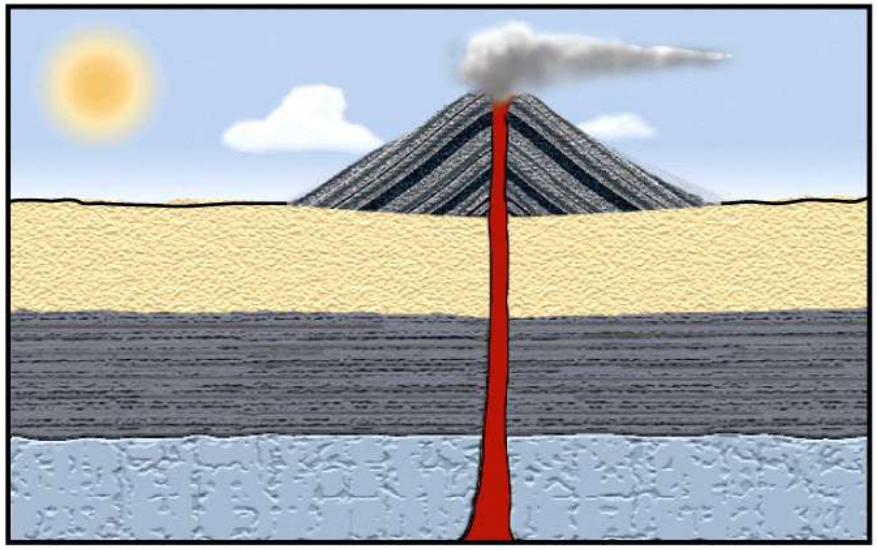
Principle of superposition

- In an undeformed sequence of layered rock each bed is older than the one above

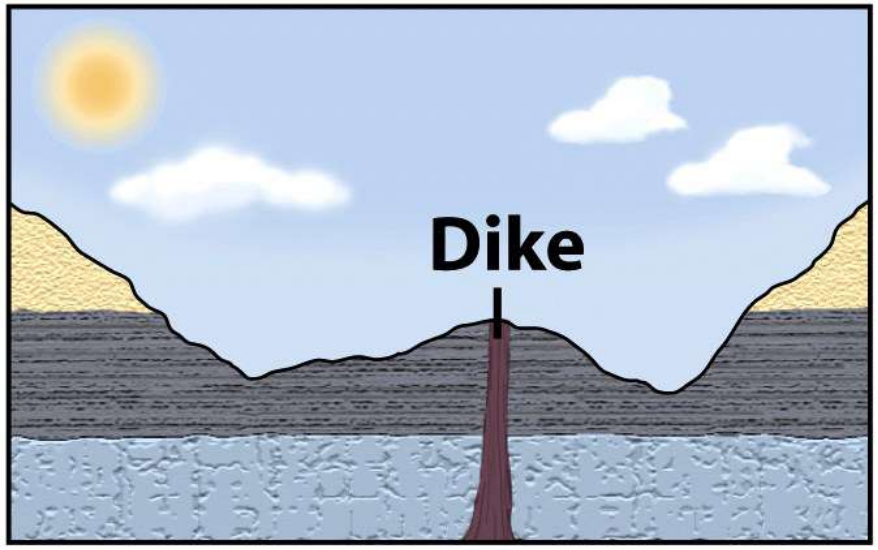


Principle of cross-cutting relations

- Younger features truncate (cut across) older features



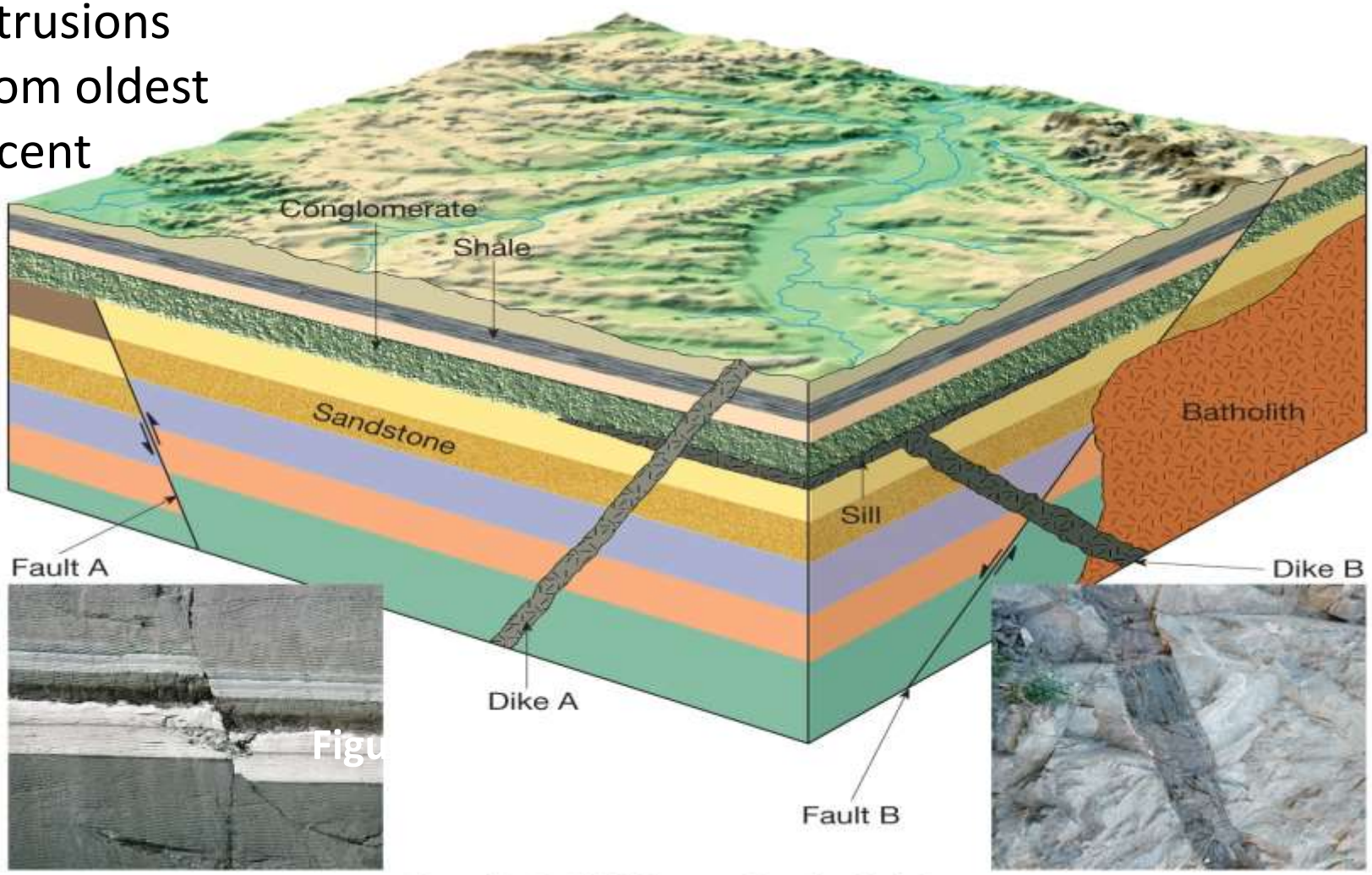
Time 1



Time 2

Cross-cutting relationships

Put the faults and igneous intrusions in order from oldest to most recent



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Cross-cutting relationships

Which is most recent feature?

a) Fault A
b) Dike A
c) Fault B
d) Dike B and sill
e) Batholith

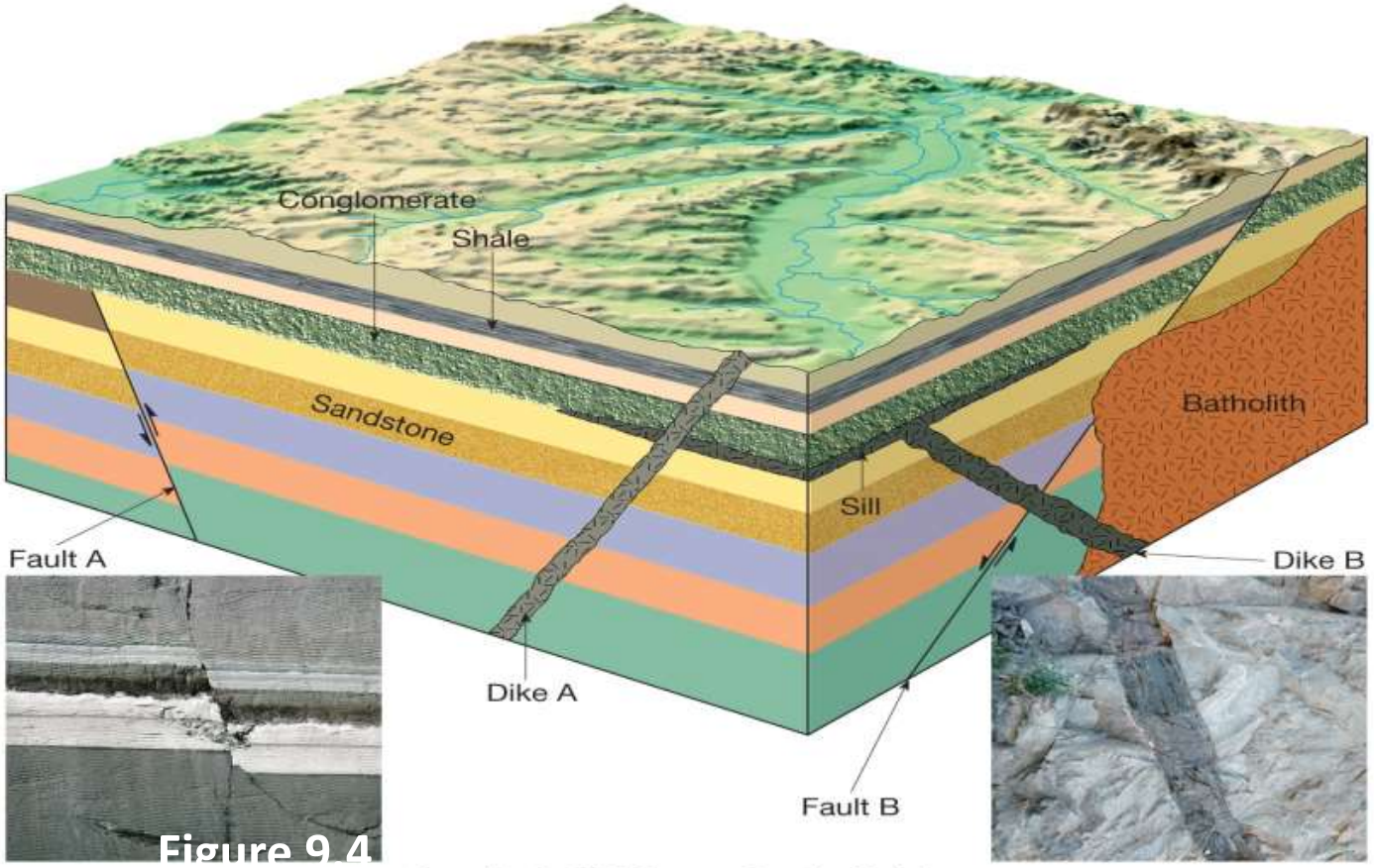

Figure 9.4

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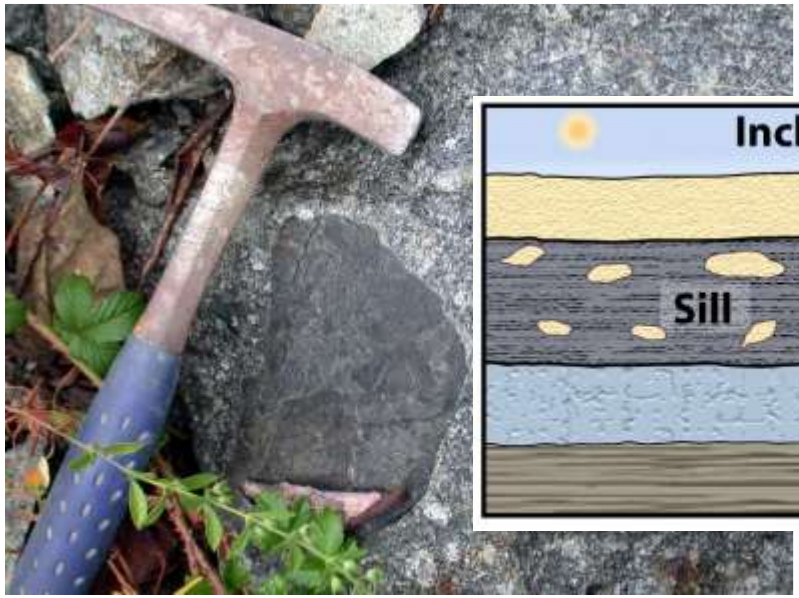
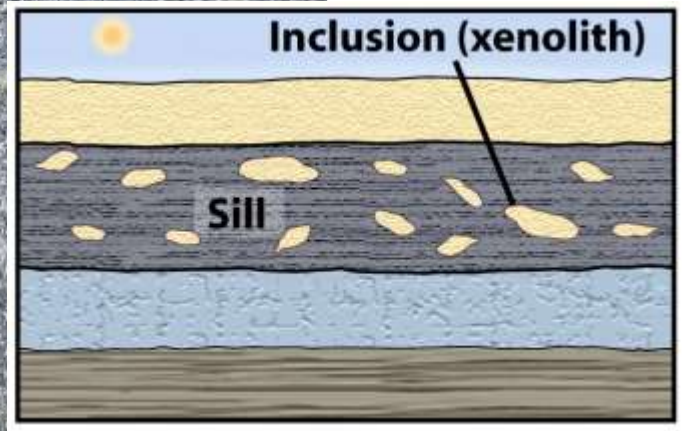
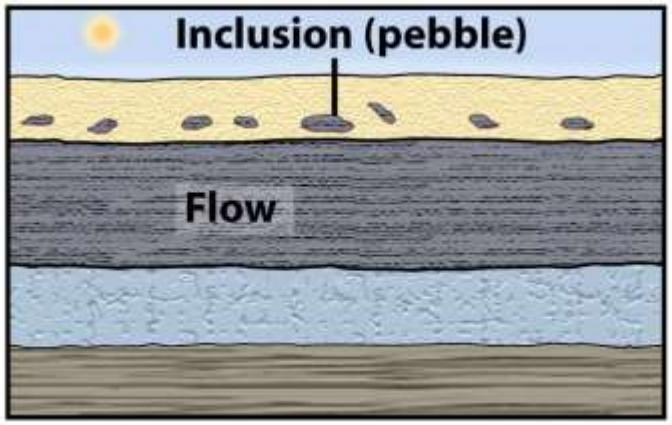
Principle of inclusions

- Inclusions – A rock fragment within another
  - Igneous xenoliths – Country rock that fell into magma
  - Weathering rubble – Debris from preexisting rocks







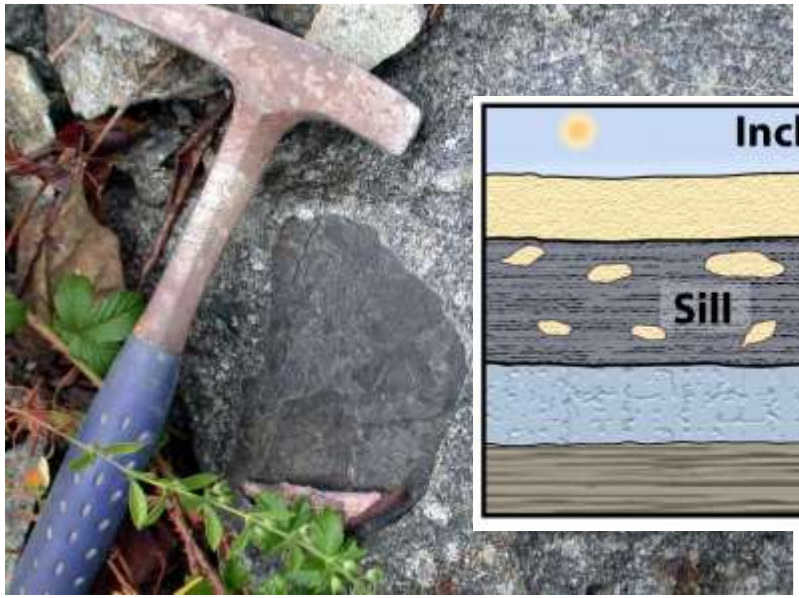
Principle of inclusions

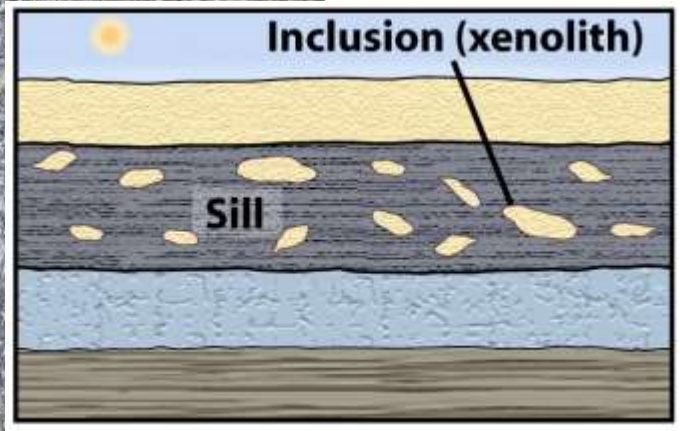
- Will an inclusion be older or younger than the rock it is in?

