



Earth's History

Uniformitarianism

The landscape developed over long periods of time through a variety of slow geologic and geomorphic processes

The processes occurring on Earth today, have always been happening on Earth.

Scheme for Sedimentary Rock Identification

INORGANIC LAND-DERIVED SEDIMENTARY ROCKS

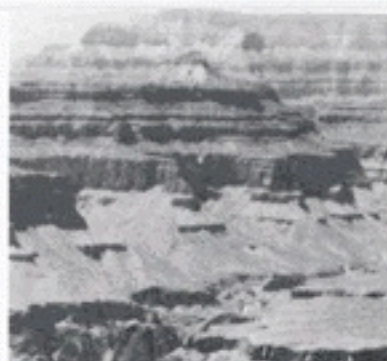
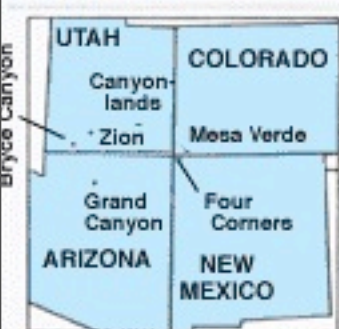
TEXTURE	GRAIN SIZE	COMPOSITION	COMMENTS	ROCK NAME	MAP SYMBOL
Clastic (fragmental)	Pebbles, cobbles, and/or boulders embedded in sand, silt, and/or clay	Mostly quartz, feldspar, and clay minerals; may contain fragments of other rocks and minerals	Rounded fragments	Conglomerate	
			Angular fragments	Breccia	
	Sand (0.2 to 0.006 cm)		Fine to coarse	Sandstone	
	Silt (0.006 to 0.0004 cm)		Very fine grain	Siltstone	
	Clay (less than 0.0004 cm)		Compact; may split easily	Shale	

CHEMICALLY AND/OR ORGANICALLY FORMED SEDIMENTARY ROCKS

TEXTURE	GRAIN SIZE	COMPOSITION	COMMENTS	ROCK NAME	MAP SYMBOL
Crystalline	Varied	Halite	Crystals from chemical precipitates and evaporites	Rock Salt	
	Varied	Gypsum		Rock Gypsum	
	Varied	Dolomite		Dolostone	
Bioclastic	Microscopic to coarse	Calcite	Cemented shell fragments or precipitates of biologic origin	Limestone	
	Varied	Carbon	From plant remains	Coal	

Relative Time

**What happened first, what
happened second, etc.**



GRAND CANYON
NATIONAL PARK
ARIZONA



ZION
NATIONAL PARK
UTAH



CANYONLANDS
NATIONAL PARK
UTAH



MESA VERDE
NATIONAL PARK
COLORADO



BRYCE CANYON
NATIONAL PARK
UTAH

TERTIARY PERIOD

CRETACEOUS PERIOD

JURASSIC PERIOD

TRIASSIC PERIOD

PERMIAN PERIOD

PENNSYLVANIAN PERIOD

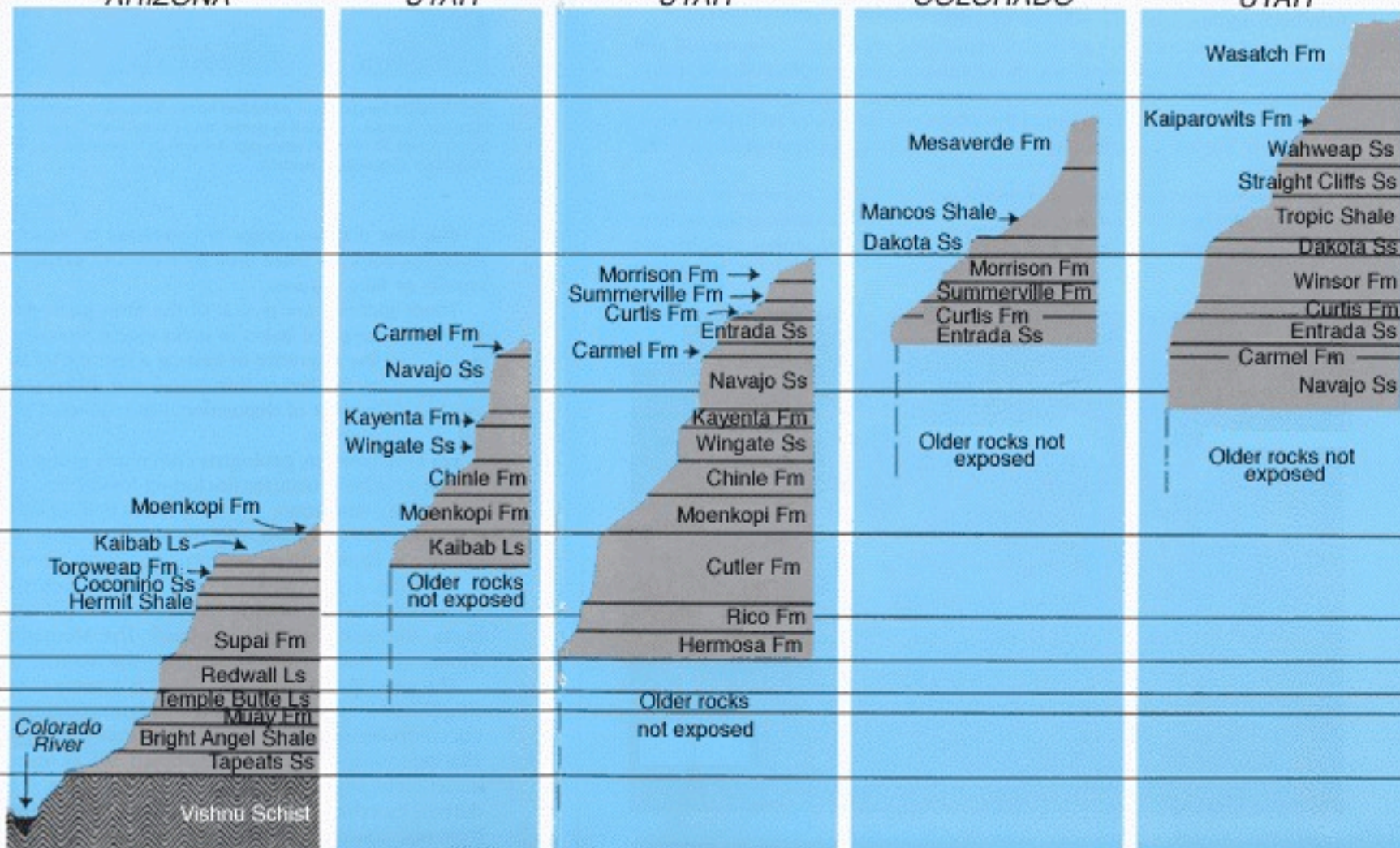
MISSISSIPPIAN PERIOD

DEVONIAN PERIOD*

CAMBRIAN PERIOD

PRECAMBRIAN PERIOD

*Rocks of Ordovician and Silurian age not present in Grand Canyon
Ss-Sandstone; Fm-Formation; Ls-Limestone



Absolute Time

Specifically when something happened.
Numerical age - "millions of years" or
some other measurement.