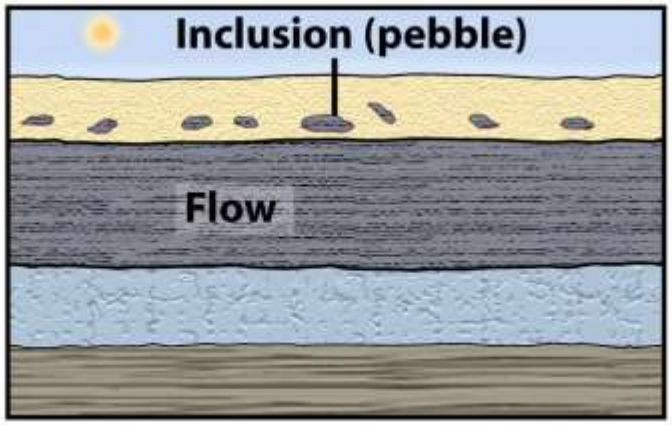
a) Younger

b) Older

c) Could be both?

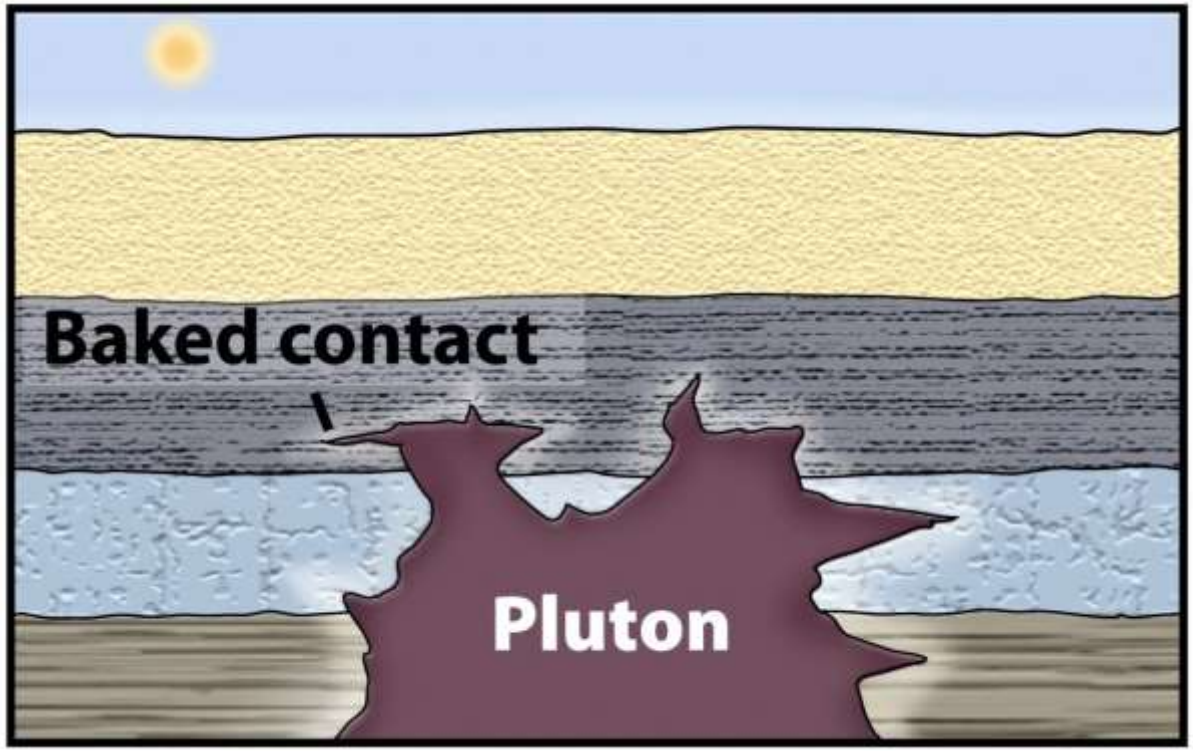






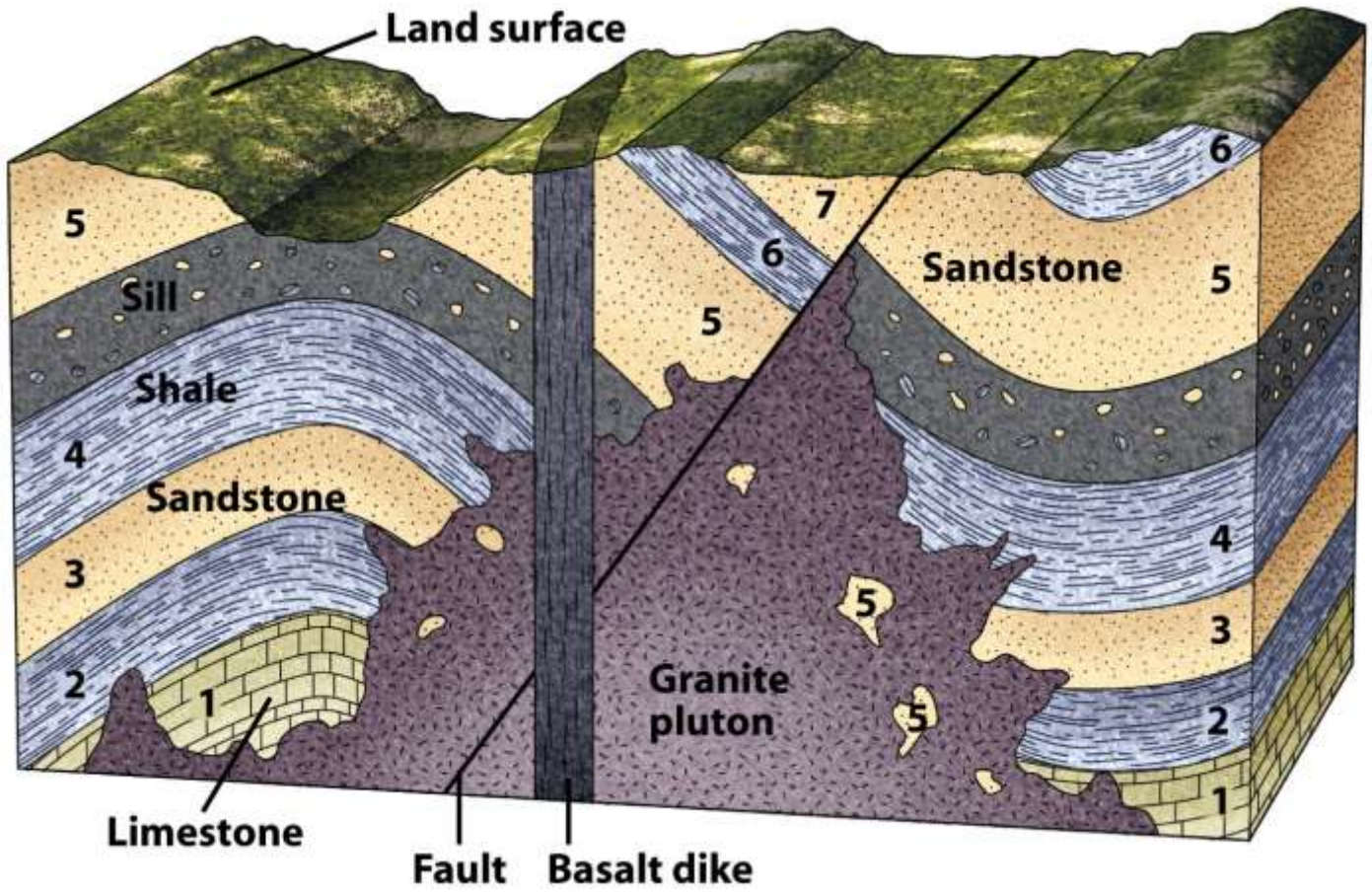
Principle of baked contacts

- Thermal metamorphism occurs when country rock is invaded by a plutonic igneous intrusion
- The baked rock must have been there first (it is older)

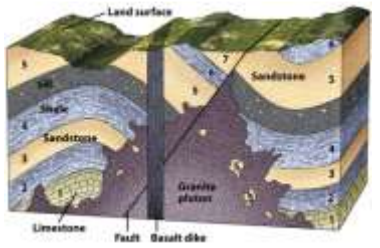


Relative Age

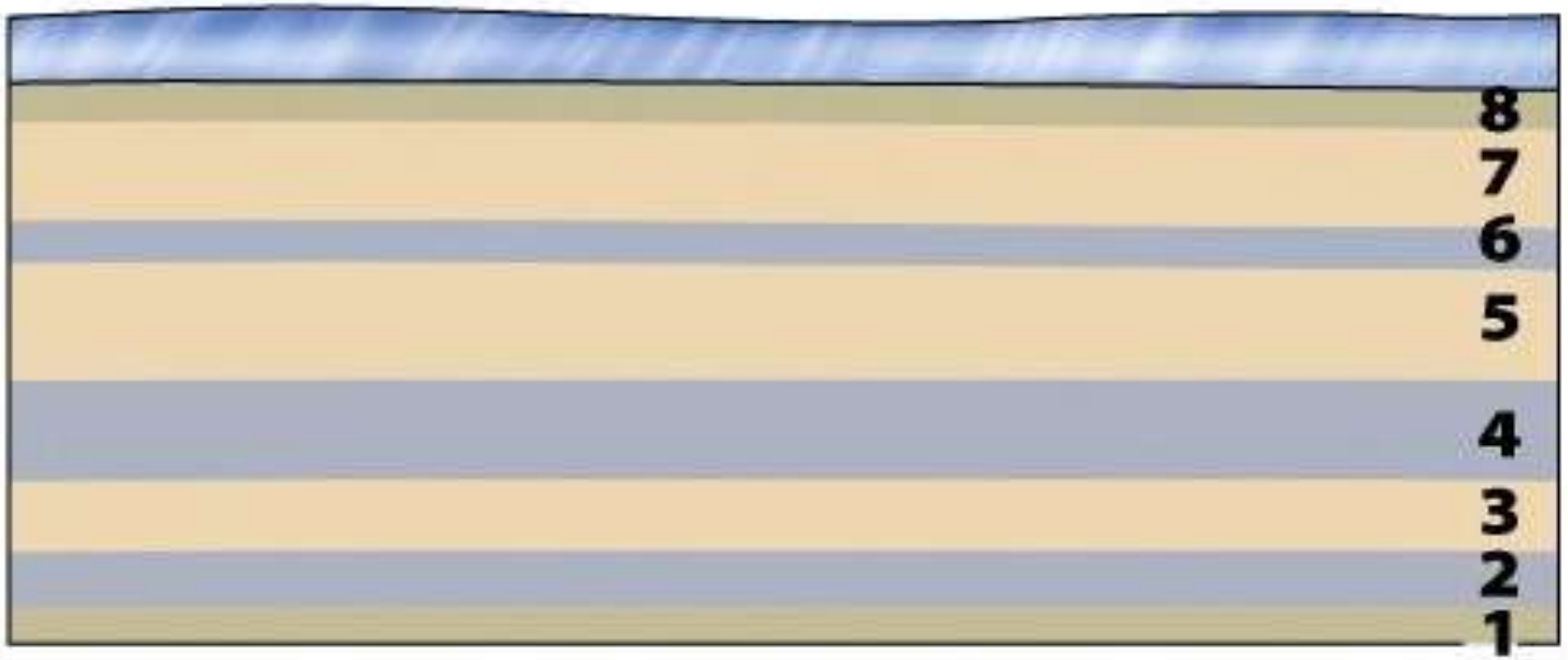
- Determining relative ages allows geologists to easily unravel complicated geologic histories



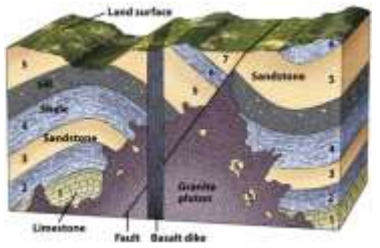
Geologic History



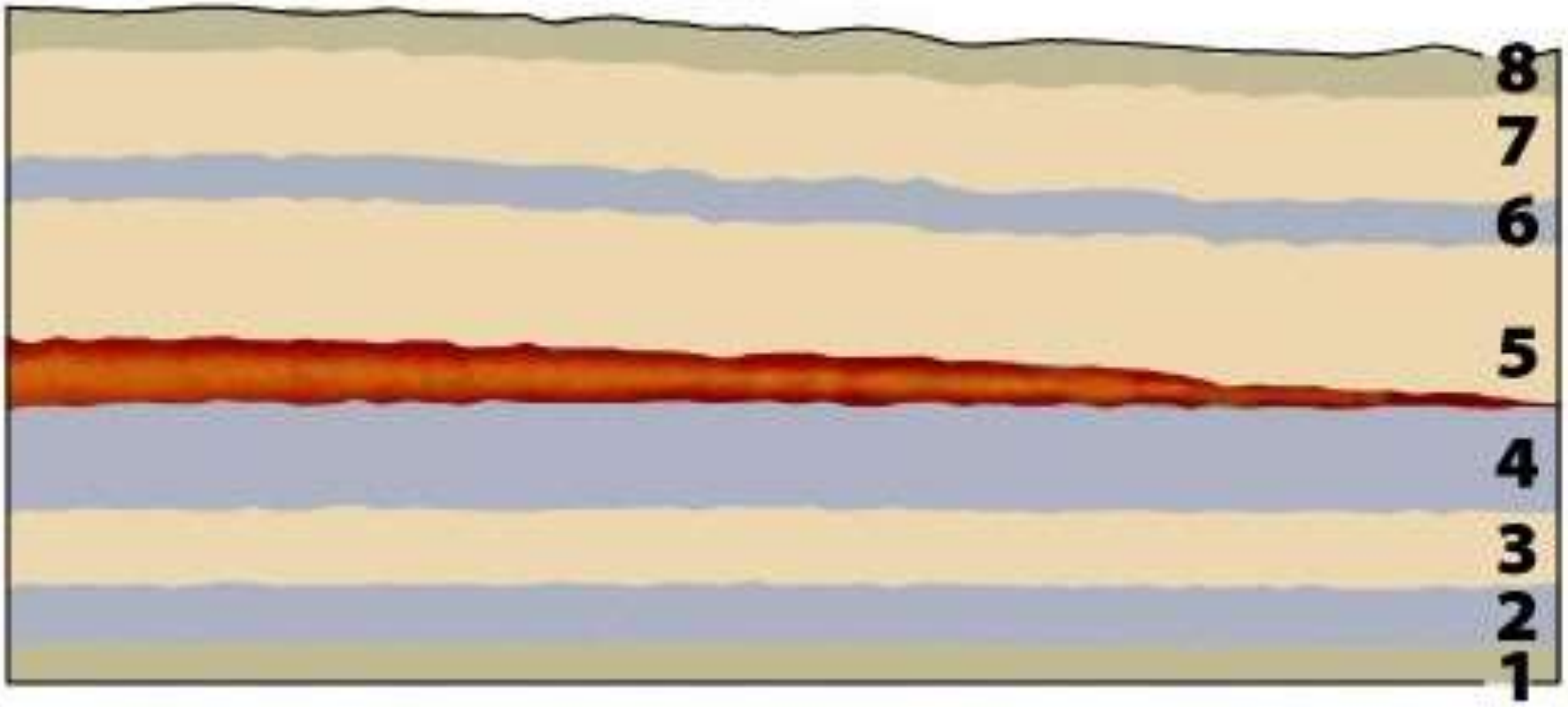
- Deposition of horizontal strata below sea level in order 1, 2, 3, 4, 5, 6, 7 and 8 (oldest to youngest).