Relative Dating

This layer
formed after
this layer



Absolute Dating

This layer formed 10
million years ago



This layer formed
100 million years ago



Geologic Cross Sections

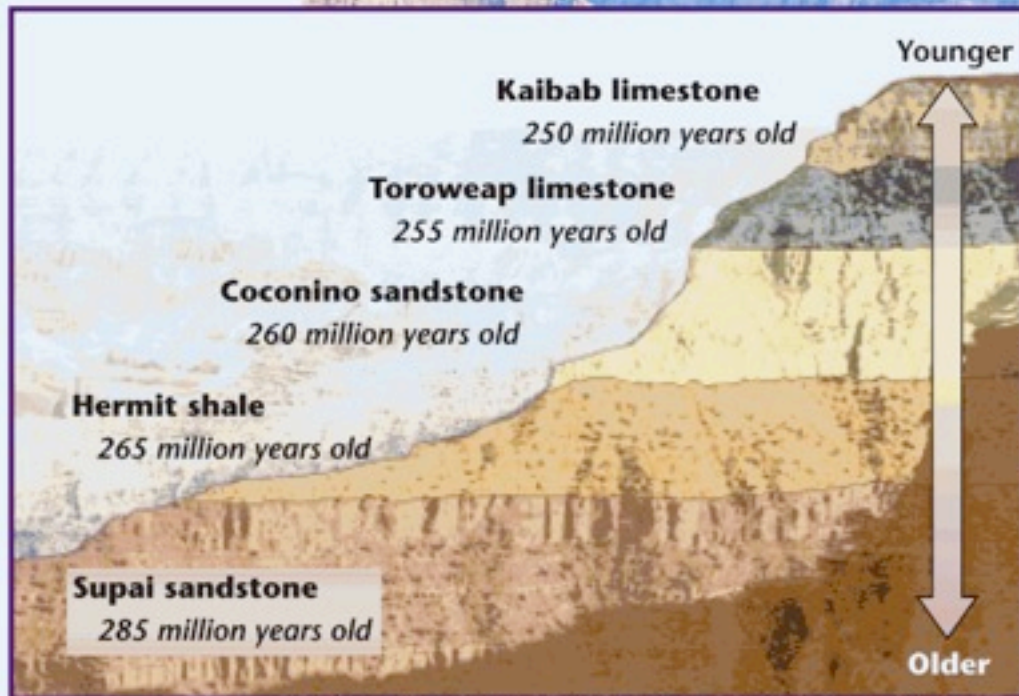
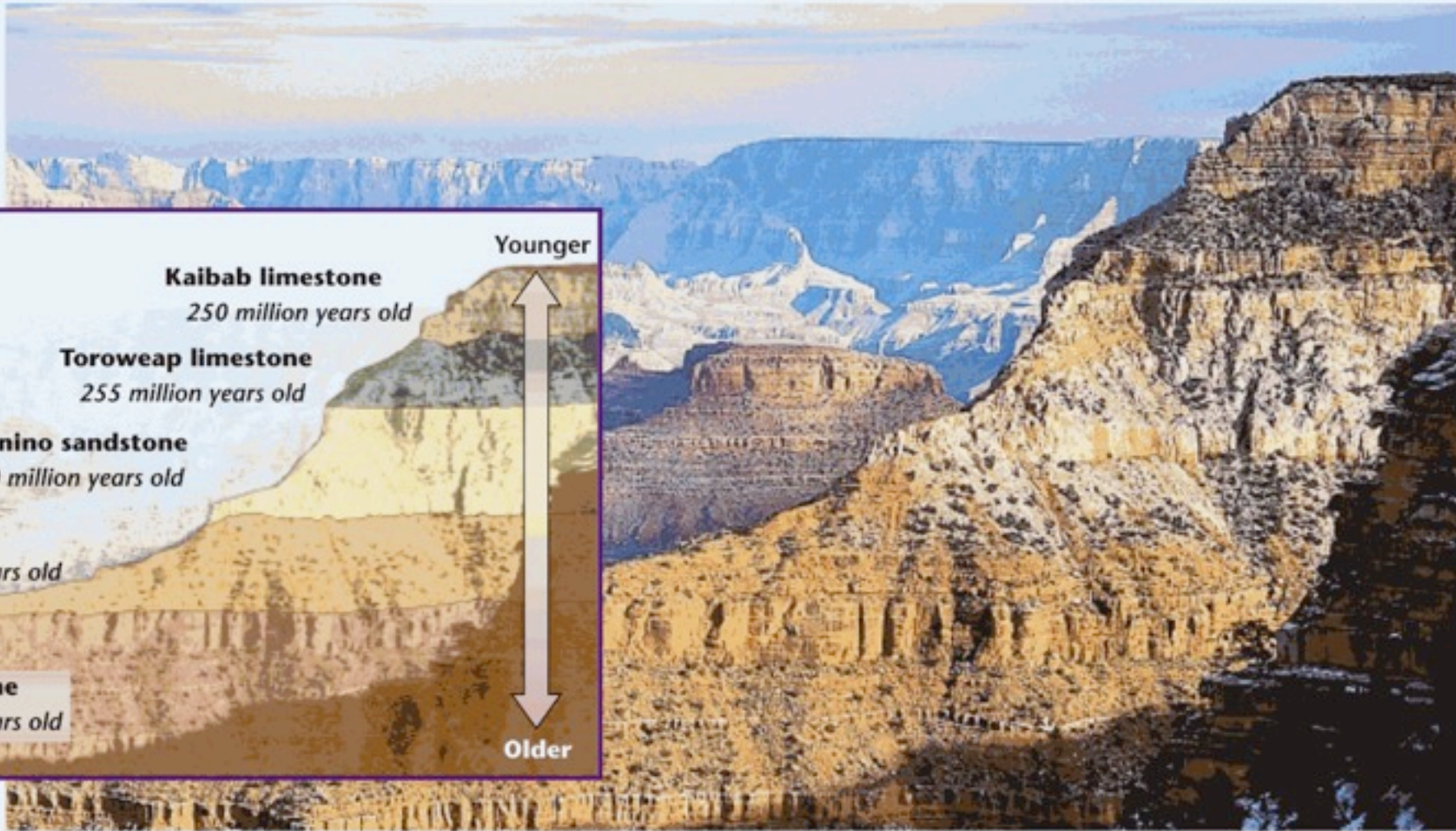
**Diagram showing the layers of
rocks in a location**

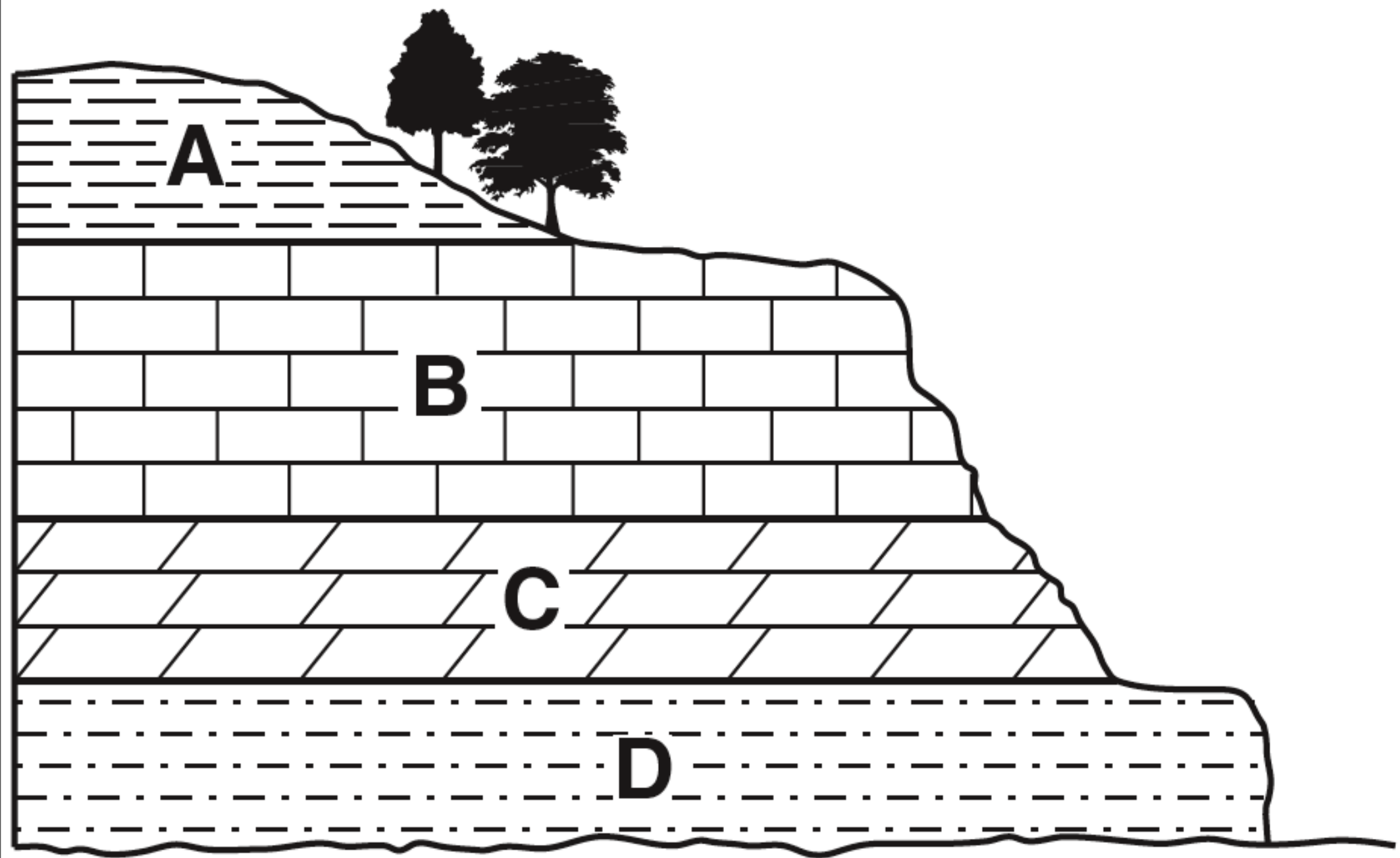
Original Horizontality

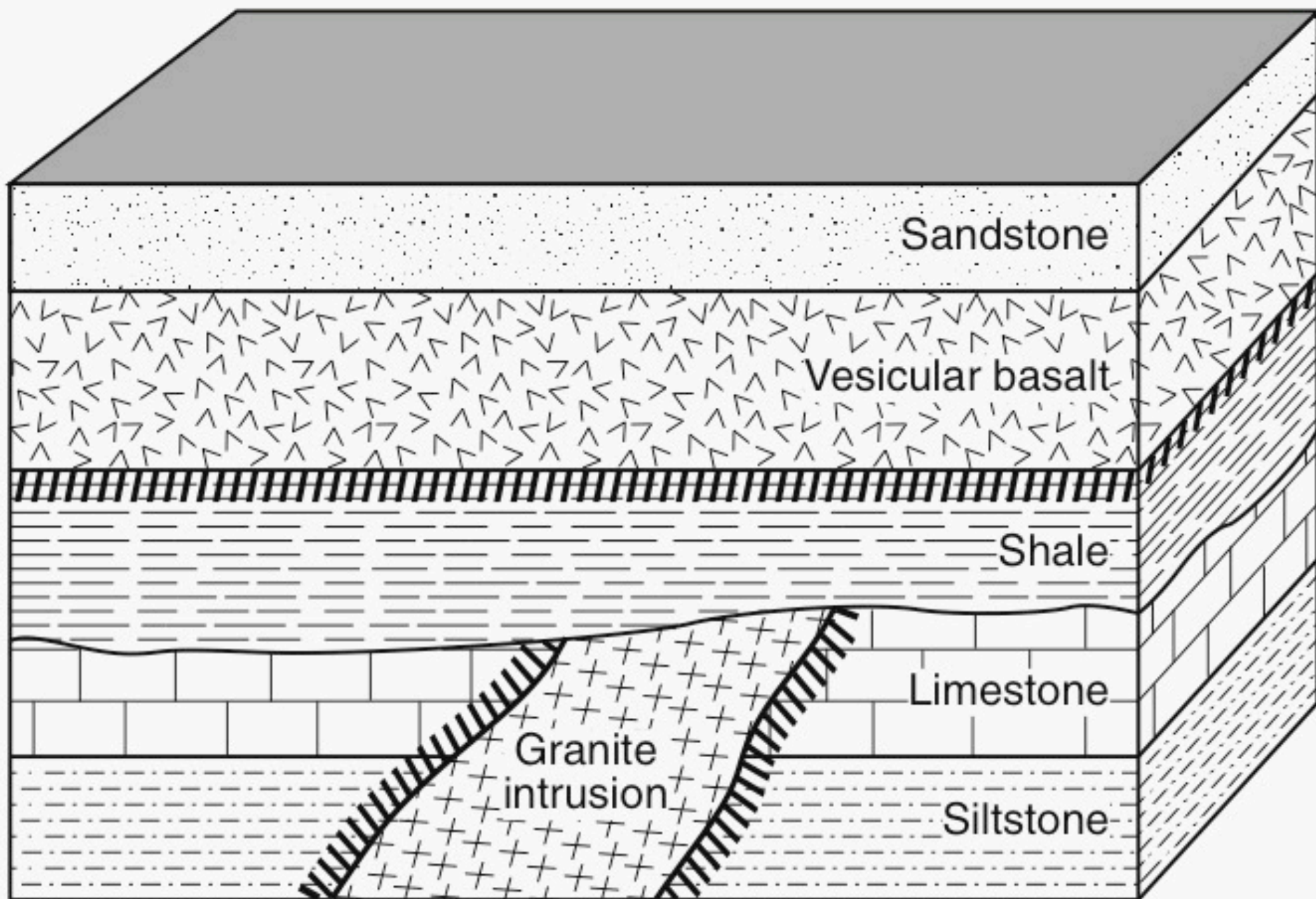
All rock layers were first laid down in flat, horizontal layers

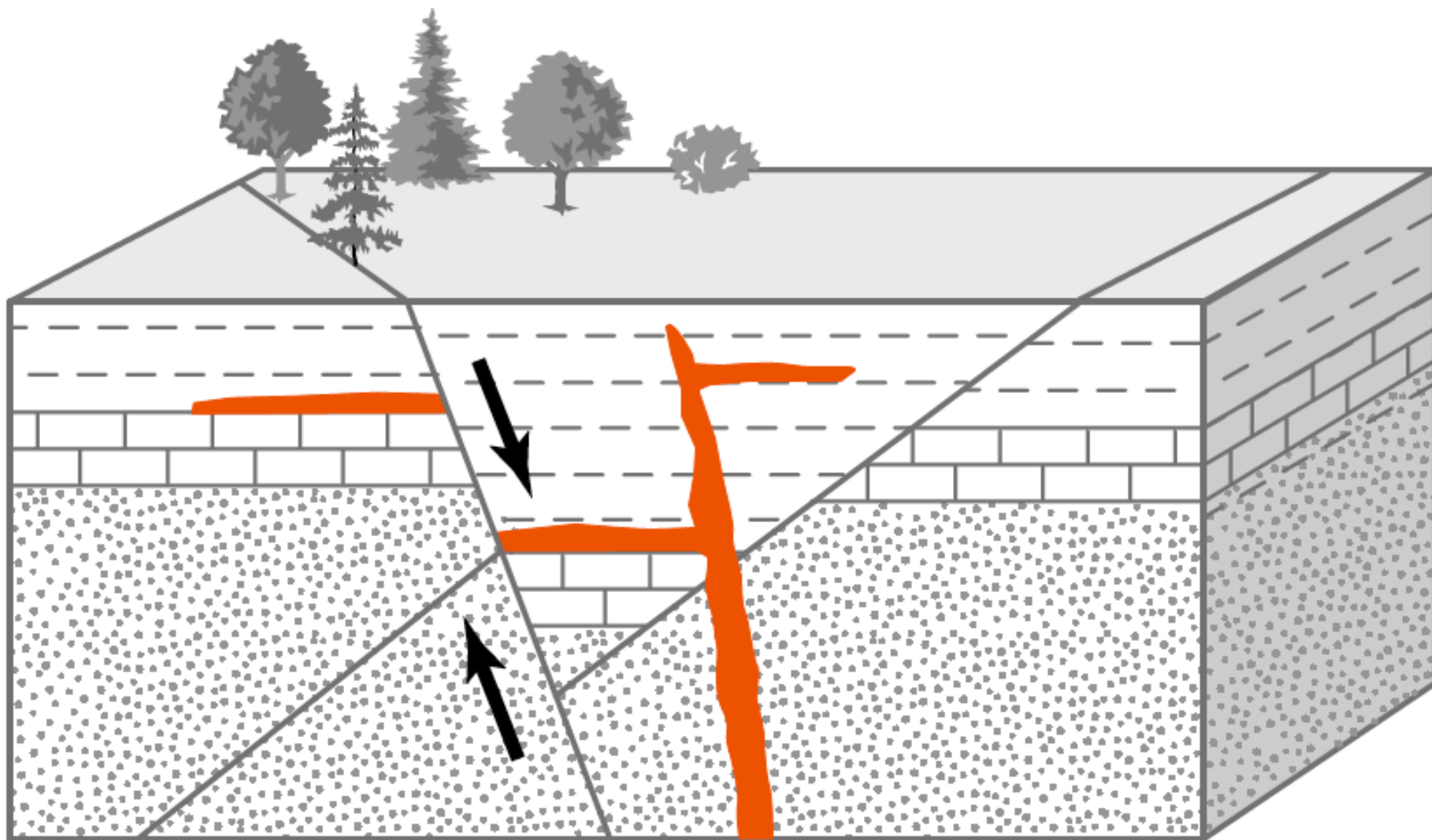
Superposition

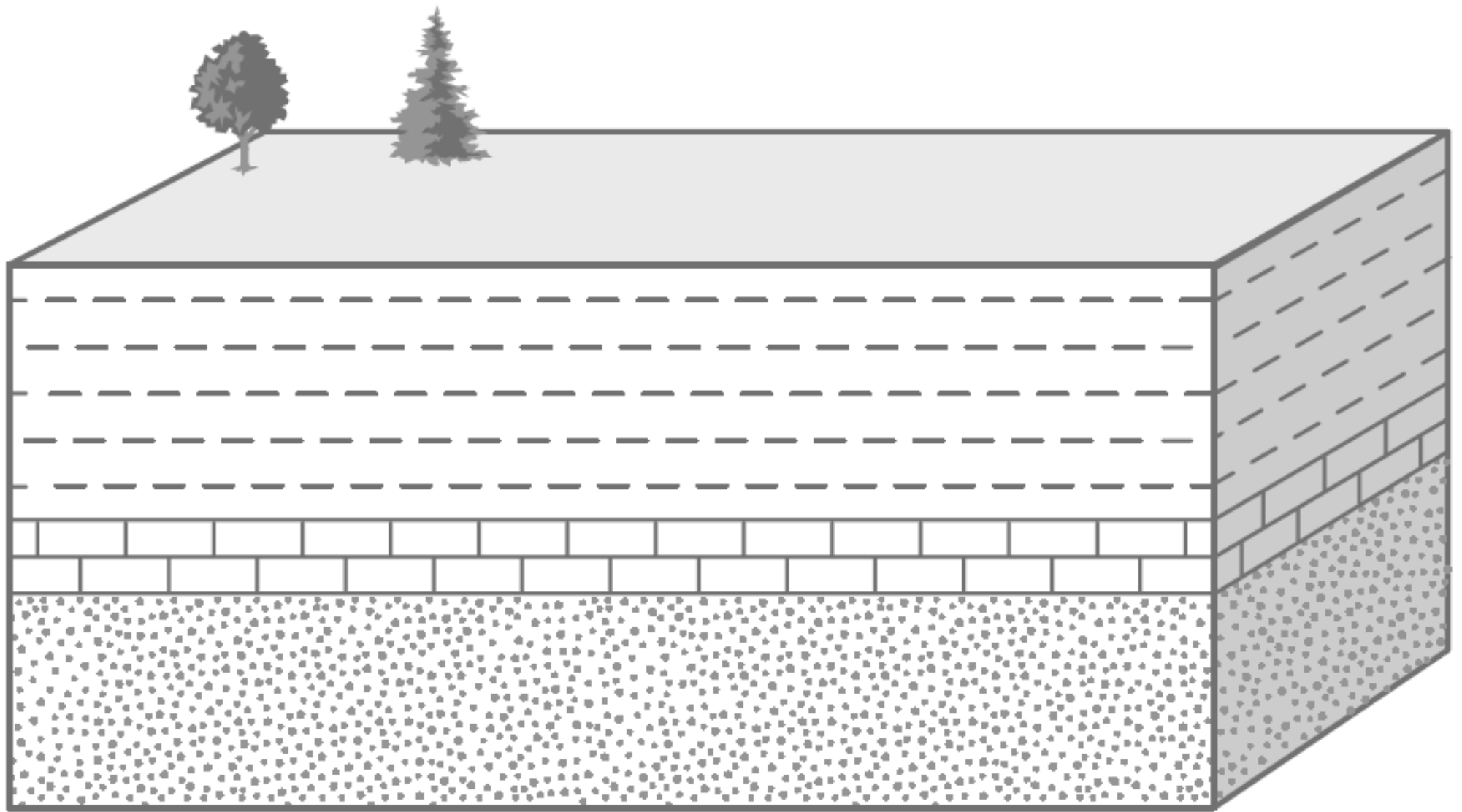
**Oldest rocks on the bottom,
youngest rocks on top**