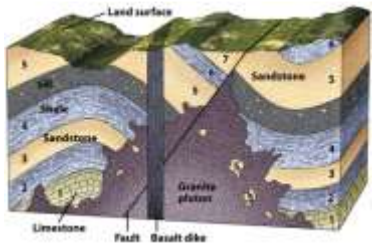
Geologic History



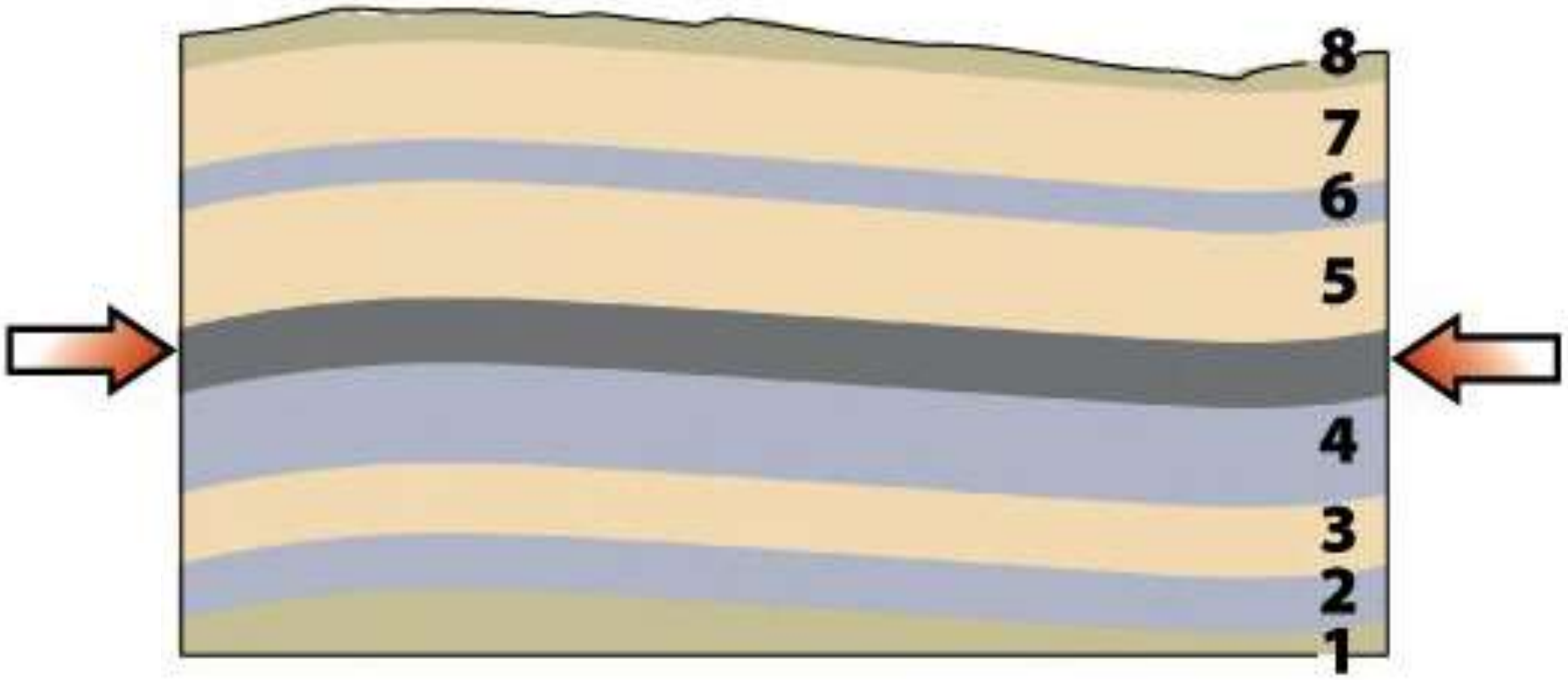
- An igneous sill intrudes.



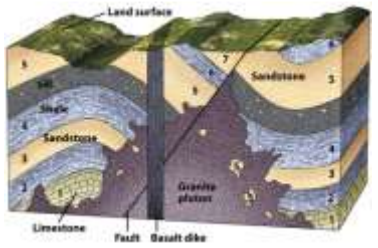
Geologic History



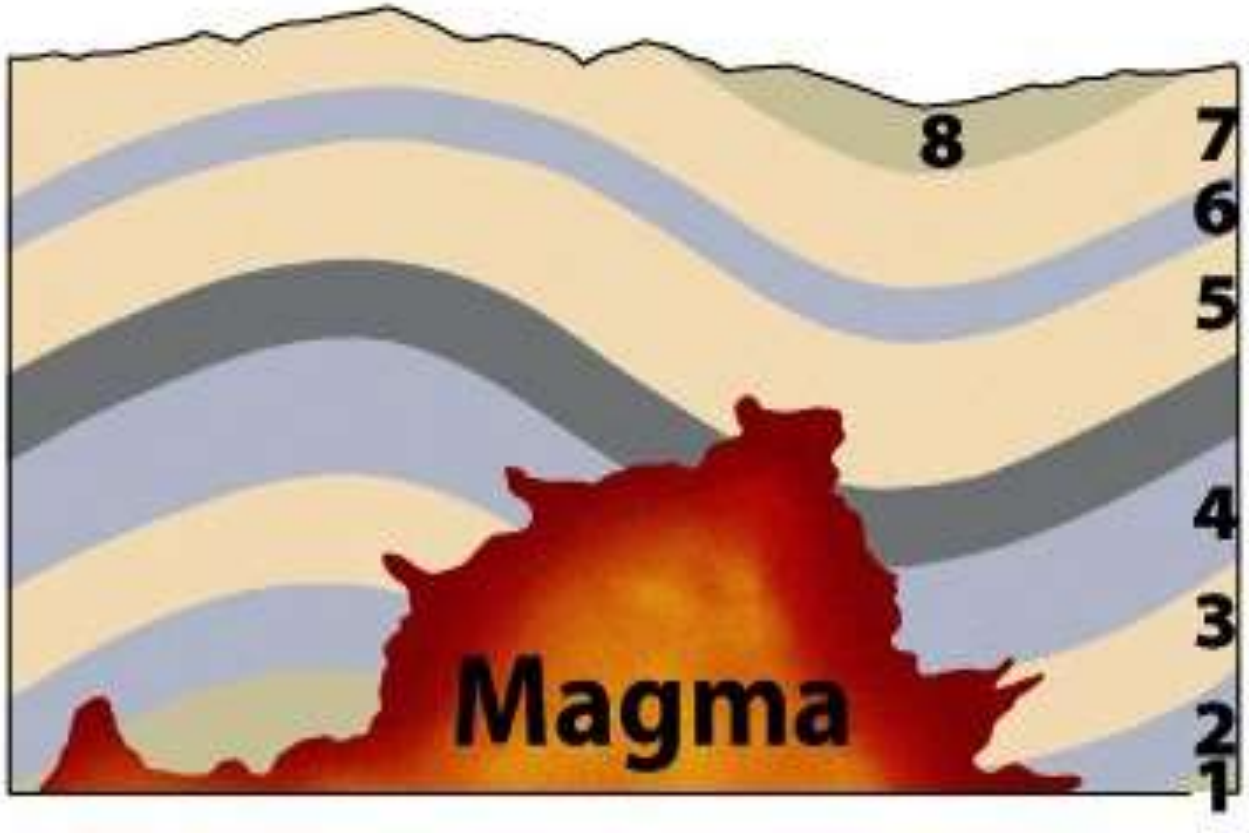
- Folding, uplift, and erosion take place.



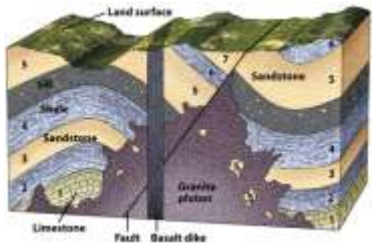
Geologic History



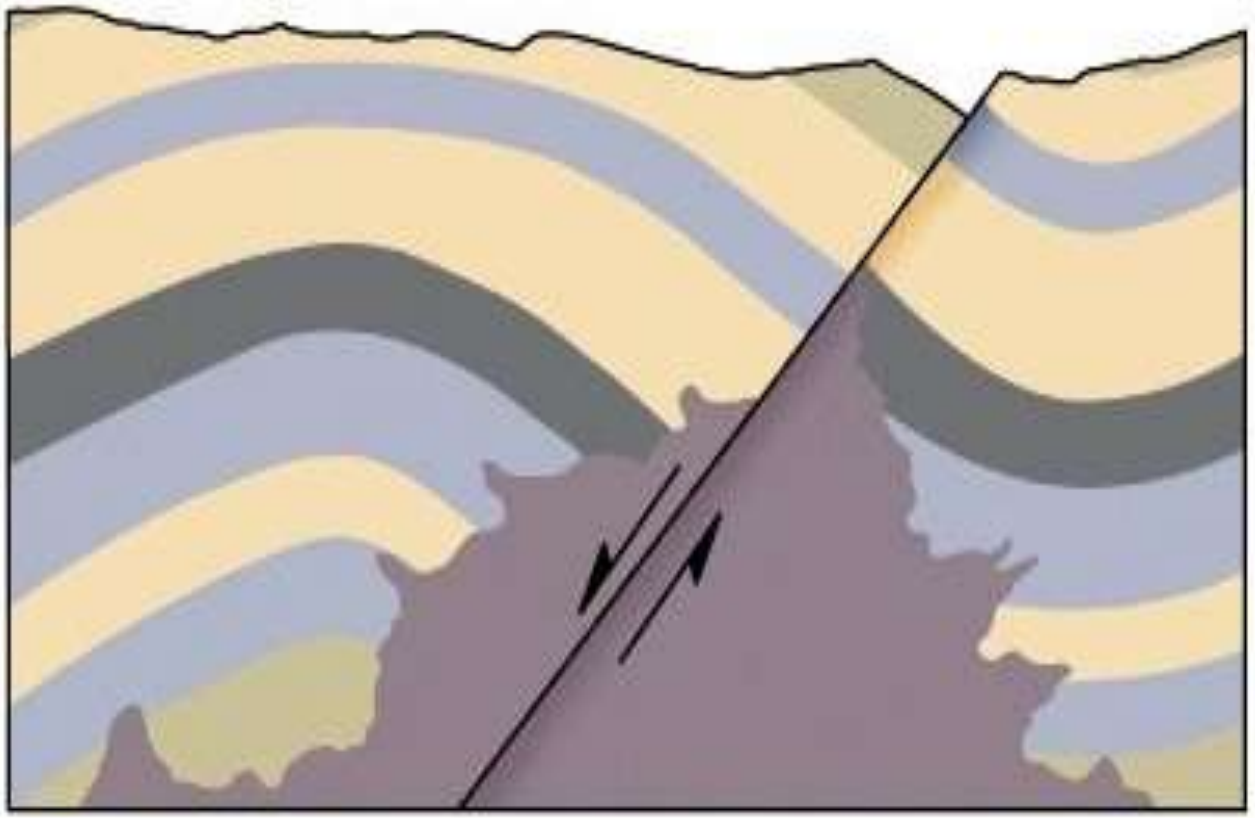
- An igneous pluton cuts older rock.



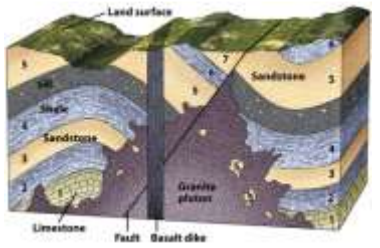
Geologic History



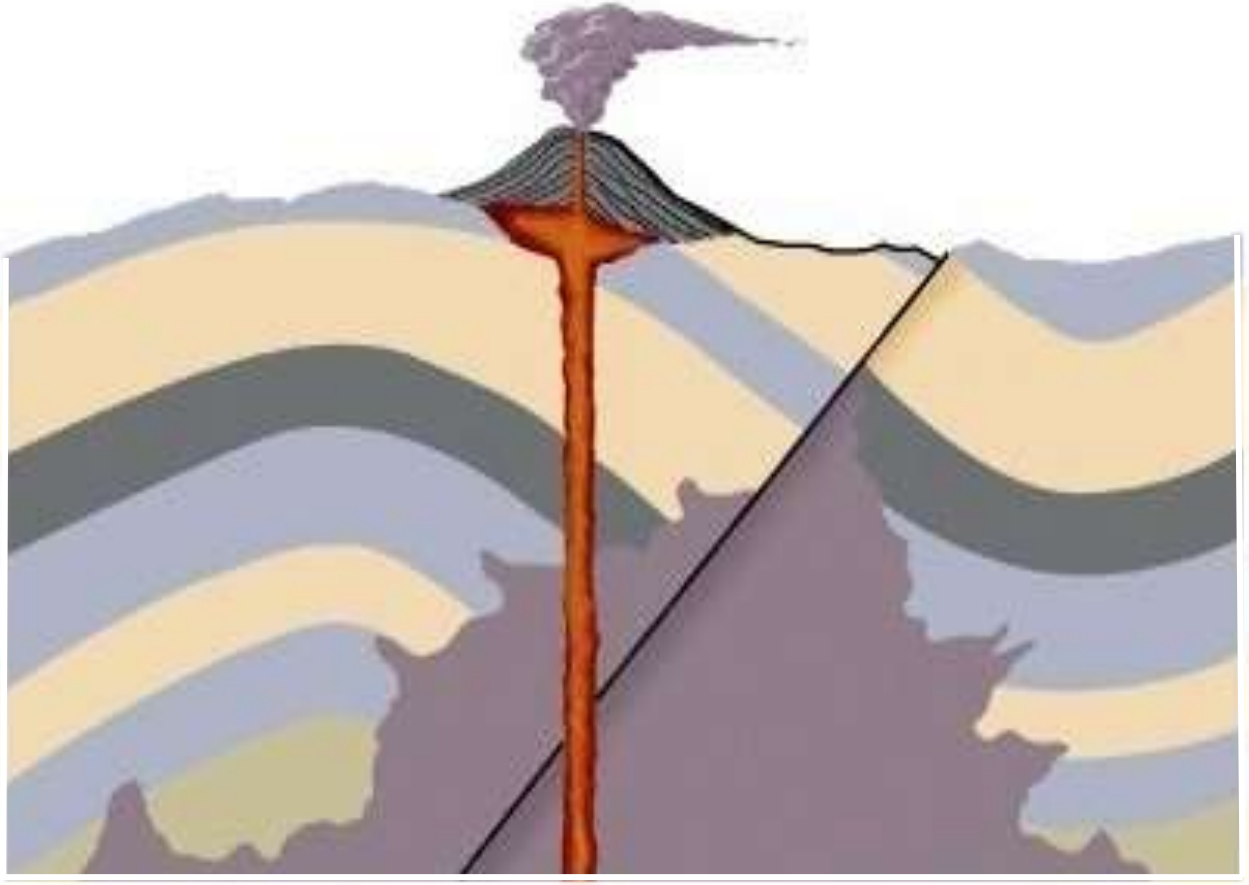
- Faulting cuts the strata and the pluton.



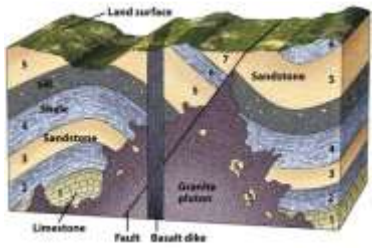
Geologic History



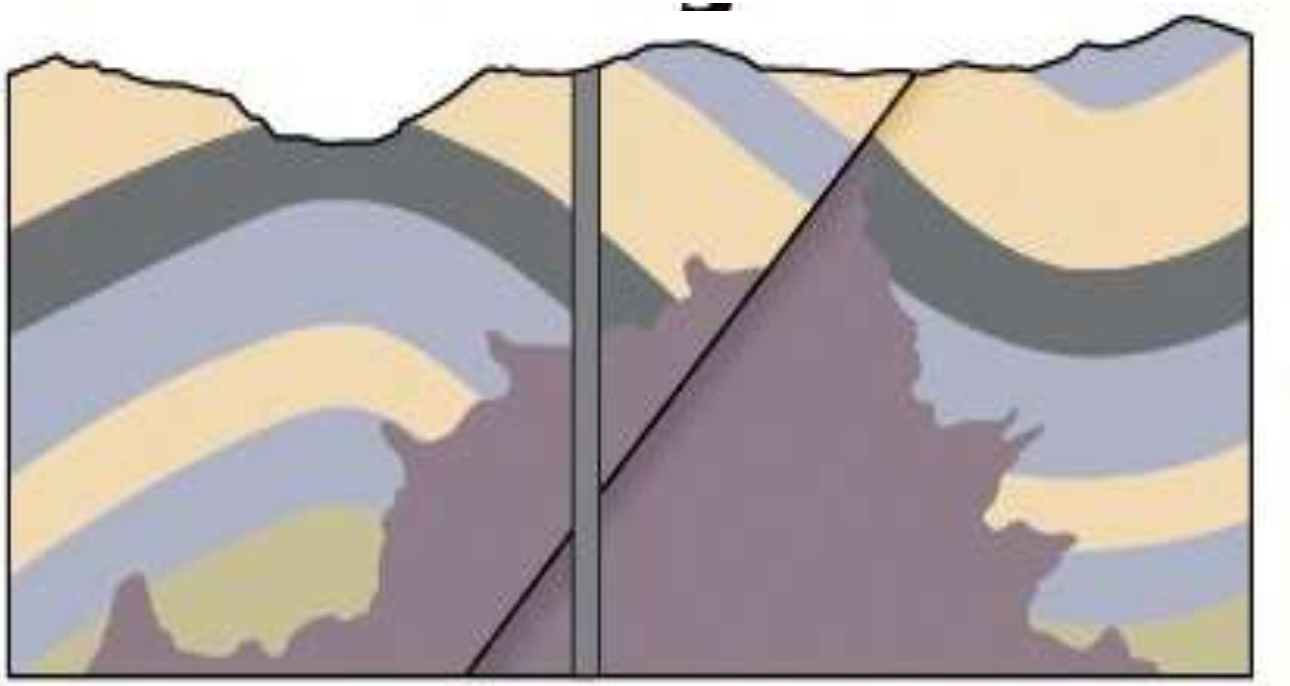
- A dike intrudes.



Geologic History



- Erosion forms the present land surface.



Unconformities

- An unconformity is a time gap in the rock record due to non-deposition or erosion

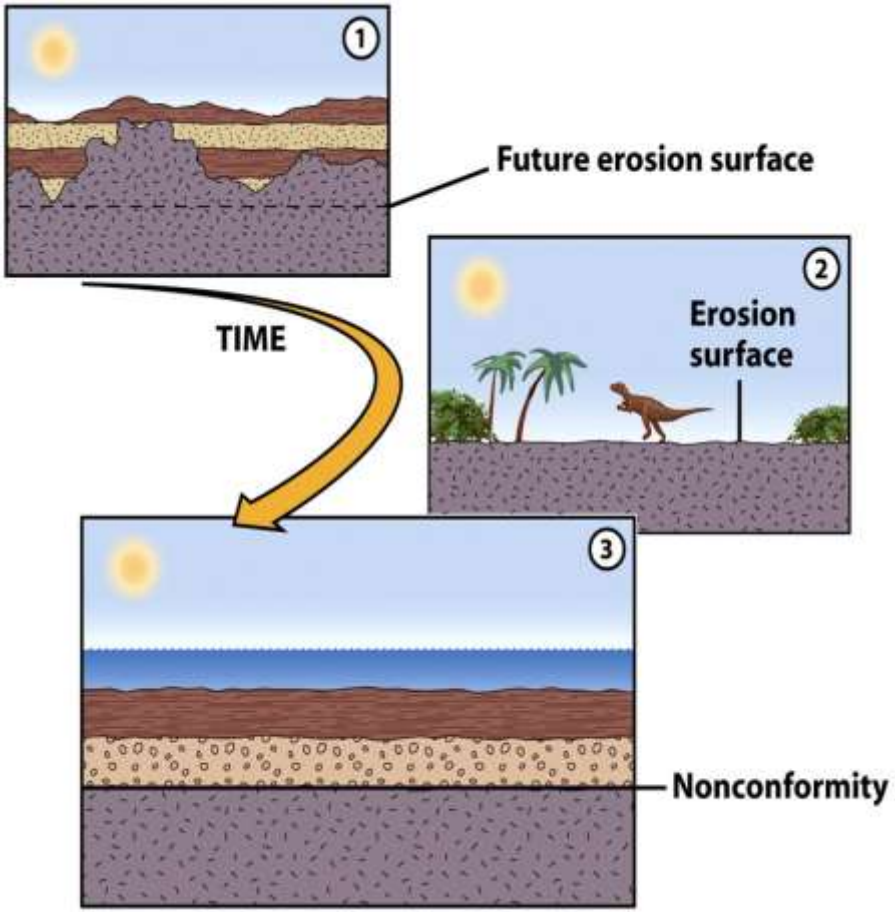
3 unconformity types

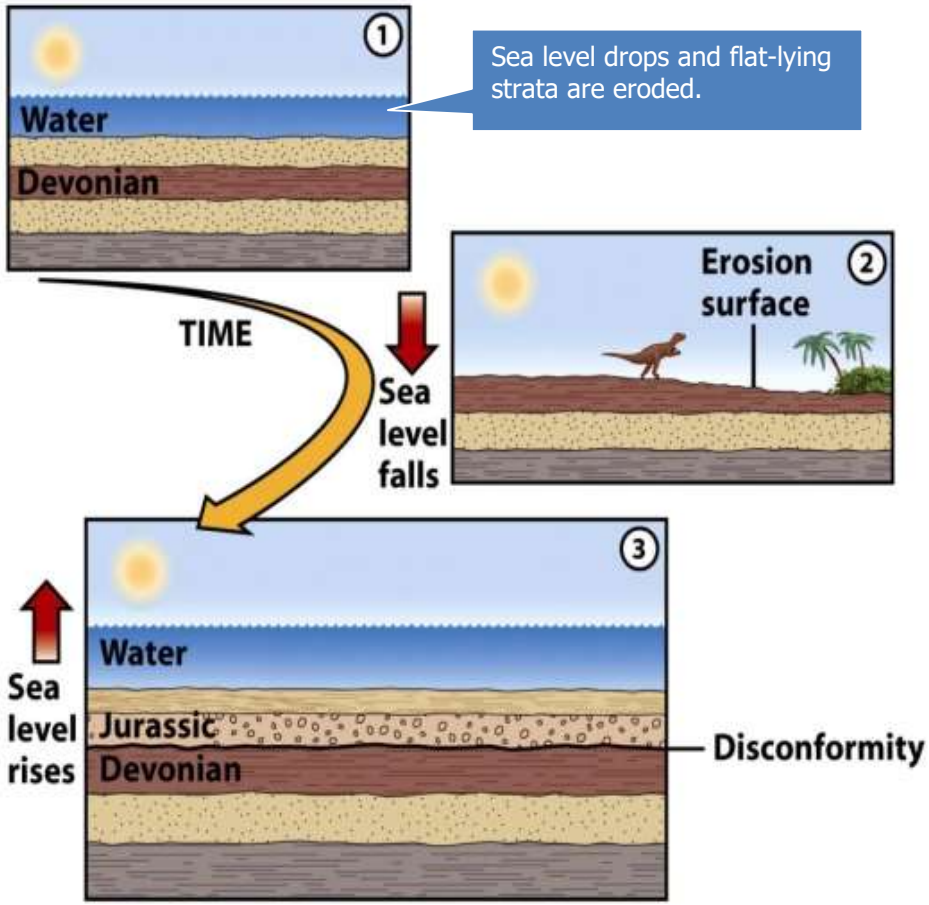
- **Angular unconformity** – tilted rocks are overlain by flat-lying rocks
- **Nonconformity** – metamorphic or igneous rocks in contact with sedimentary strata
- **Disconformity** – strata on either side of the unconformity are parallel

Angular unconformity

- Represents a huge gap in time
  - Horizontal marine sediments deformed by orogenesis
  - High mountains are eroded away to below sea level
  - Sediments deposited horizontally on the erosion surface

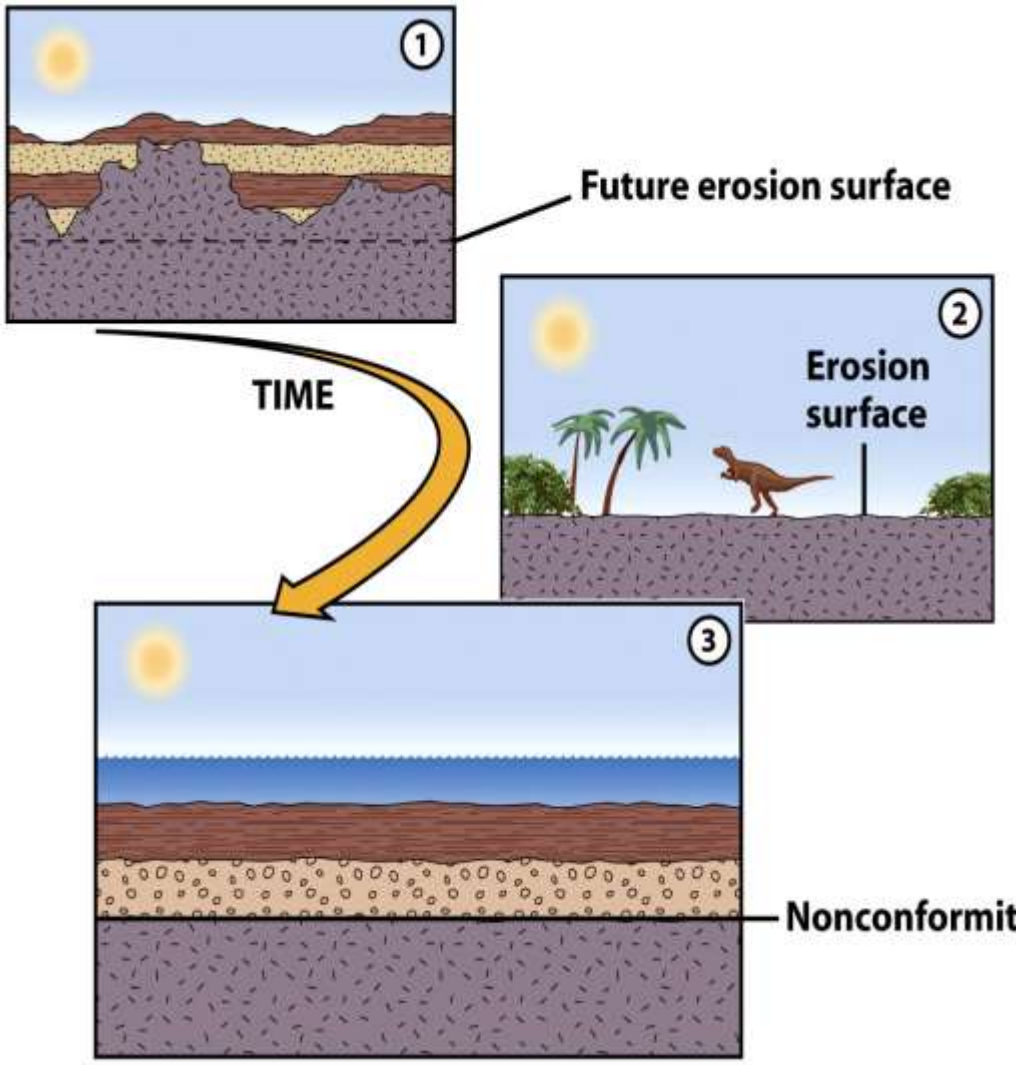
Nonconformity and Disconformity





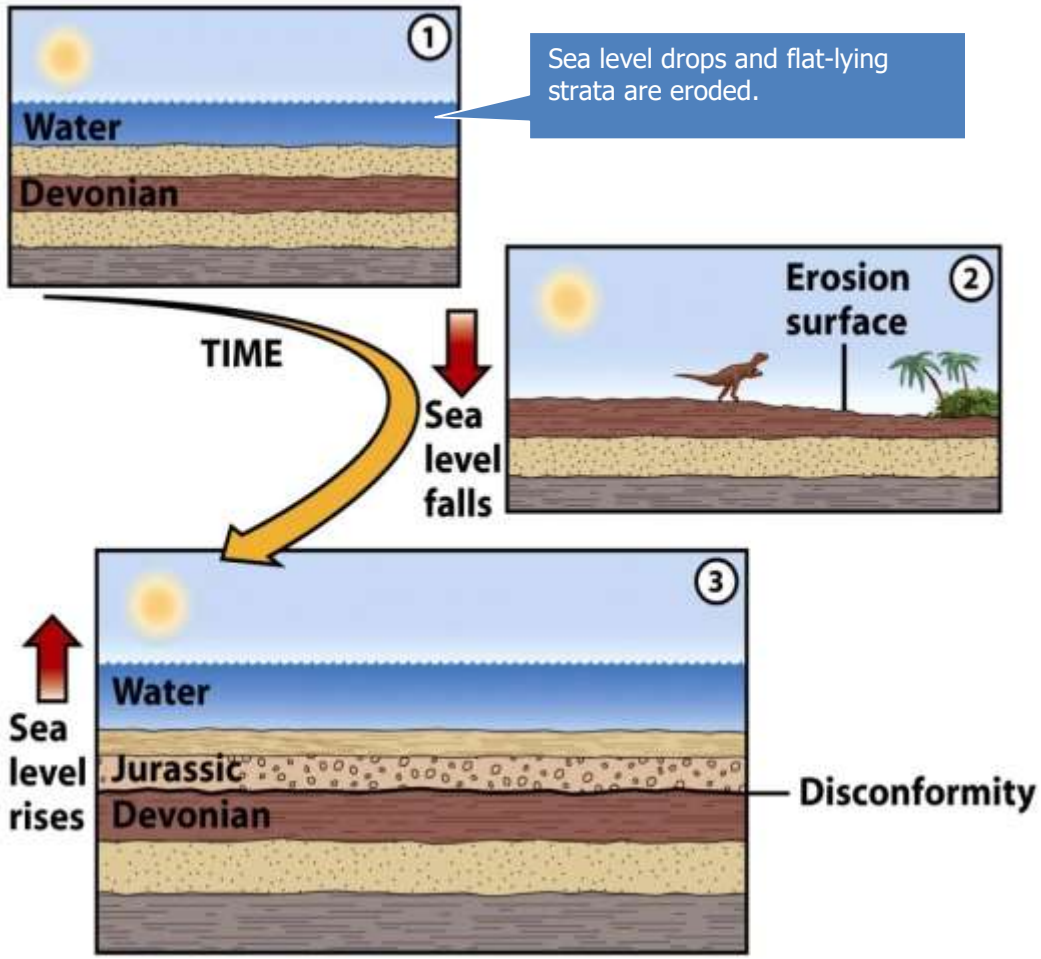
Nonconformity

- Metamorphic or igneous rocks overlain by sedimentary strata
  - Crystalline igneous or metamorphic rocks were exposed by erosion and uplift
  - Sediment was deposited on this eroded surface