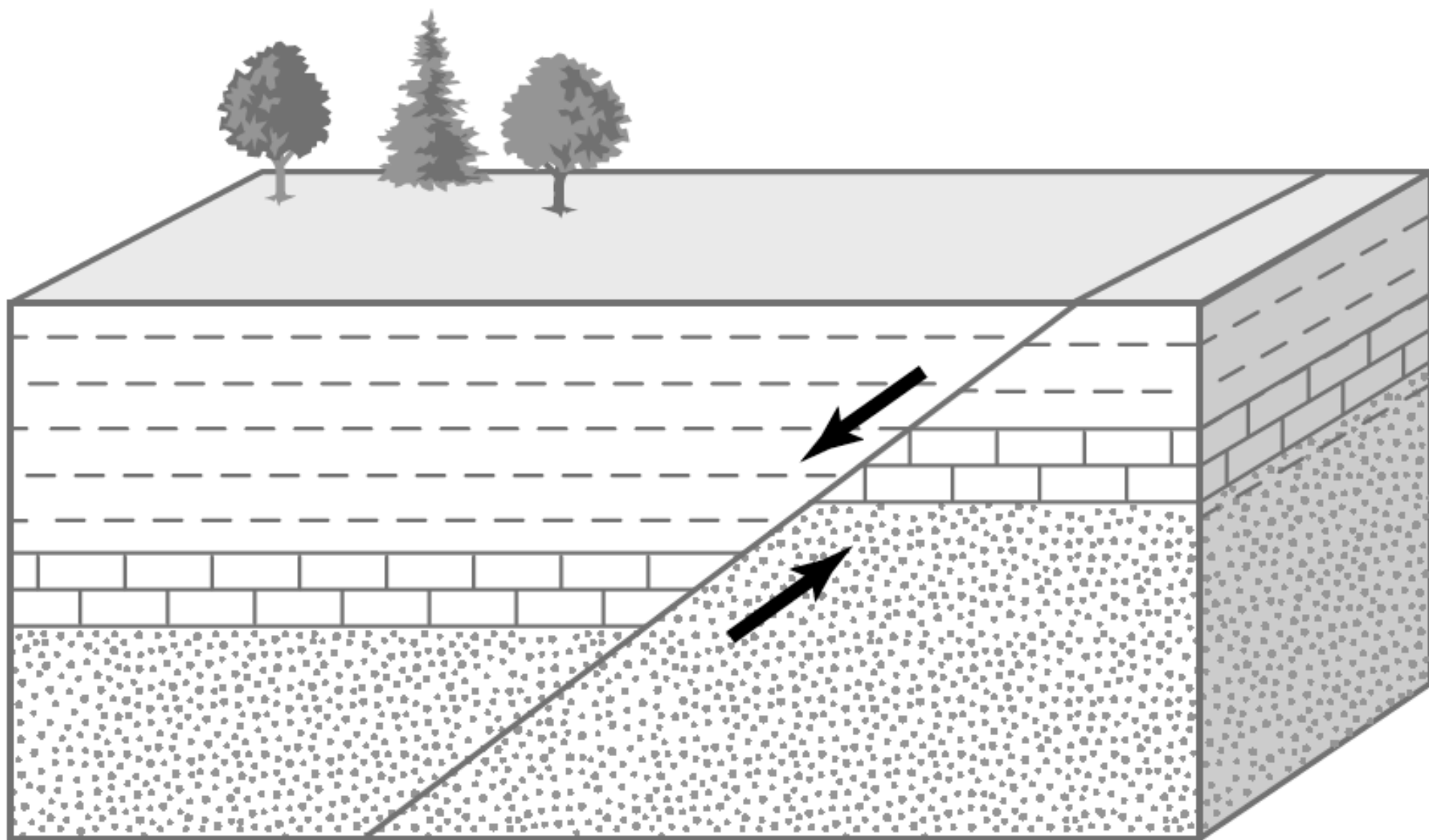


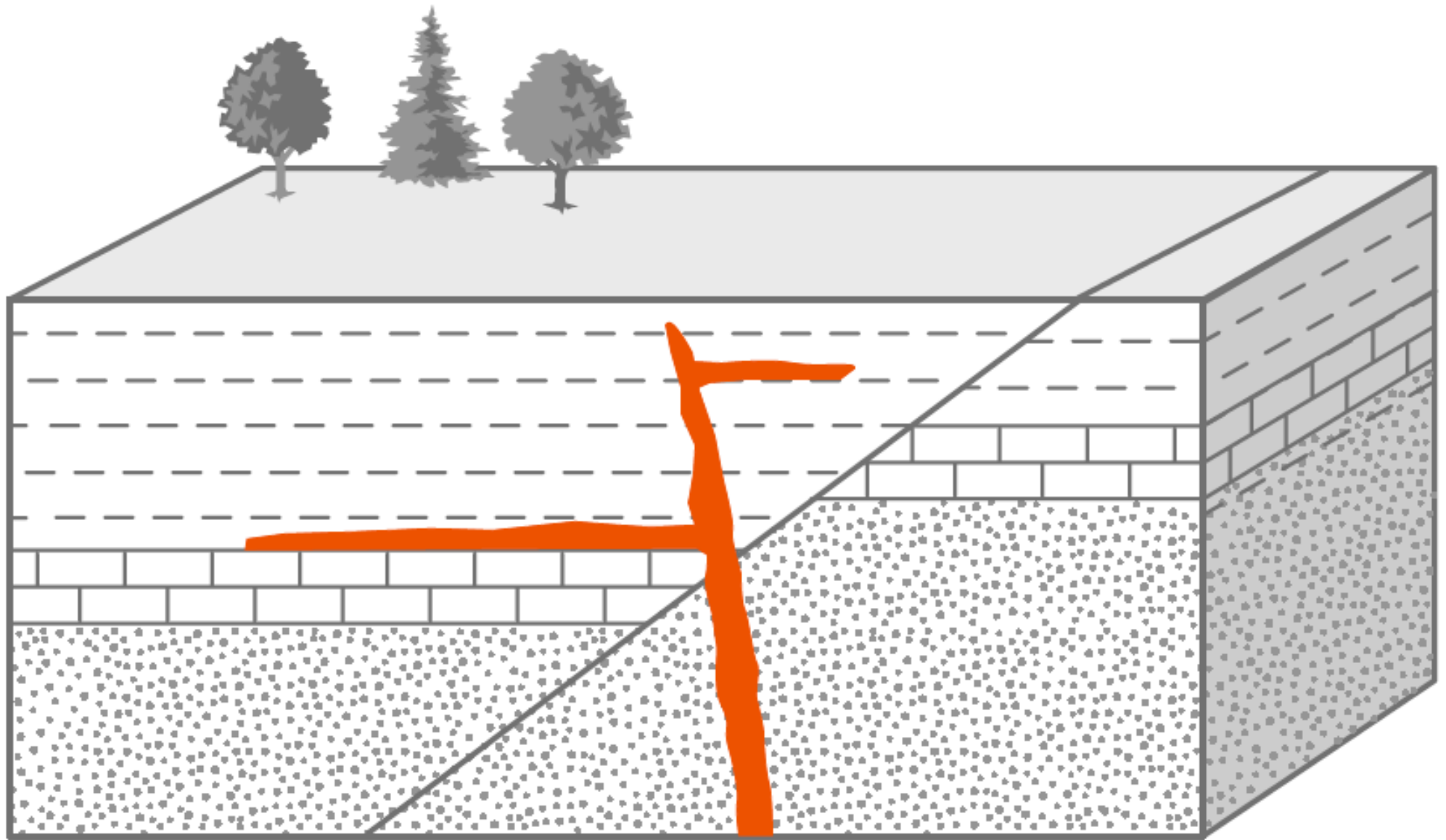


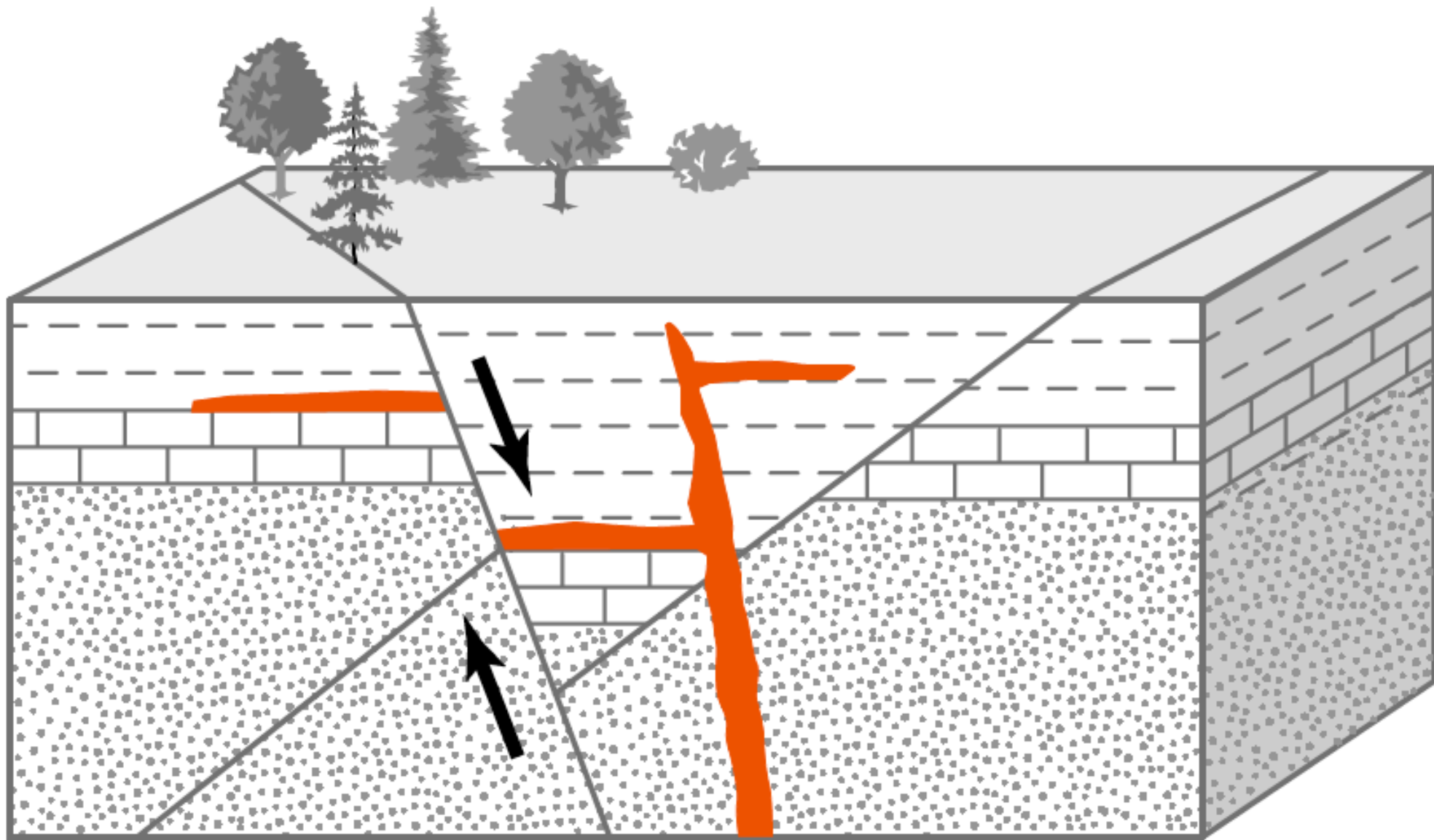






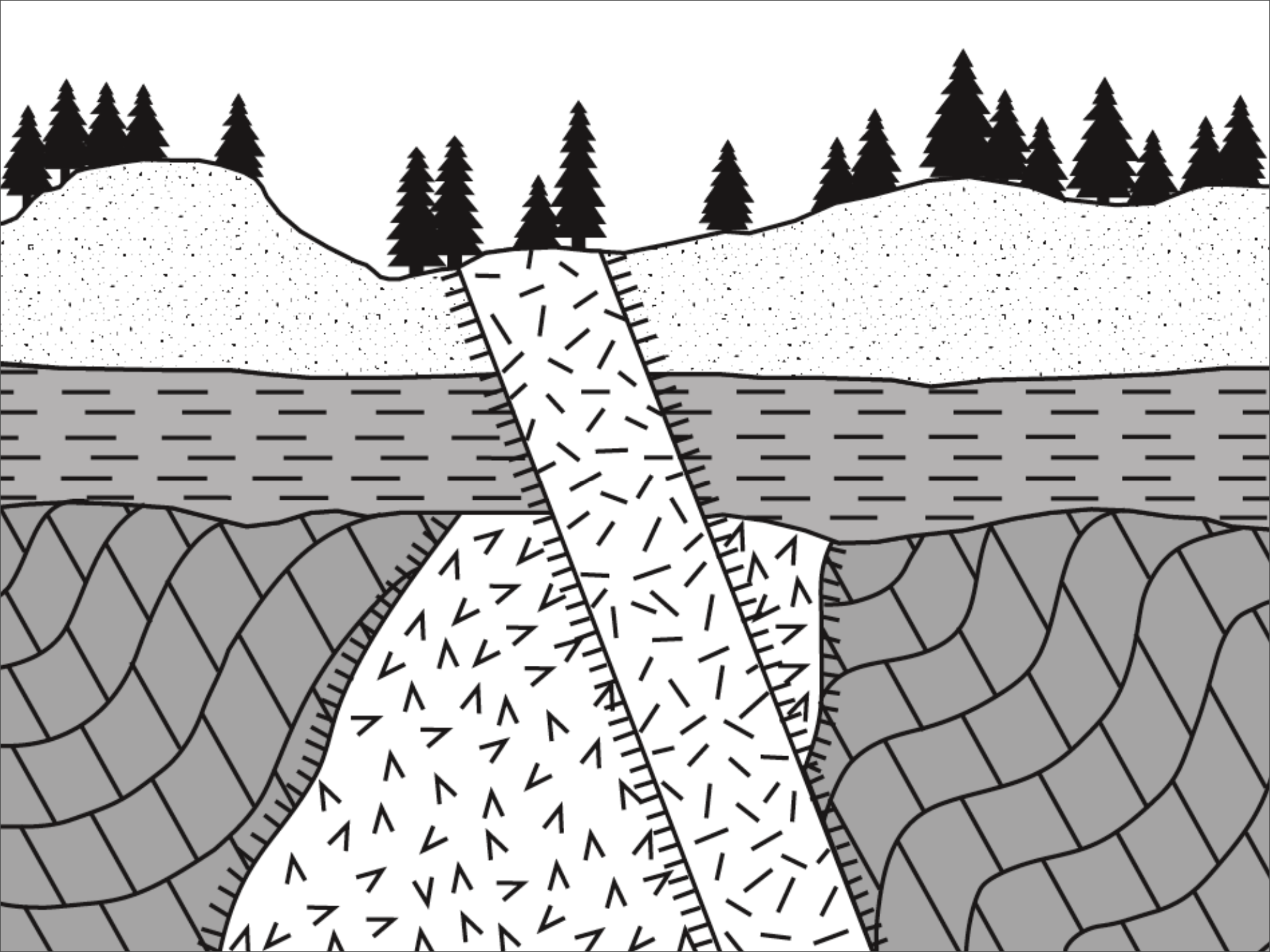






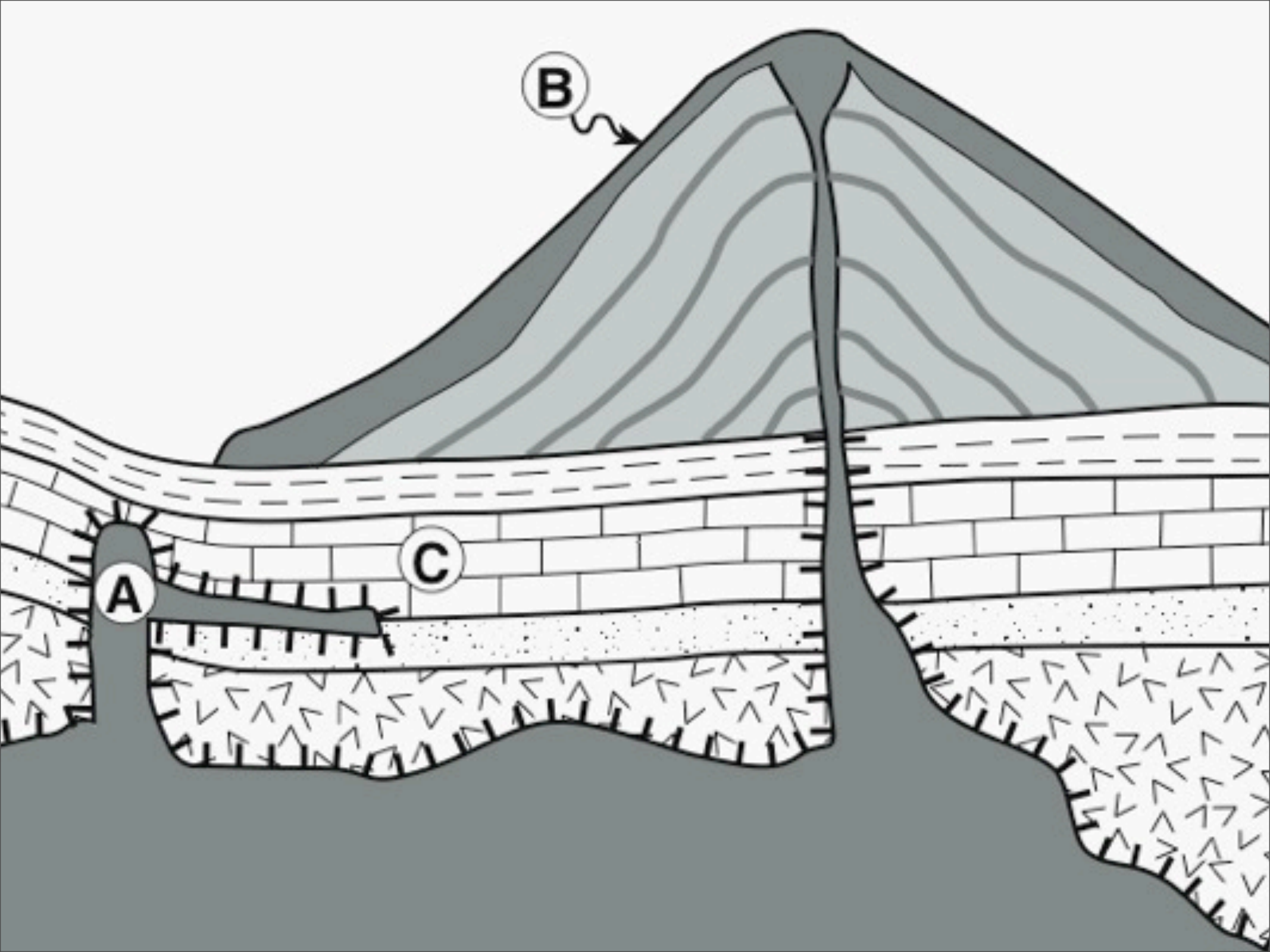
Intrusions

Igneous intrusions are younger than the rocks they cut through



Extrusions

Igneous extrusions are younger than the rocks beneath them



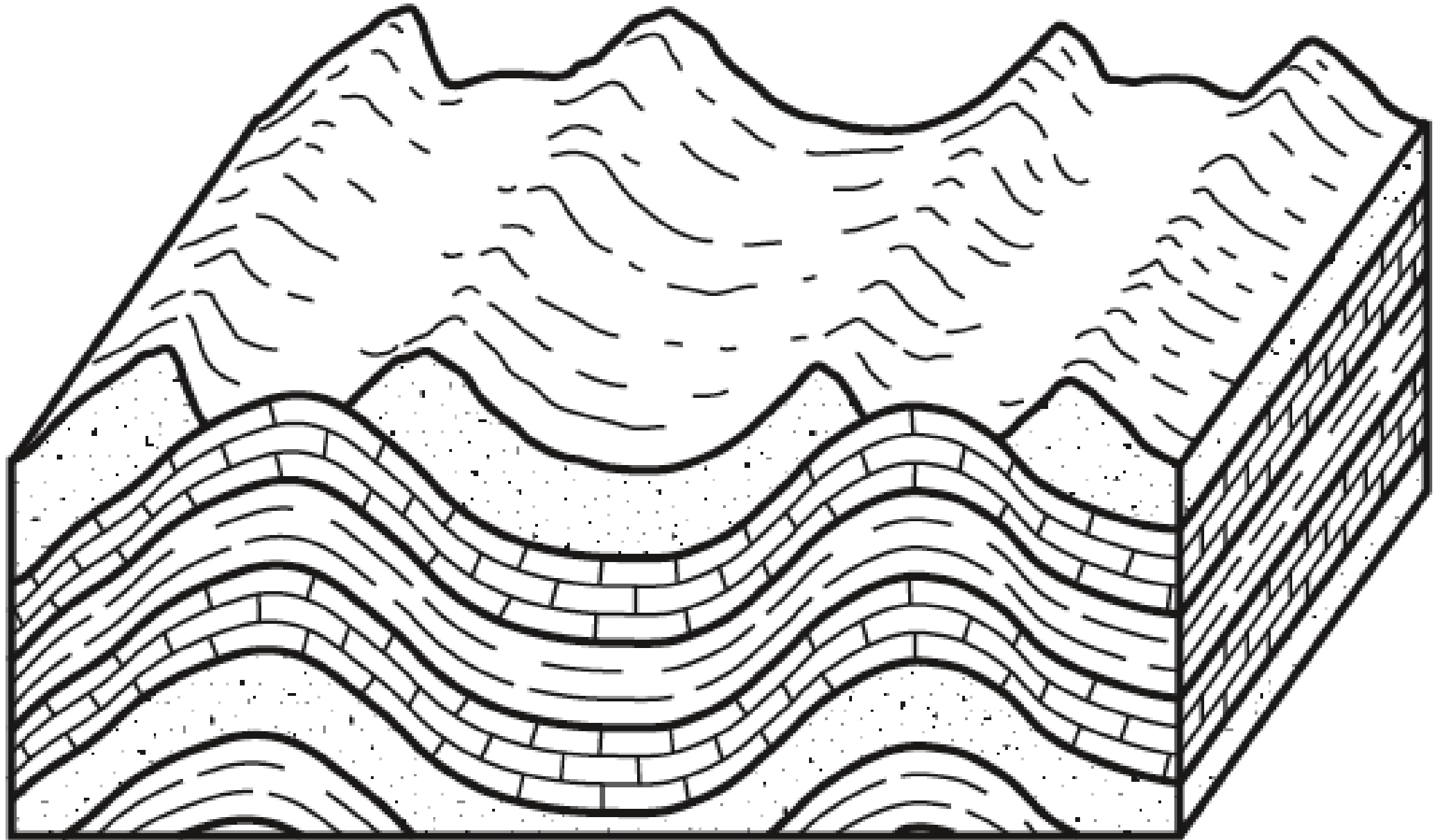
Inclusions

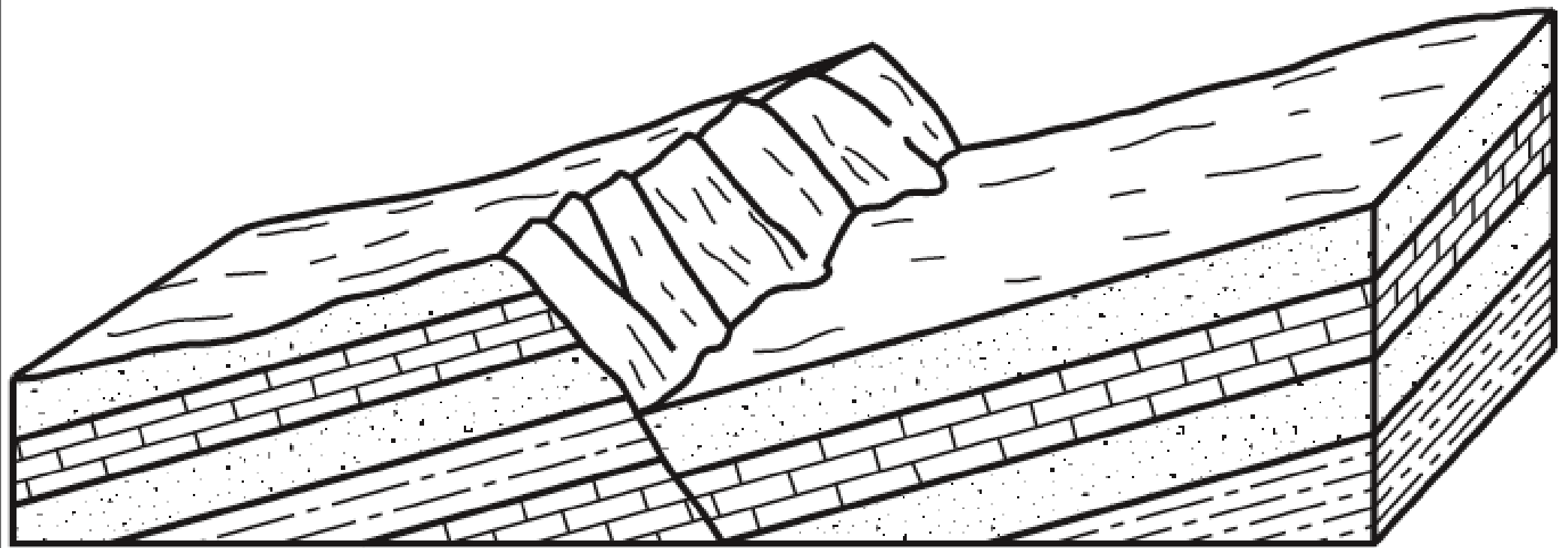
The individual sediments that make up a sedimentary rock must be older than the rock itself



Folds, Faults, and Tilts

Any folds, faults, or tilts found in a rock sequence must be younger than the layers that they affect



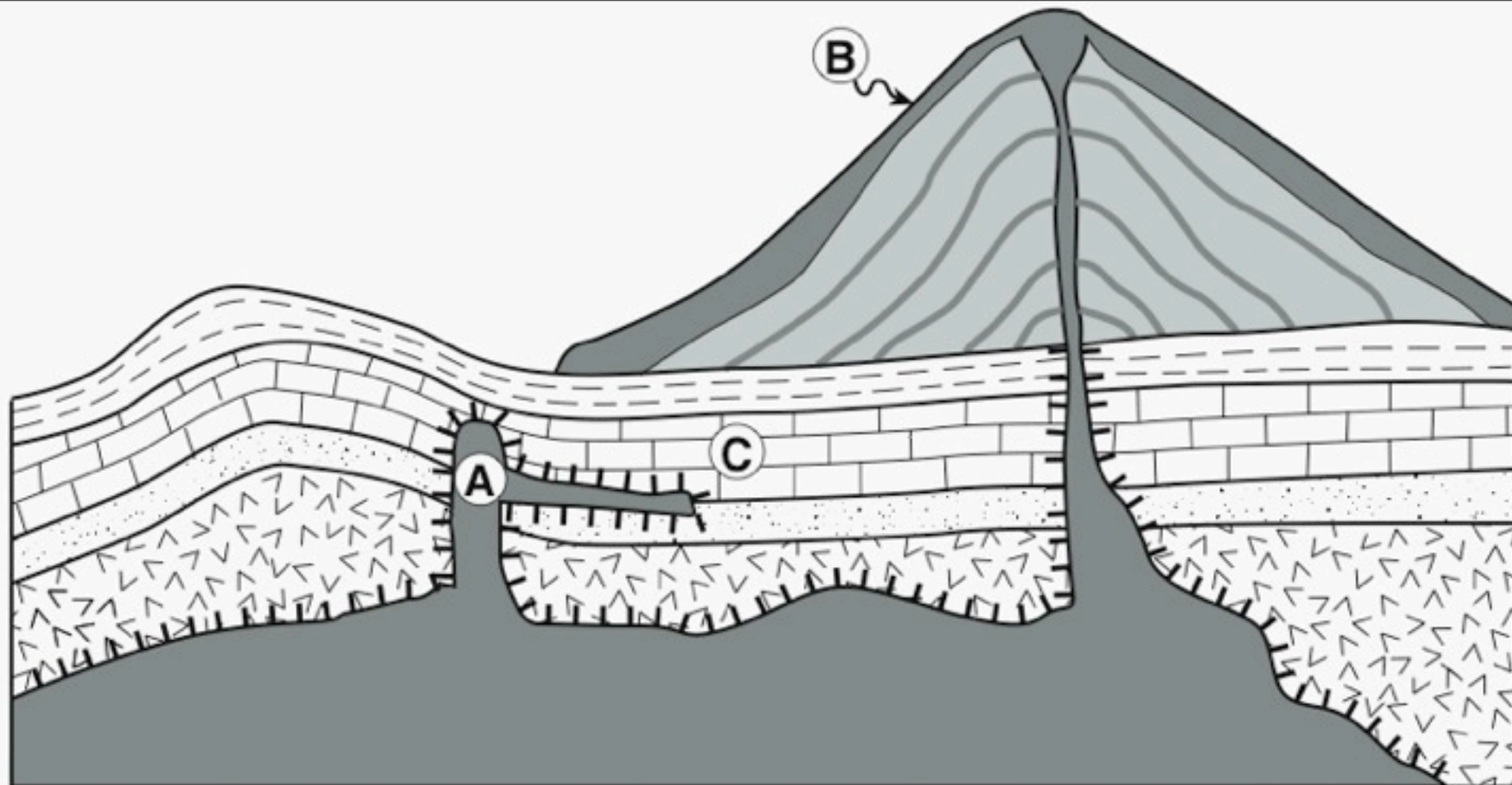


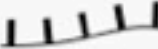
Things to Remember...

**Sedimentary rocks form
underwater**

**Weathering and erosion occurs
on dry land**

**Fossils are only found in
sedimentary rocks**