Disconformity

- Parallel strata bracketing non-deposition
  - Due to an interruption in sedimentation
  - May be difficult to recognize



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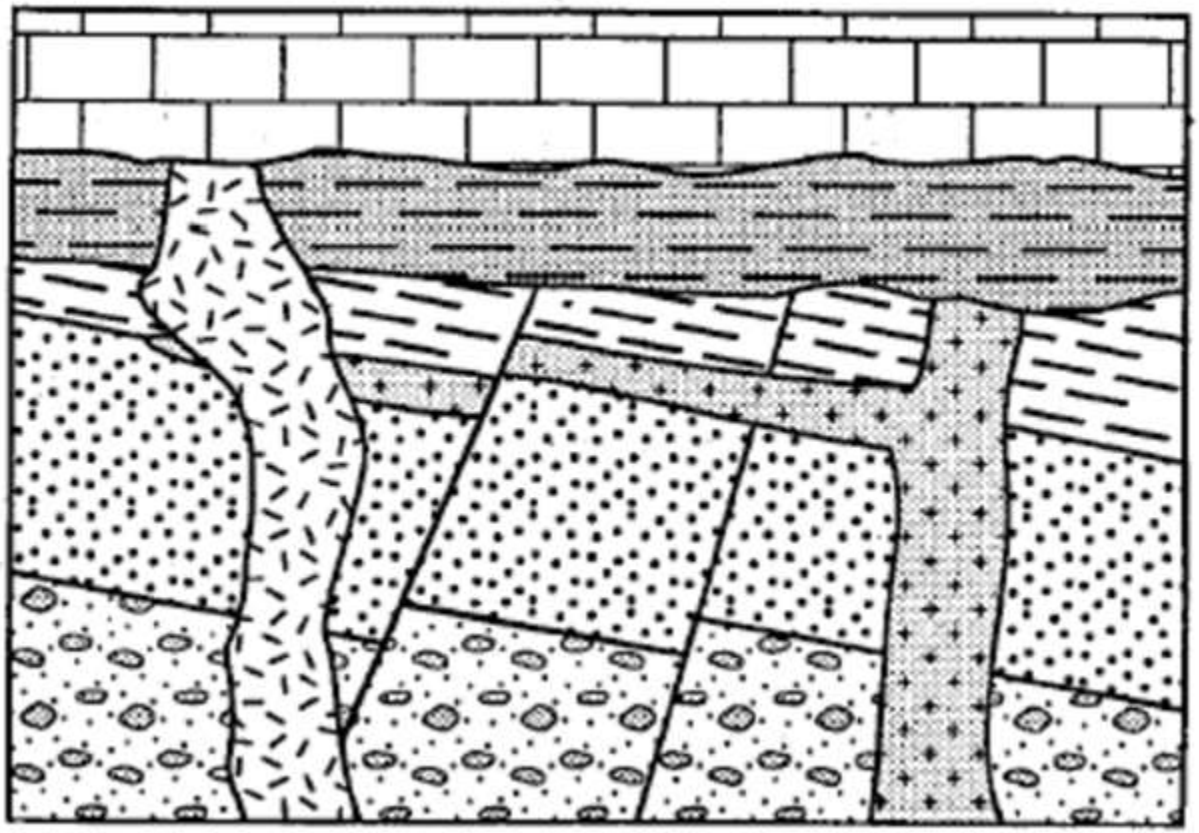
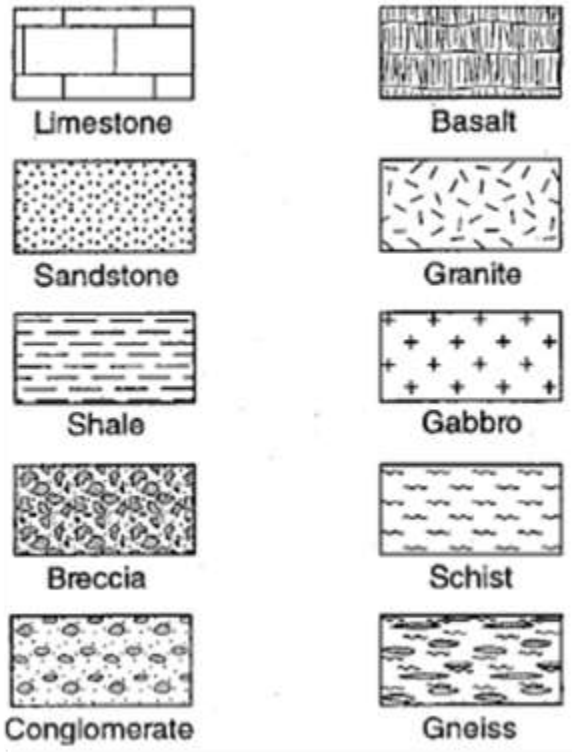
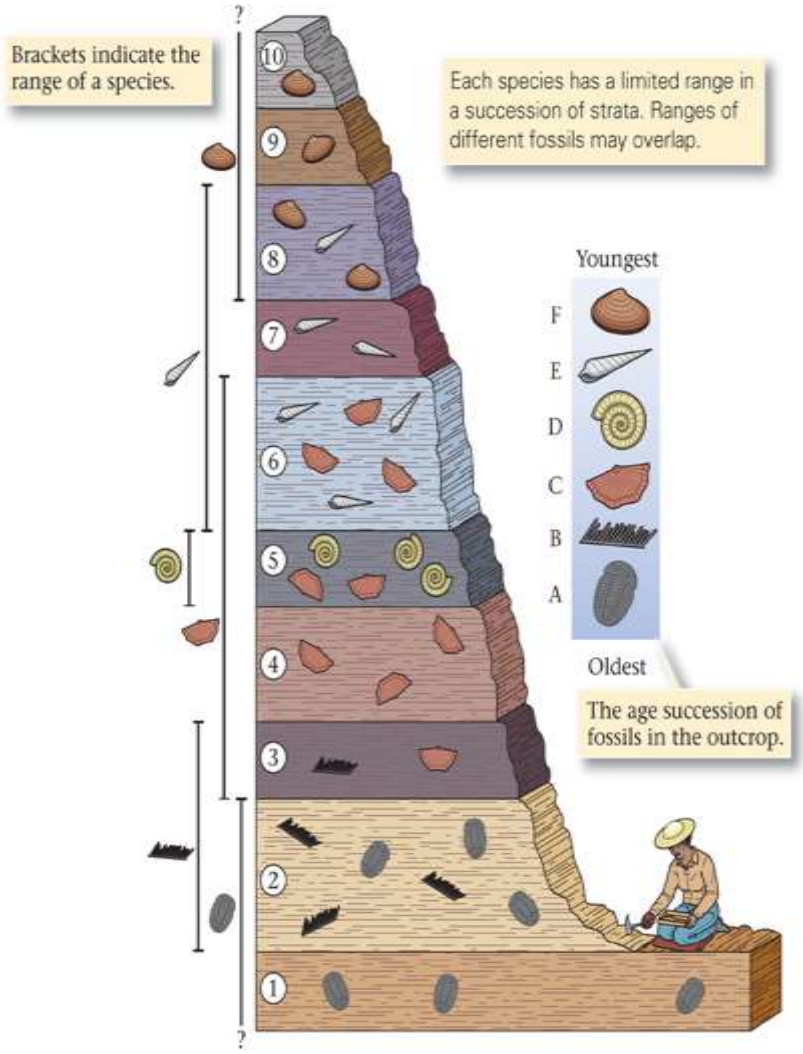
Unconformity exercise





Fossil Succession

- Fossil range – First and last appearance
  - Each fossil has a unique range
  - Overlapping ranges provide distinctive time markers
- Permit correlation of strata



Dating rocks using index fossils

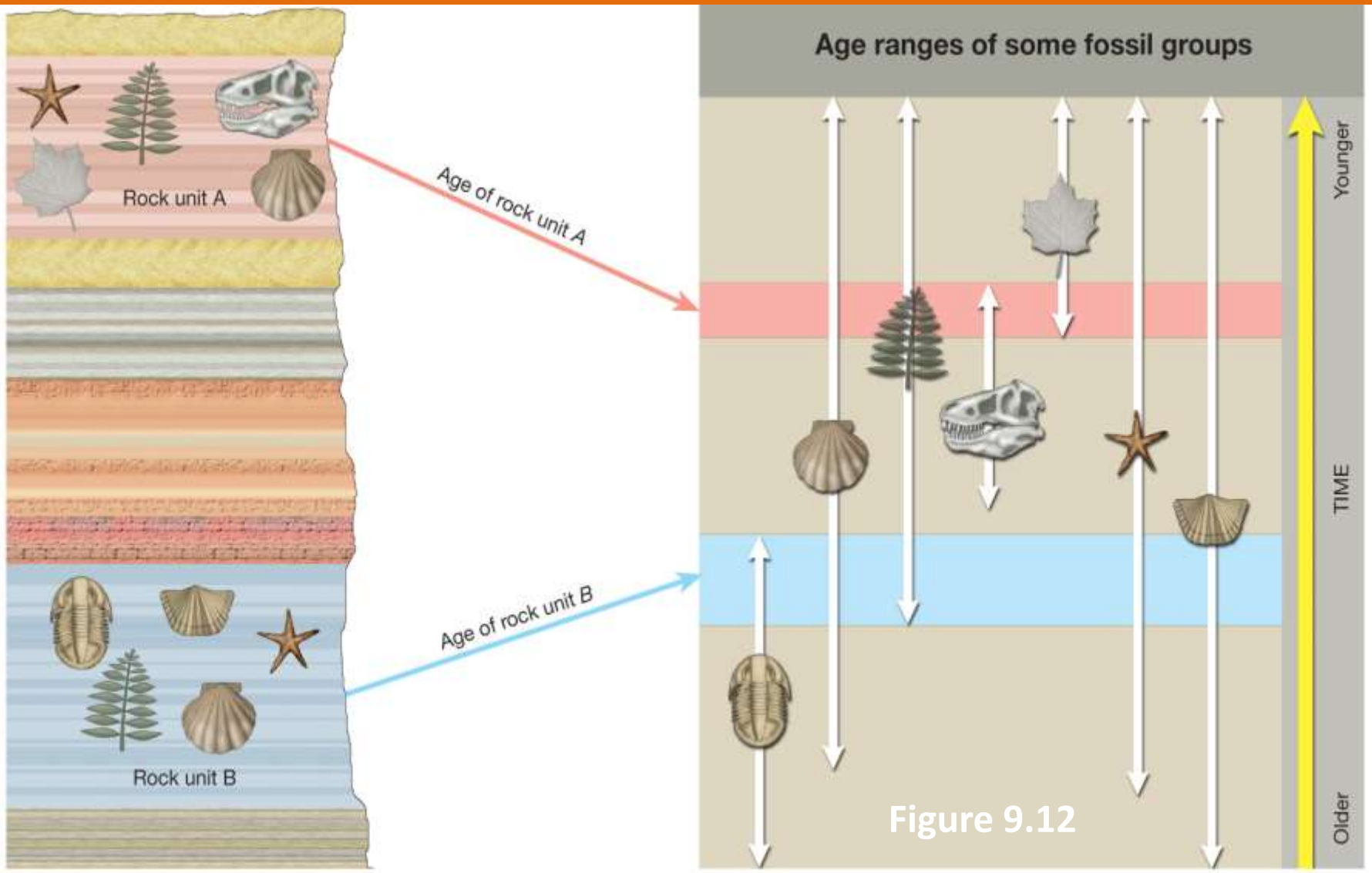


Figure 9.12

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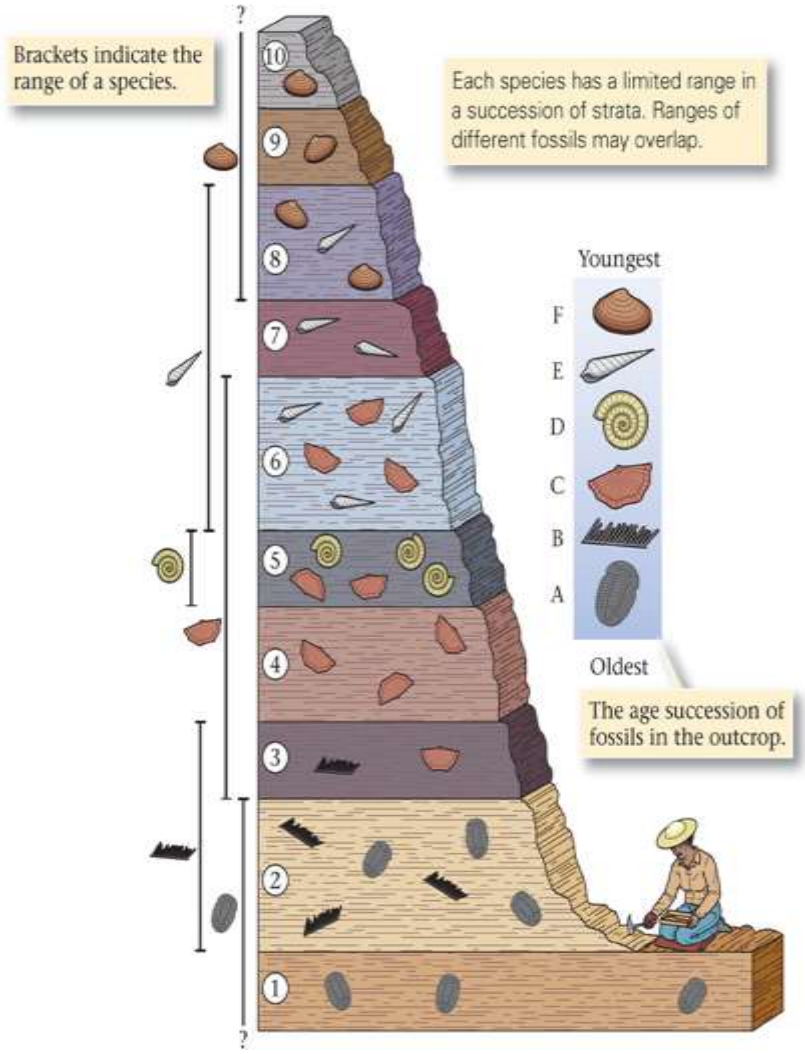
Fossil Succession