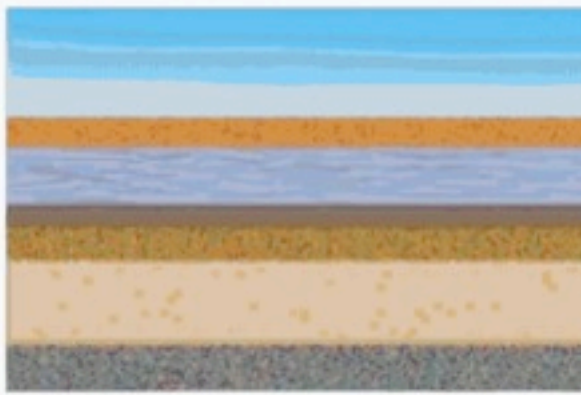
Key	
	Igneous rock A and B
	Gabbro
	Limestone
	Sandstone
	Shale
	Ash layers
	Contact metamorphism

Unconformities

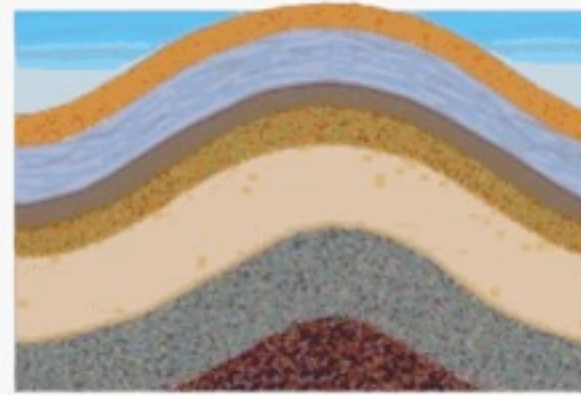
Buried erosional surface

Represents a missing piece of the
rock record

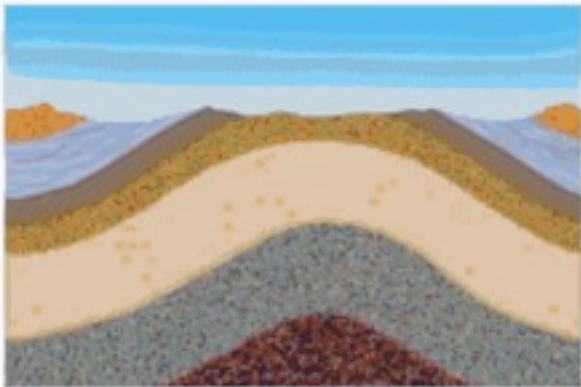
Evidence of uplift, weathering and
erosion, and subsidence



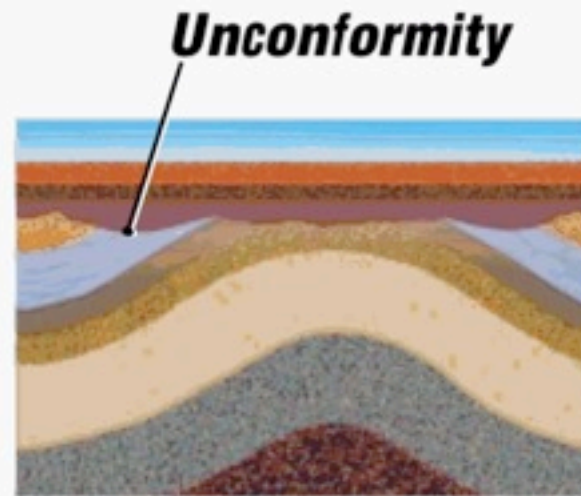
1. Sedimentary rocks form in horizontal layers.