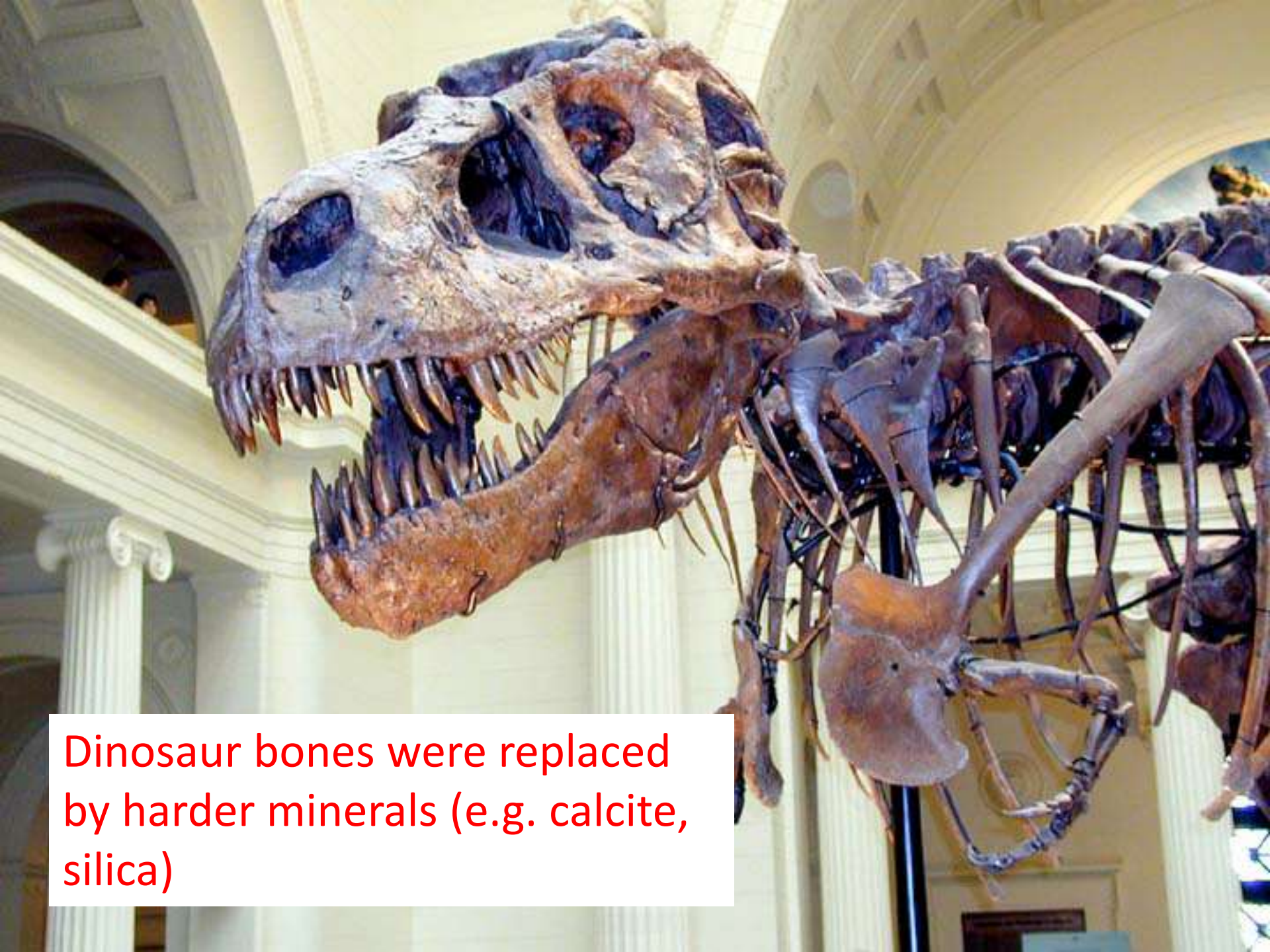
- Fossil range – First and last appearance
  - Each fossil has a unique range
  - Overlapping ranges provide distinctive time markers
- Permit correlation of strata
- Index fossil – geographically widespread fossil that is limited to a short span of geologic time



Types of fossils

- Hard remains of relatively recent organisms
  - Teeth, bones, shells, etc.
- “Petrified” remains
  - Small internal cavities and pores filled with precipitated minerals
  - Replacement of solid material with mineral matter
- Molds and casts
- Carbonization
- Impression
- Amber preservation
- Trace fossils


Petrified Wood in Petrified
Forest National Park, AZ

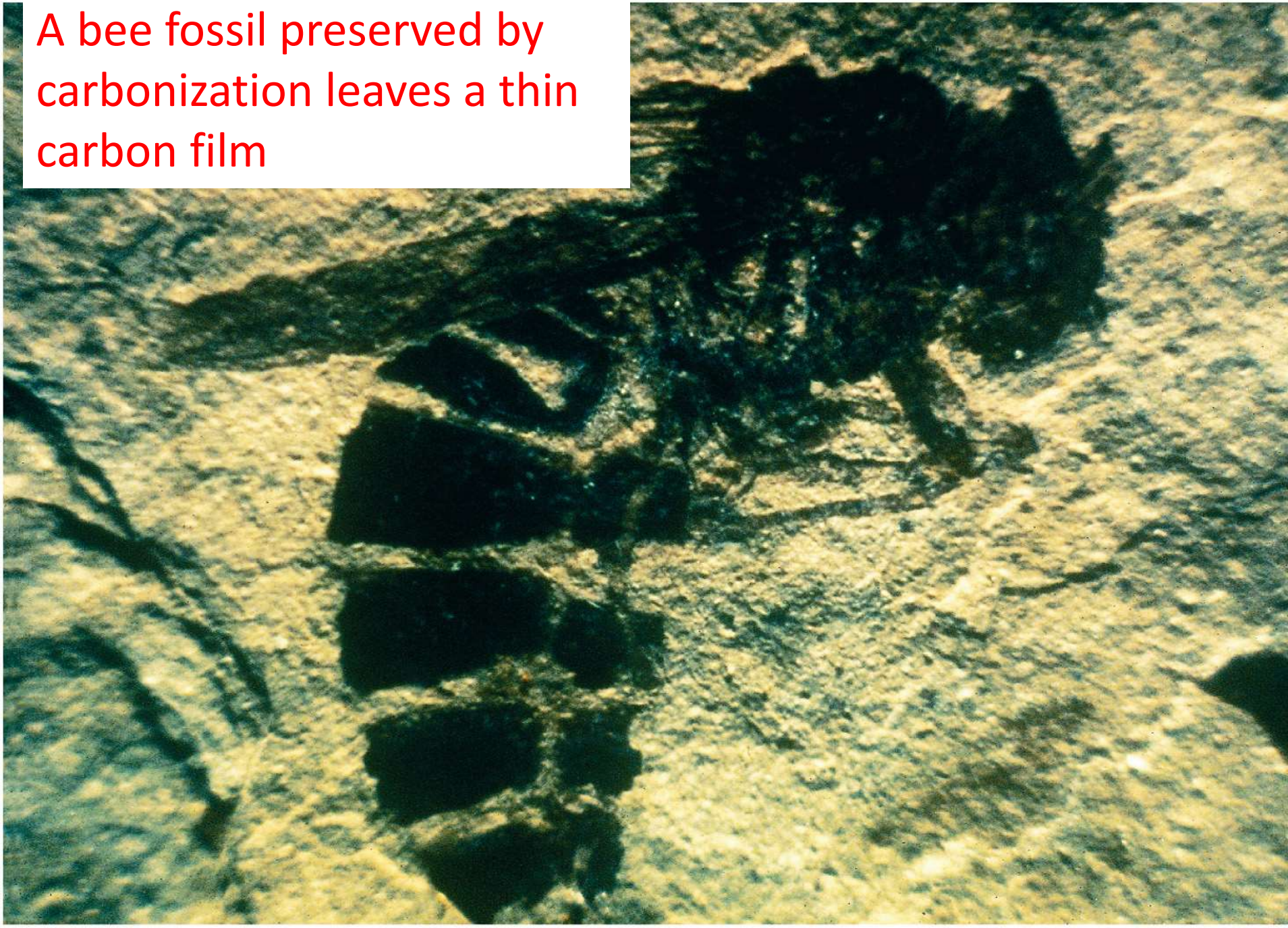


Dinosaur bones were replaced by harder minerals (e.g. calcite, silica)


Mold and cast of a trilobite (An extinct arthropod from the Early Paleozoic Period)

B.

A bee fossil preserved by carbonization leaves a thin carbon film



Impressions are often preserved in fine sediment, even after the thin carbon film is lost

D.

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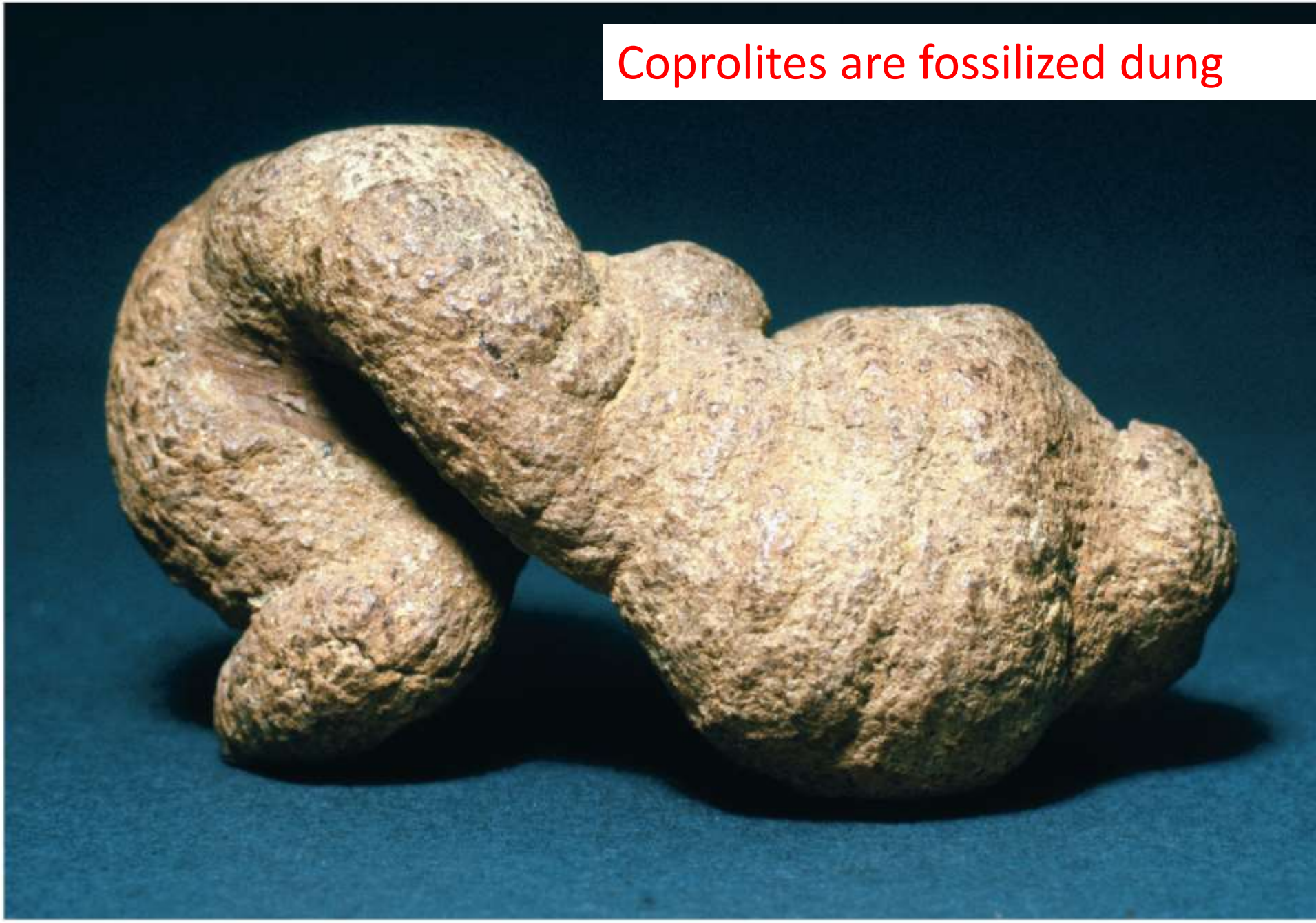
E.



F.

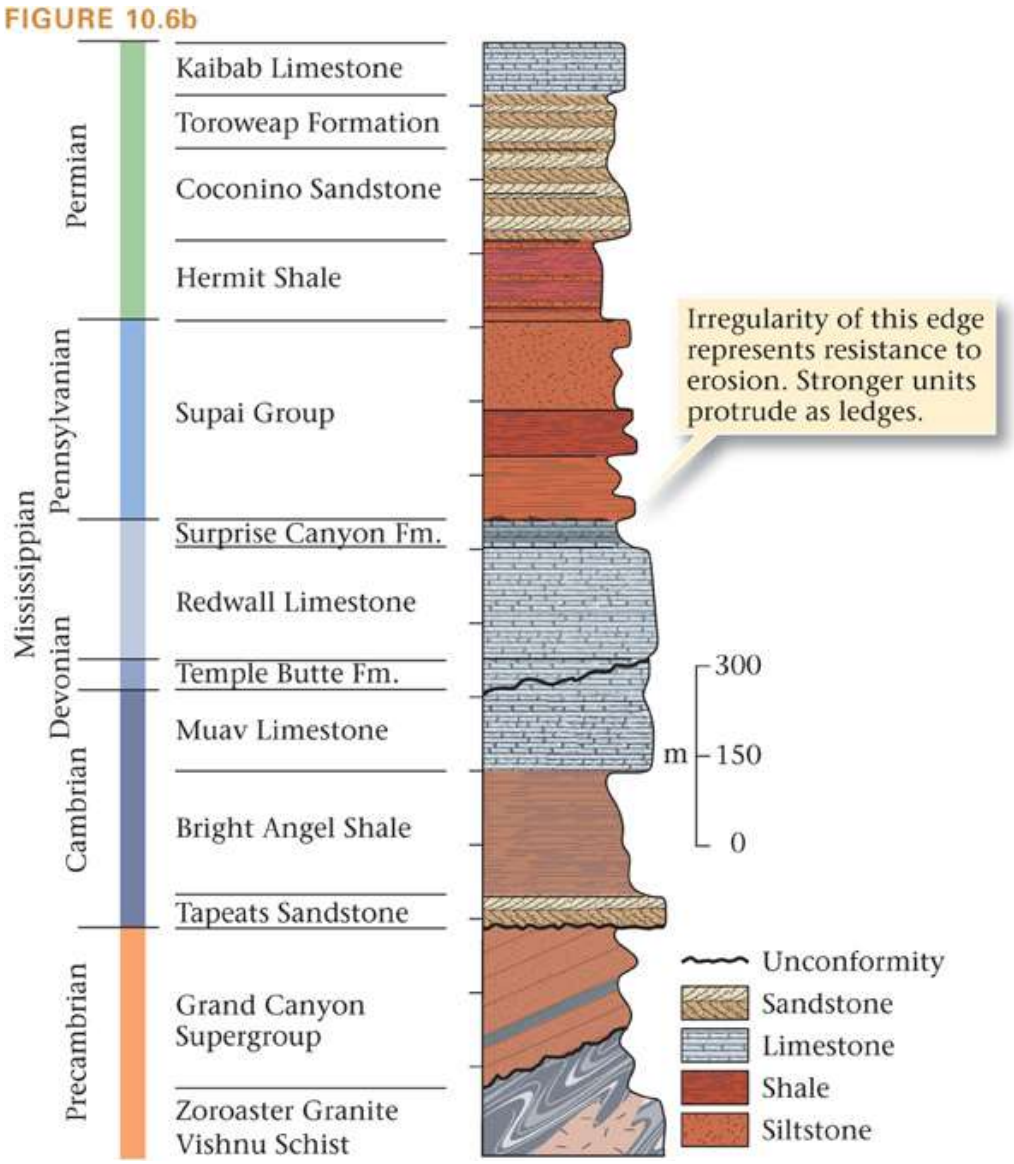
What is needed for fossil preservation?

What is needed for fossil preservation?

- Rapid burial
- Possession of hard parts (skeleton, shell, etc.)
- Fossil record is therefore biased towards organisms that lived in sedimentary environments and that possessed hard parts!

Stratigraphic Columns

- Stratigraphic columns depict strata in a region
  - Drawn to scale to accurately portray relative thicknesses
  - Rock types are depicted by graphical fill patterns
  - Divided into formations
    - Mappable rock units

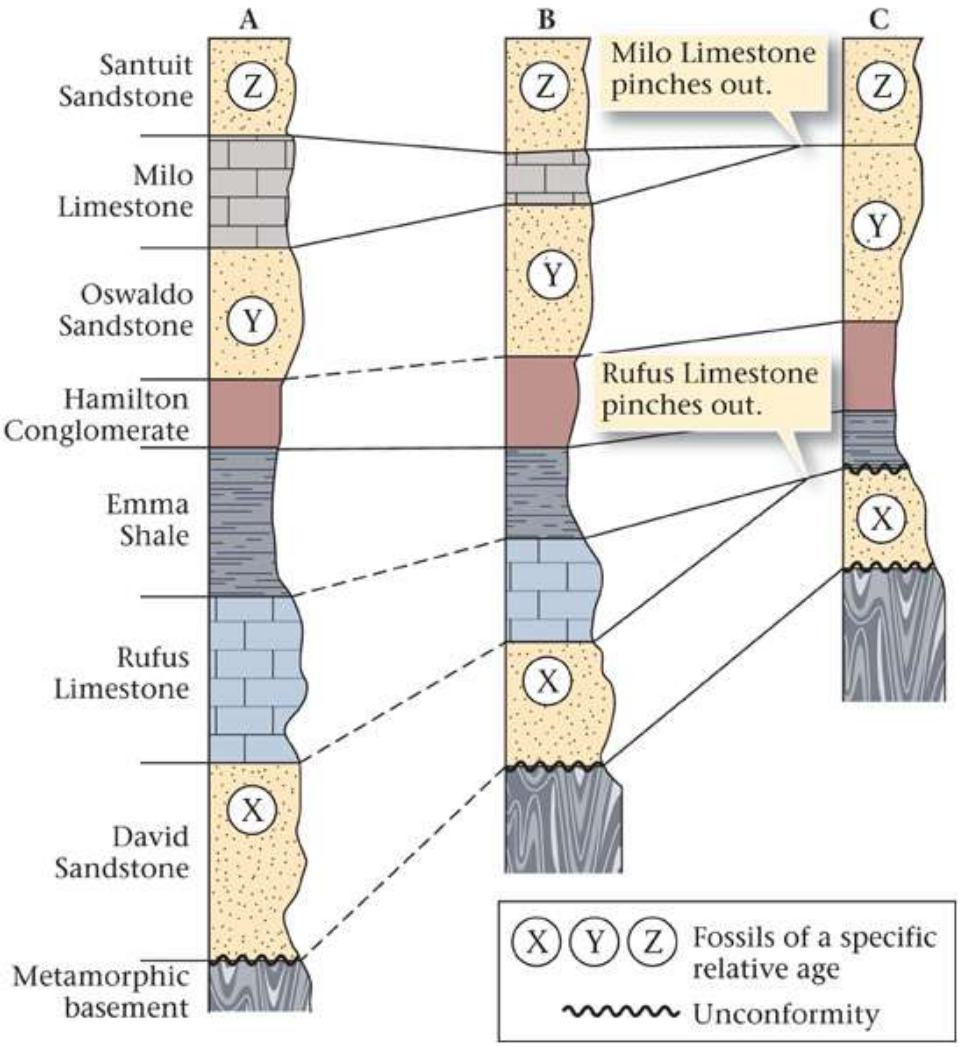


Stratigraphic Correlation

- In 1793, William “Strata” Smith was the first to note that strata could be matched or “correlated” across great distances
  - Similar rock types in a similar order
  - Rock layers contained the same distinctive fossils
- After years of work, he made the first geologic map

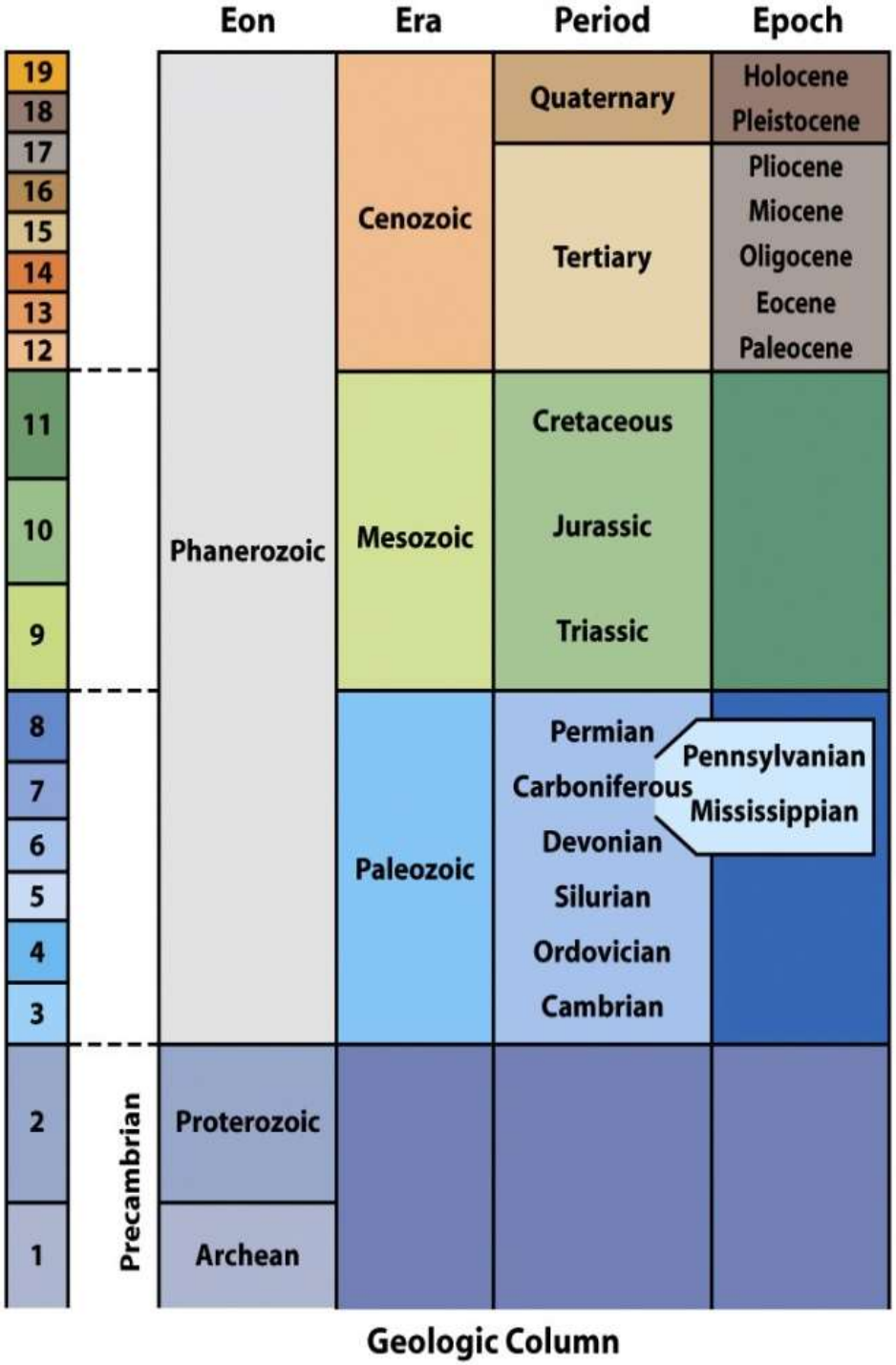
Stratigraphic Correlation

- Fossil correlation – Based on fossils within rocks
  - Applicable to broad areas
- Lithologic correlation is based on rock type
  - Limited to correlation between nearby region
- Can you think of other ways that we could match up strata from different places?



The Geologic Column

- A composite stratigraphic column was constructed using relative dating principles & correlation by the late 19th century
  - Assembled from incomplete sections across the globe
  - It brackets almost the entirety of Earth's history

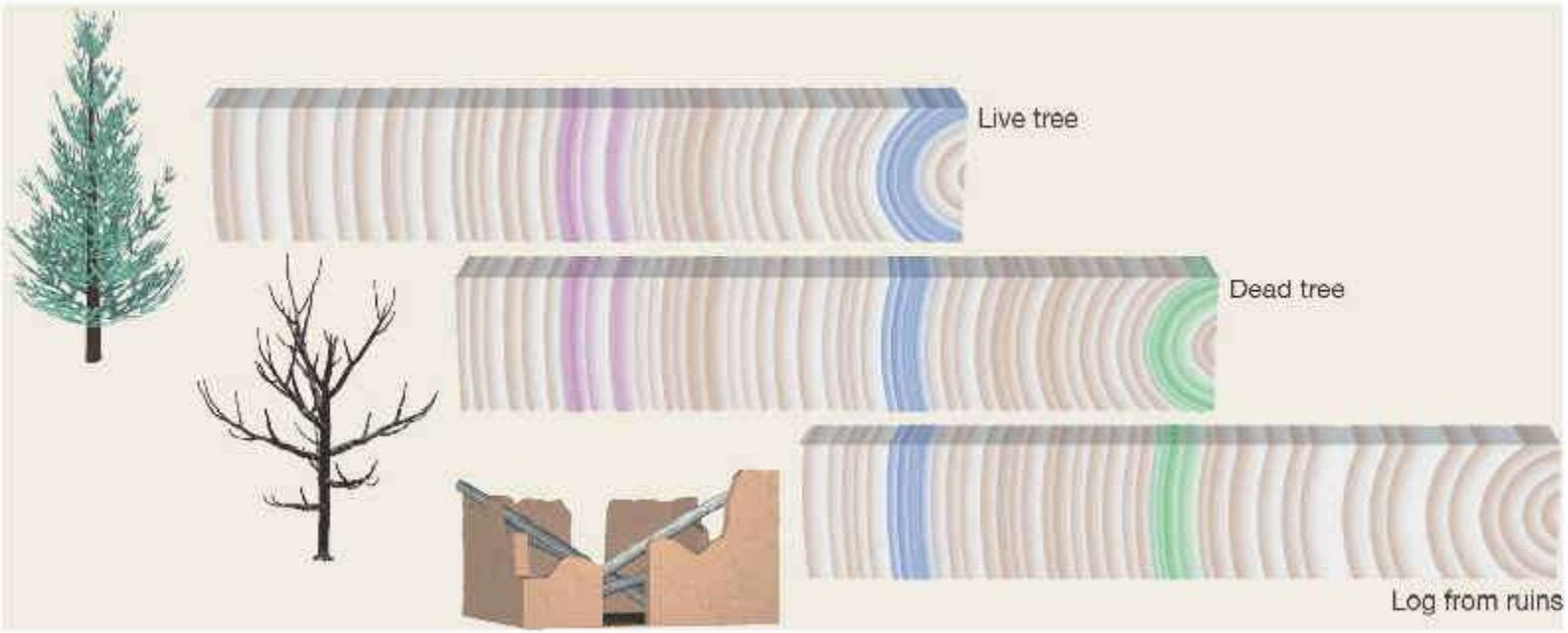


~~Absolute~~ Numerical Dating

- Many relative ages can now be assigned actual dates
- Numerical dating is also called geochronology

What ways can you think of on long and much shorter timescales?

- Tree rings (dendrochronology)

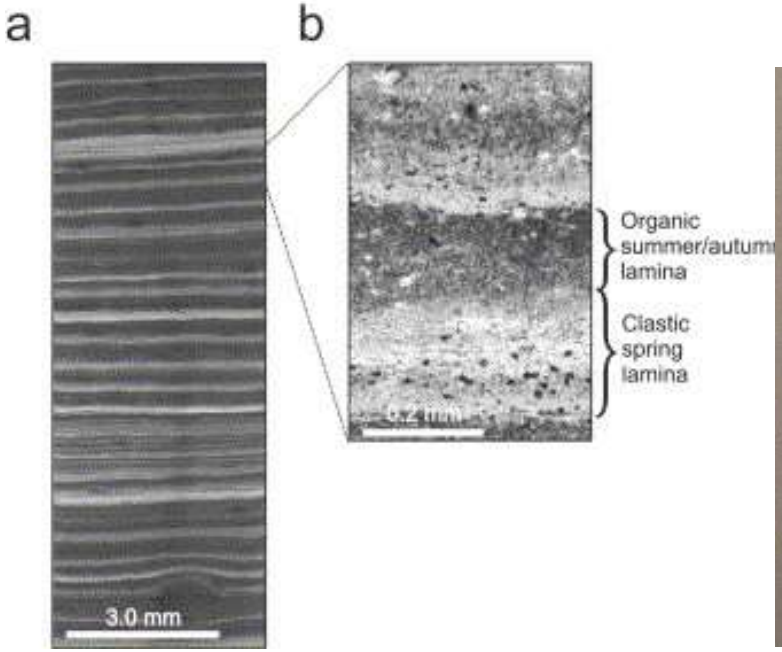


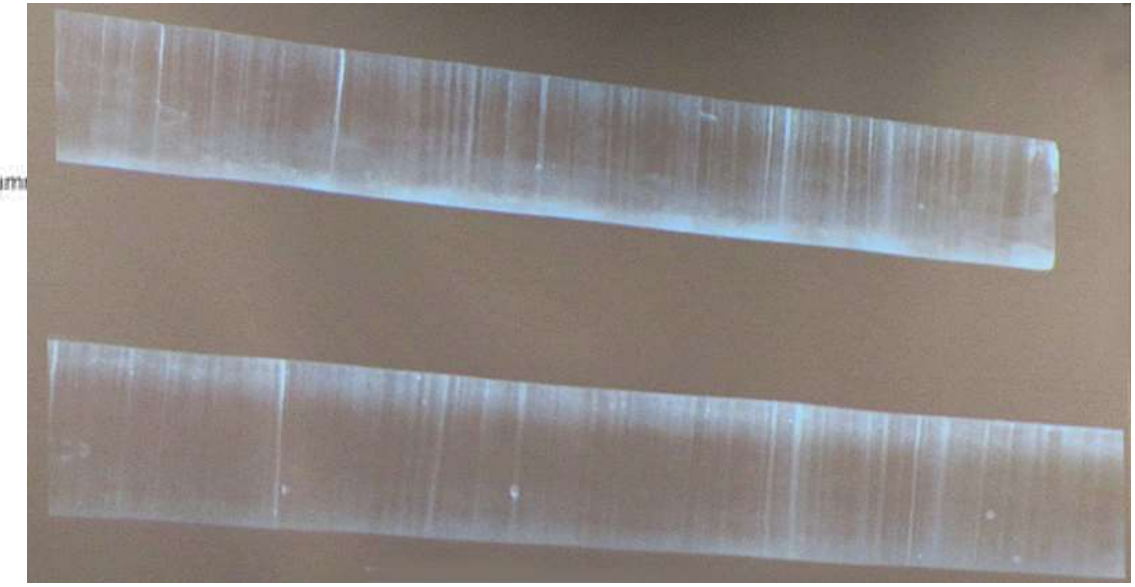
~~Absolute~~ Numerical Dating

- Many relative ages can now be assigned actual dates
- Numerical dating is also called geochronology

What ways can you think of on long and much shorter timescales?