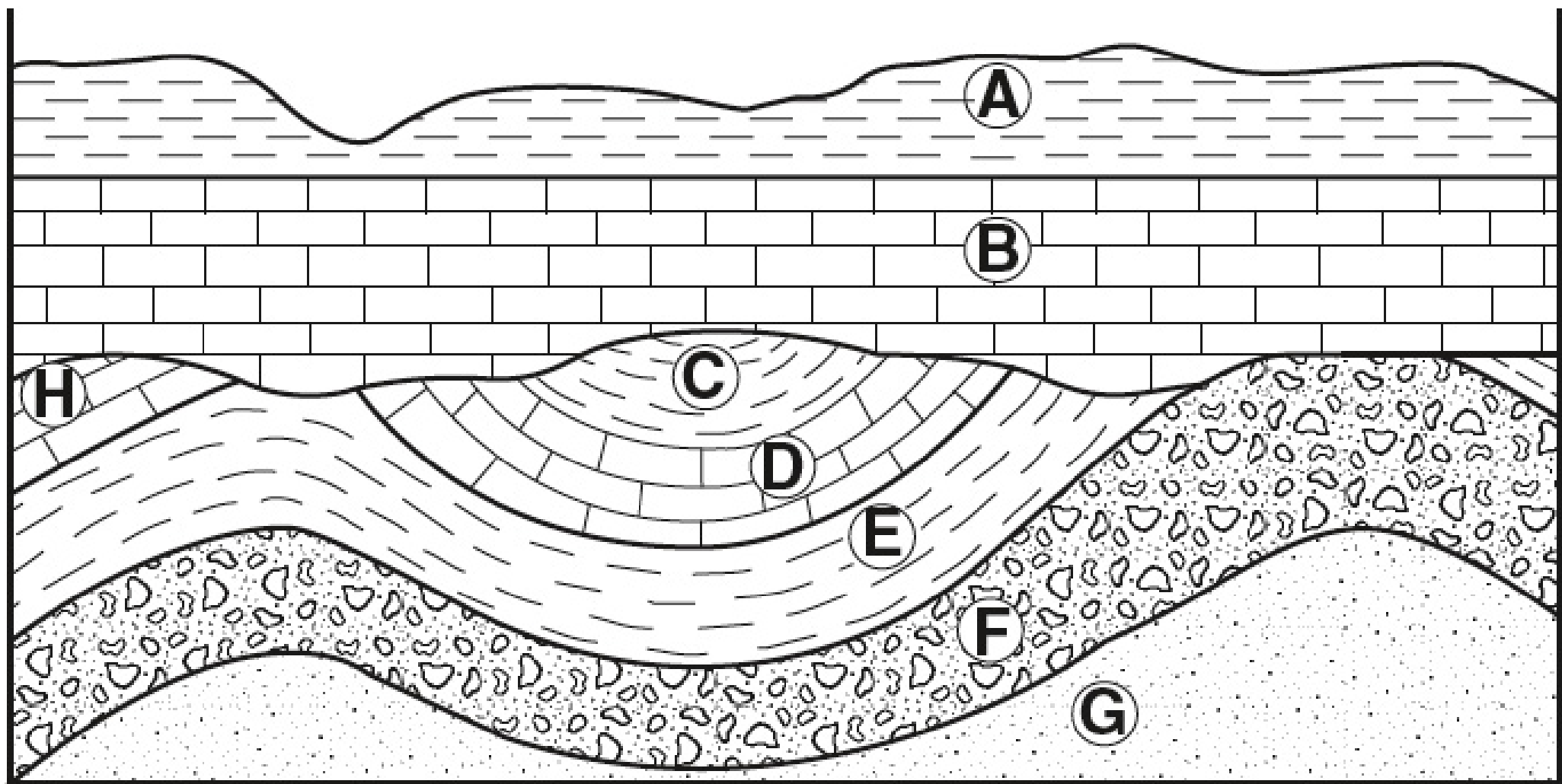
2. Folding tilts the rock layers.