- annual layers in sediment or in ice





Radiometric Dating

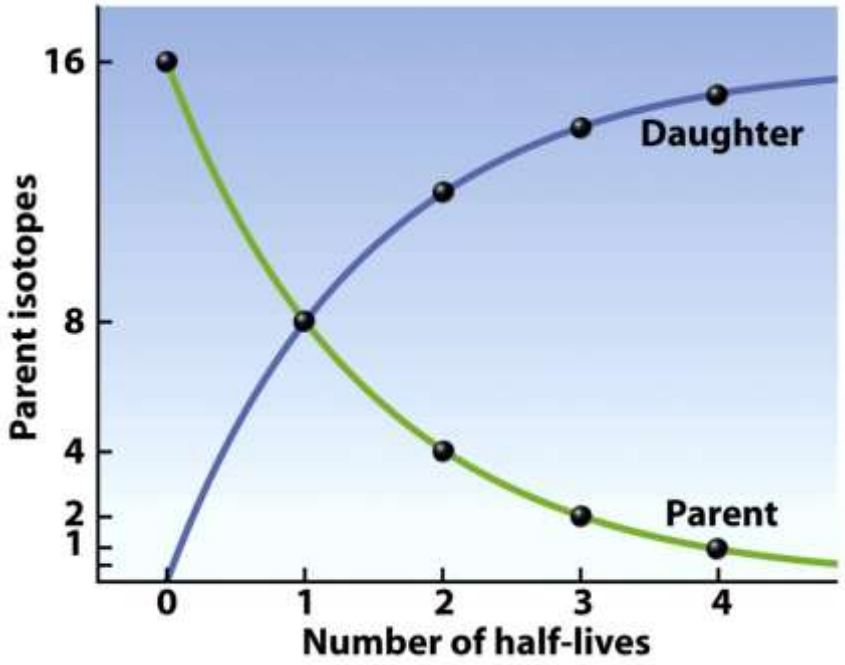
- Based on radioactive decay of atoms in minerals
  - Radioactive decay proceeds at a known, fixed rate
  - Radioactive elements act as internal clocks

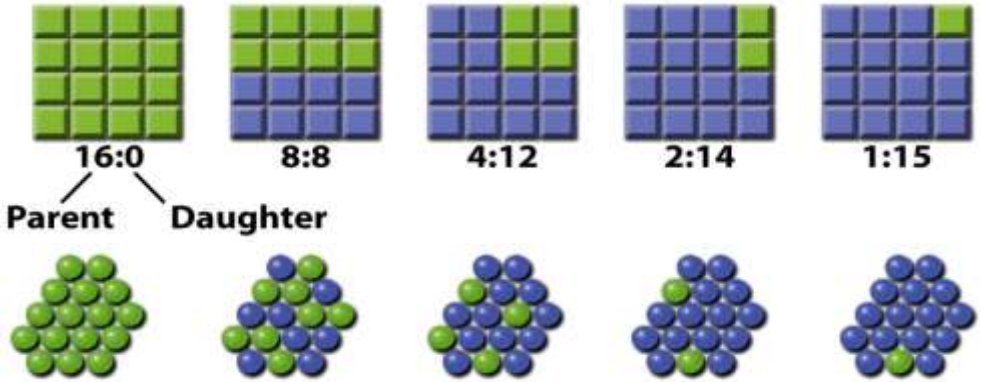
Examples of isotope systems used to date rocks:

$^{147}Sm \rightarrow {}^{143}Nd$	$t_{1/2}$ = 106 Gyrs	Garnets, micas
$^{87}Rb \rightarrow {}^{87}Sr$	$t_{1/2}$ = 48.8 Gyrs	Mica, feldspar, hornblende
$^{238}U \rightarrow {}^{206}Pb$	$t_{1/2}$ = 4.5 Gyrs	Zircon, apatite, uraninite
$^{40}K \rightarrow {}^{40}Ar$	$t_{1/2}$ = 1.3 Gyrs	Mica, feldspar, hornblende
$^{235}U \rightarrow {}^{207}Pb$	$t_{1/2}$ = 0.72 Gyrs	Zircon, apatite, uraninite

Radiometric dating

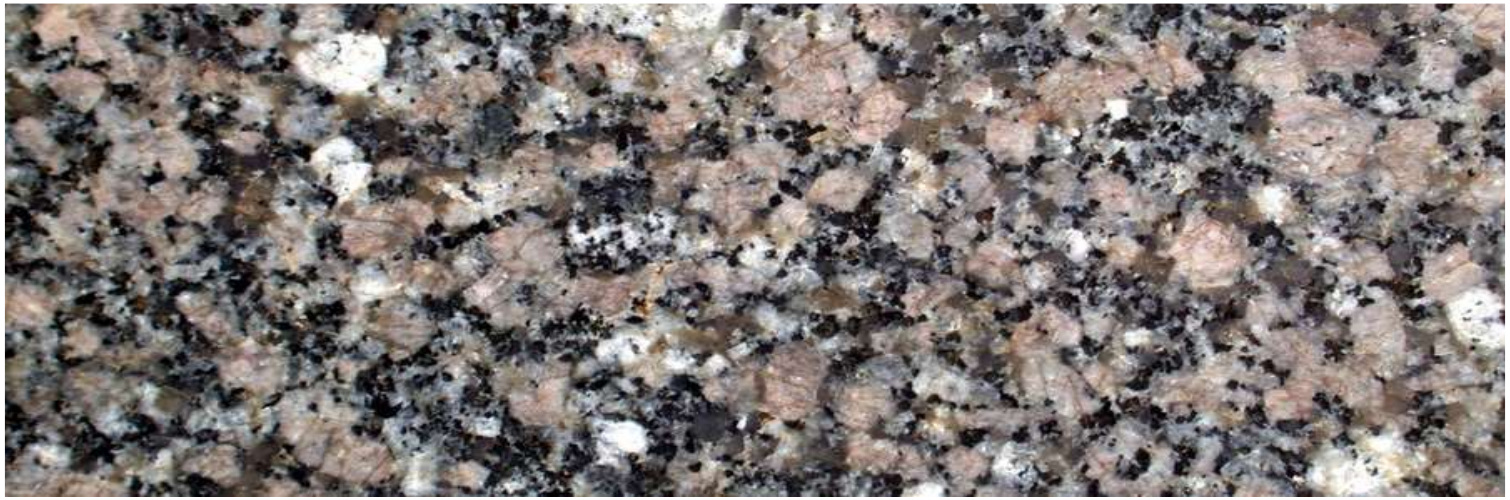
- Half-life = time taken for half of radioactive elements to decay
- Comparing the ratio of parent to daughter yields the age of the sample
- Requires very good analytical precision
- What are we assuming?





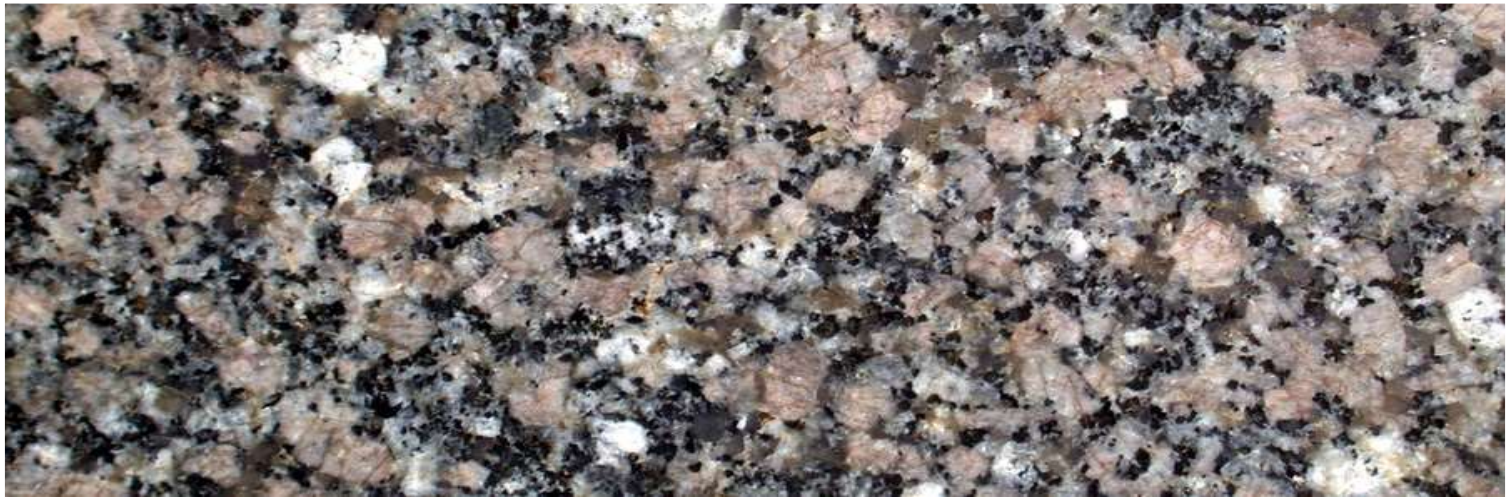
What is a Radiometric Date?

- What do you have to think about when trying to get a radiometric date? What are you actually dating?
- Which of these are best for radiometric dating?
  a) Sedimentary rocks
  b) Igneous rocks
  c) Metamorphic rocks

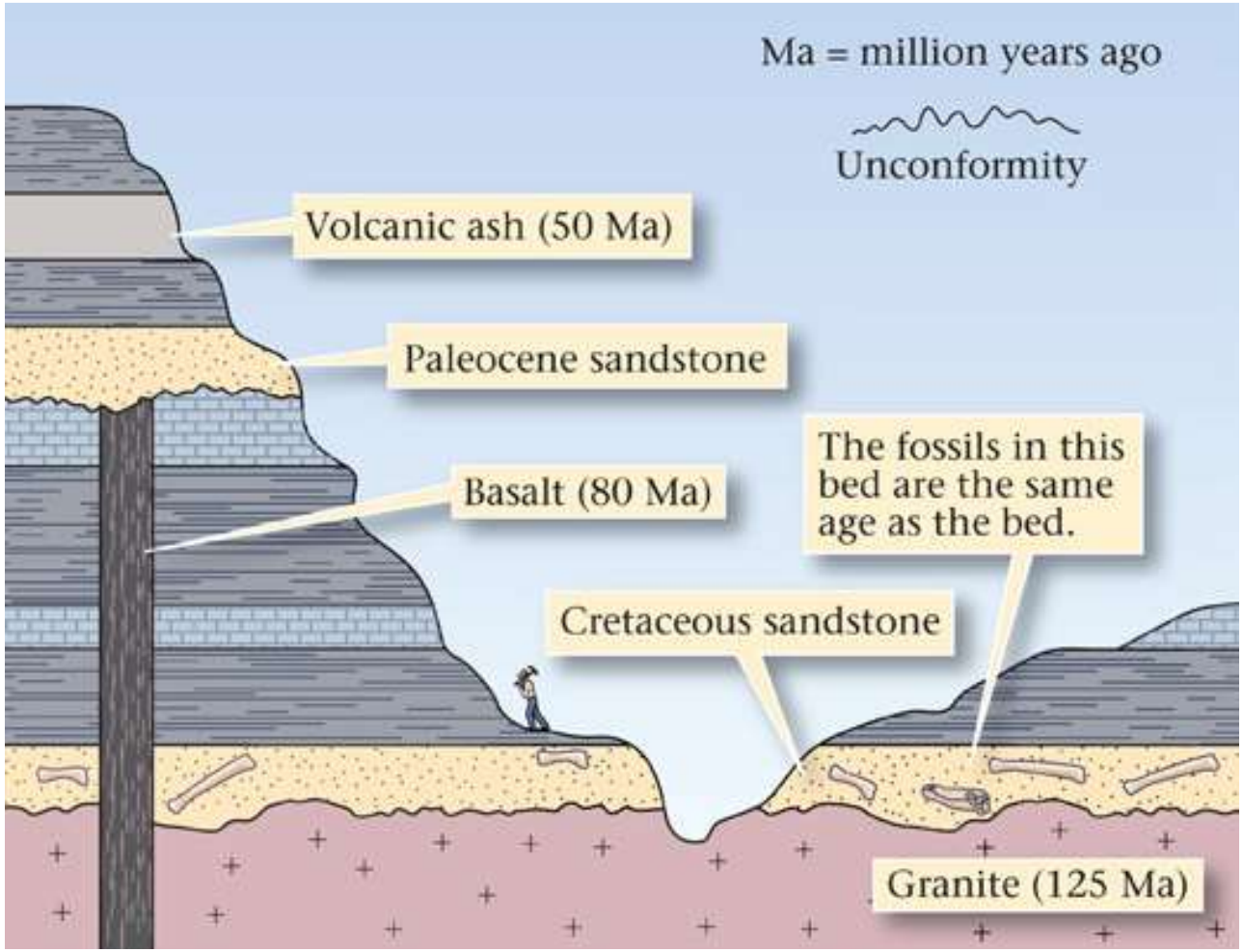


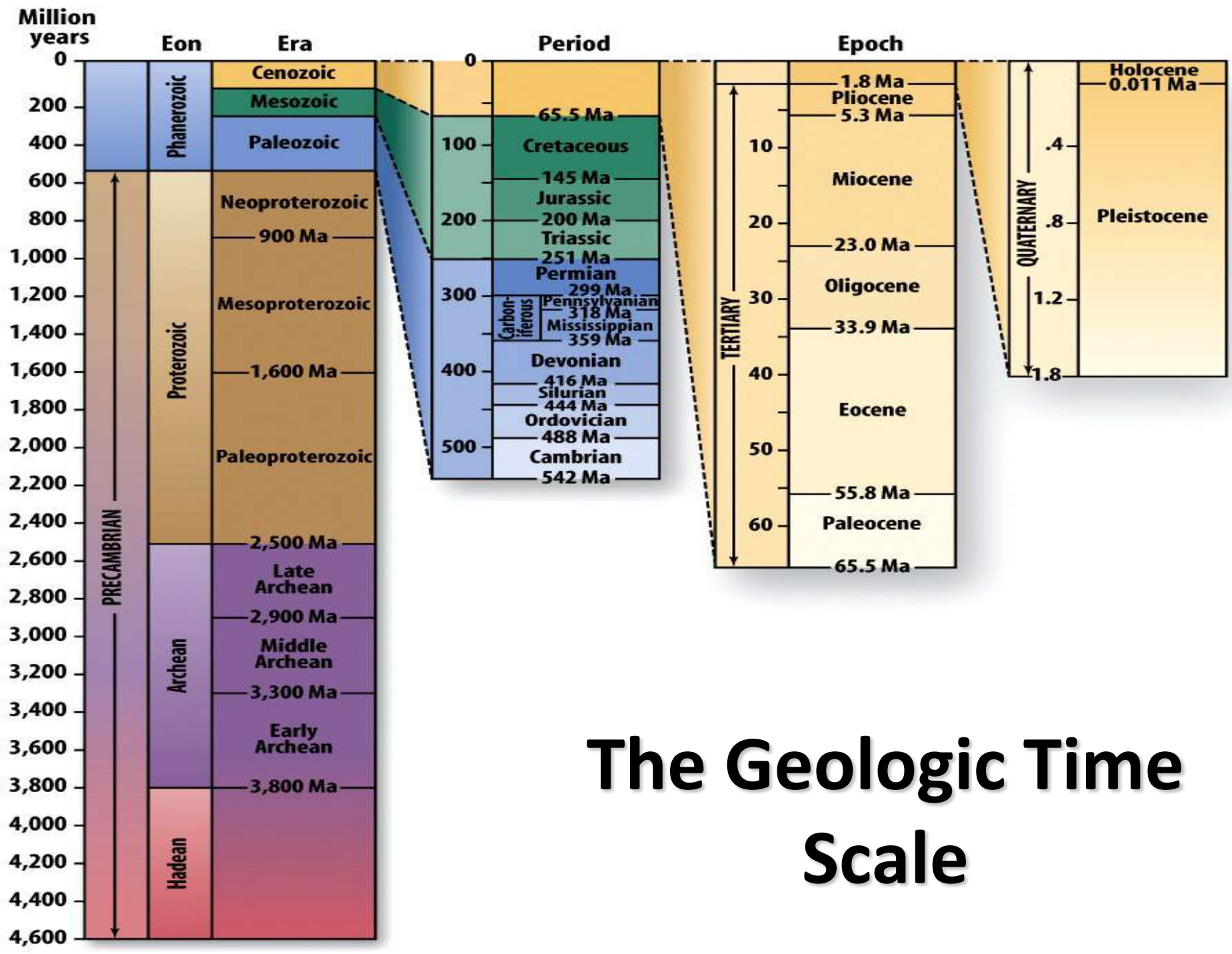
What is a Radiometric Date?

- Radiometric dates give the time a mineral began to preserve all atoms of parent and daughter isotopes
  - Requires cooling below a “closure temperature”
  - If rock is reheated, the radiometric clock can be reset
- Igneous rocks are best for geochronologic work
- Most sedimentary rocks cannot be directly dated



Dating the Geologic Column





The Geologic Time Scale