3. The surface is eroded.

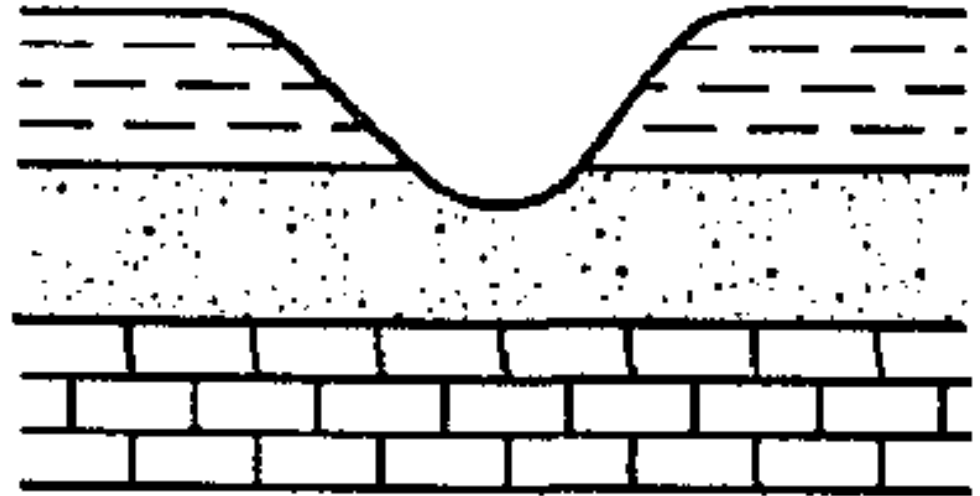


4. New sediment is deposited, forming an unconformity.



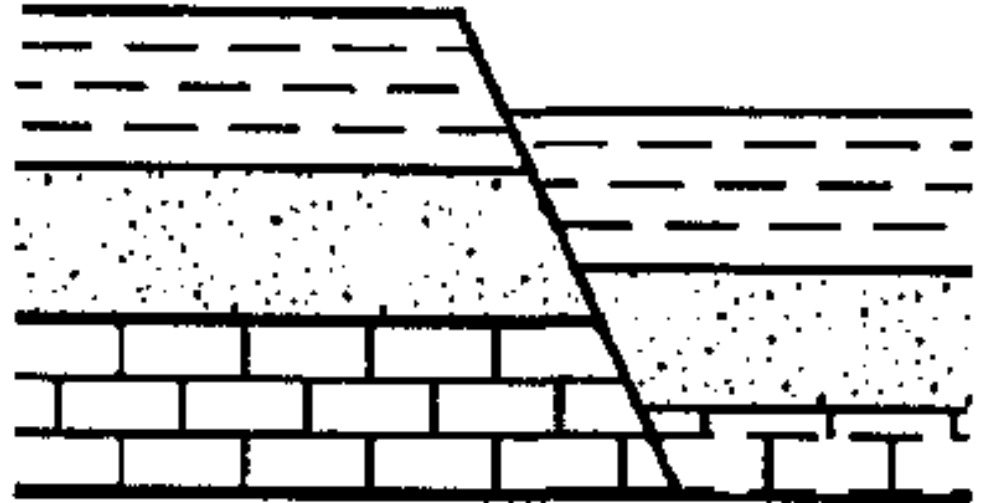
Sequence 1: Uplift & Erosion

1. Deposition of Limestone
2. Deposition of Sandstone
3. Deposition of Shale
4. Uplift and Erosion



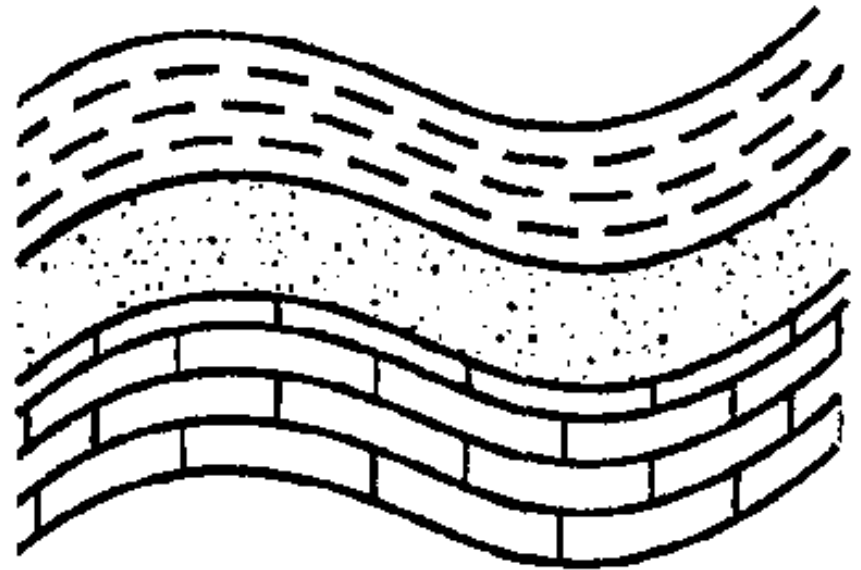
Sequence 2: Faulting

1. Deposition of Limestone
2. Deposition of Sandstone
3. Deposition of Shale
4. Faulting



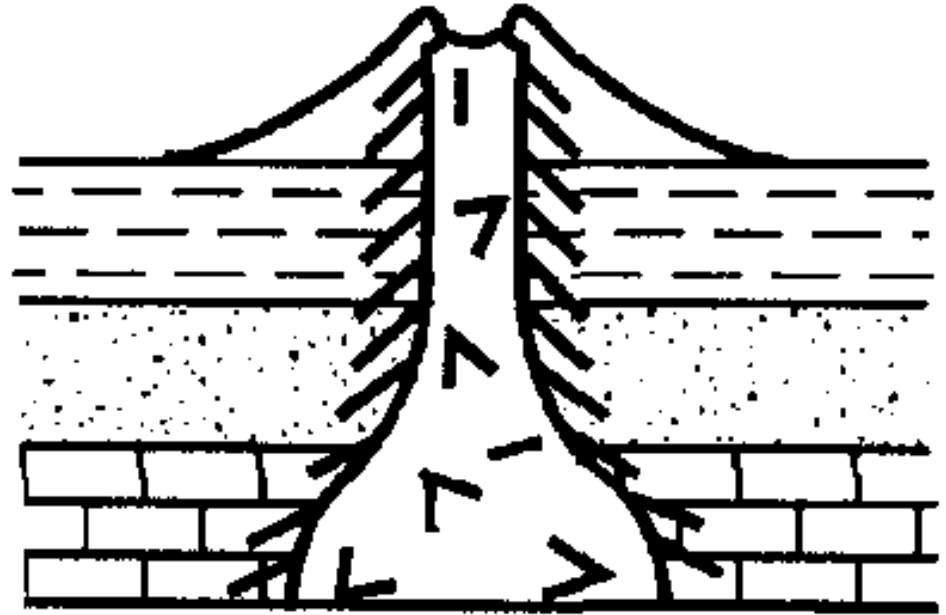
Sequence 3: Folding

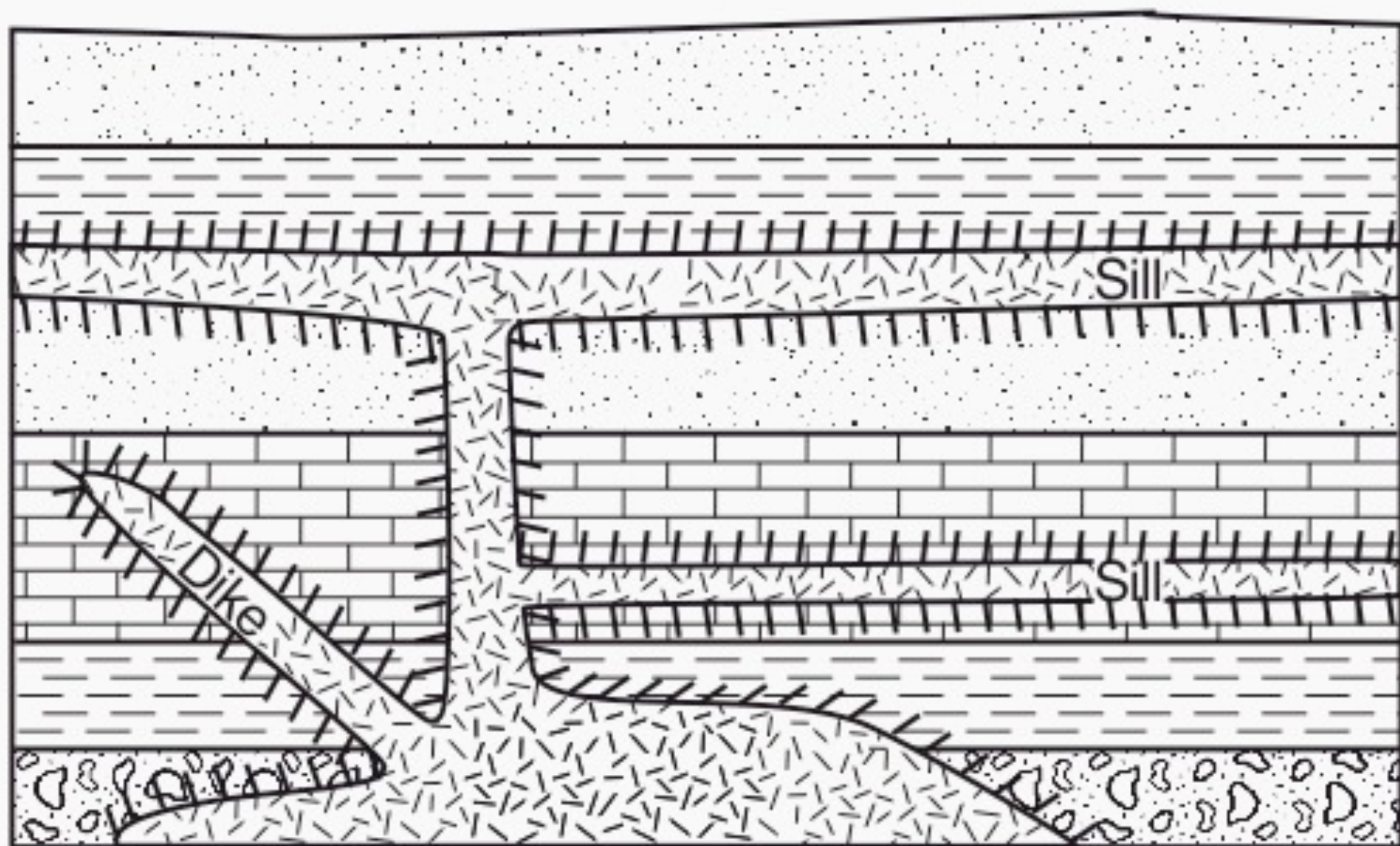
1. Deposition of Limestone
2. Deposition of Sandstone
3. Deposition of Shale
4. Folding

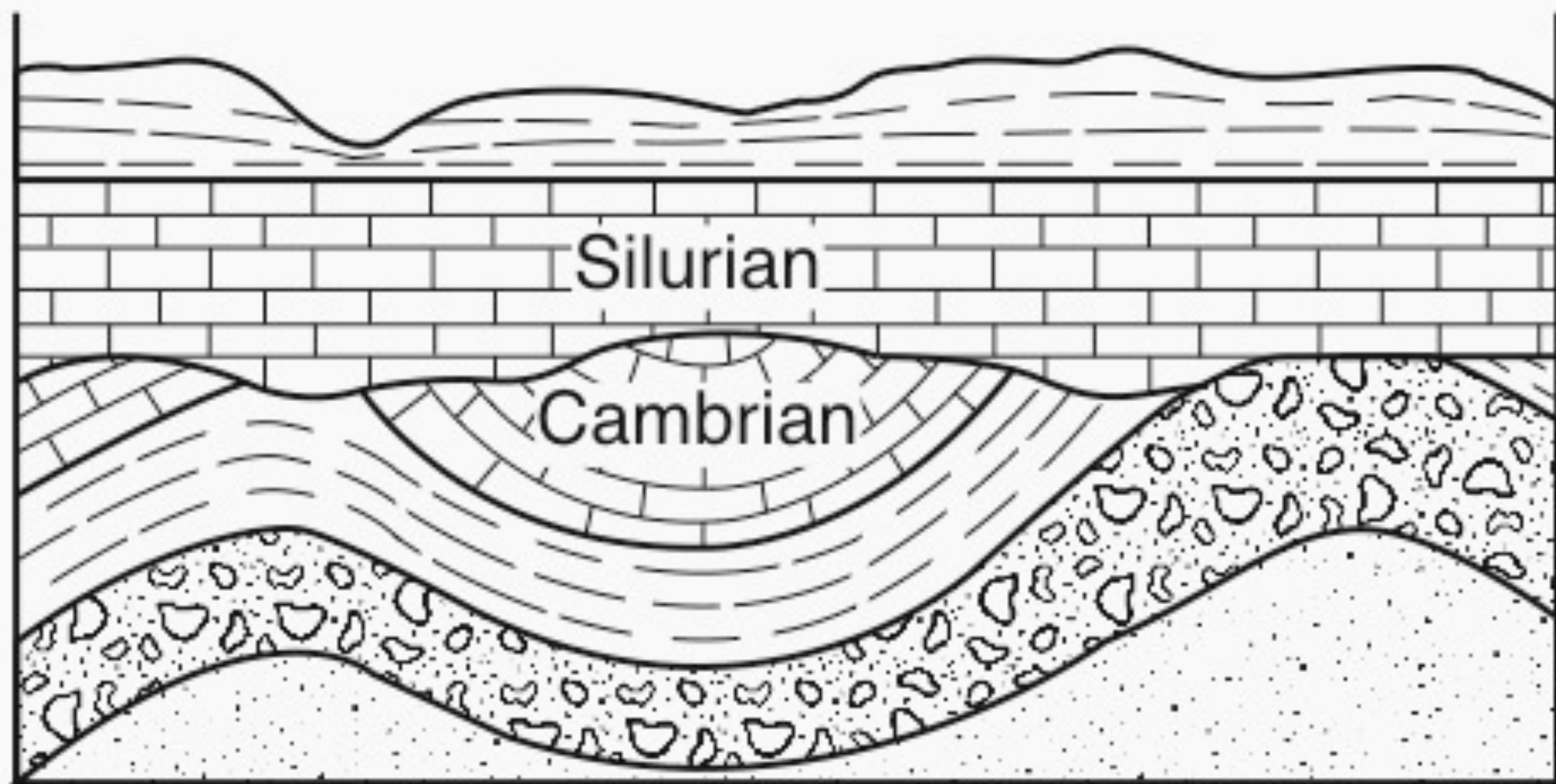


Sequence 4: Igneous Intrusion

1. Deposition of Limestone
2. Deposition of Sandstone
3. Deposition of Shale
4. Igneous Intrusion
5. Contact metamorphism
occurs along with intrusion









Key



Shale



Sandstone



Limestone



Conglomerate

} Sedimentary rocks

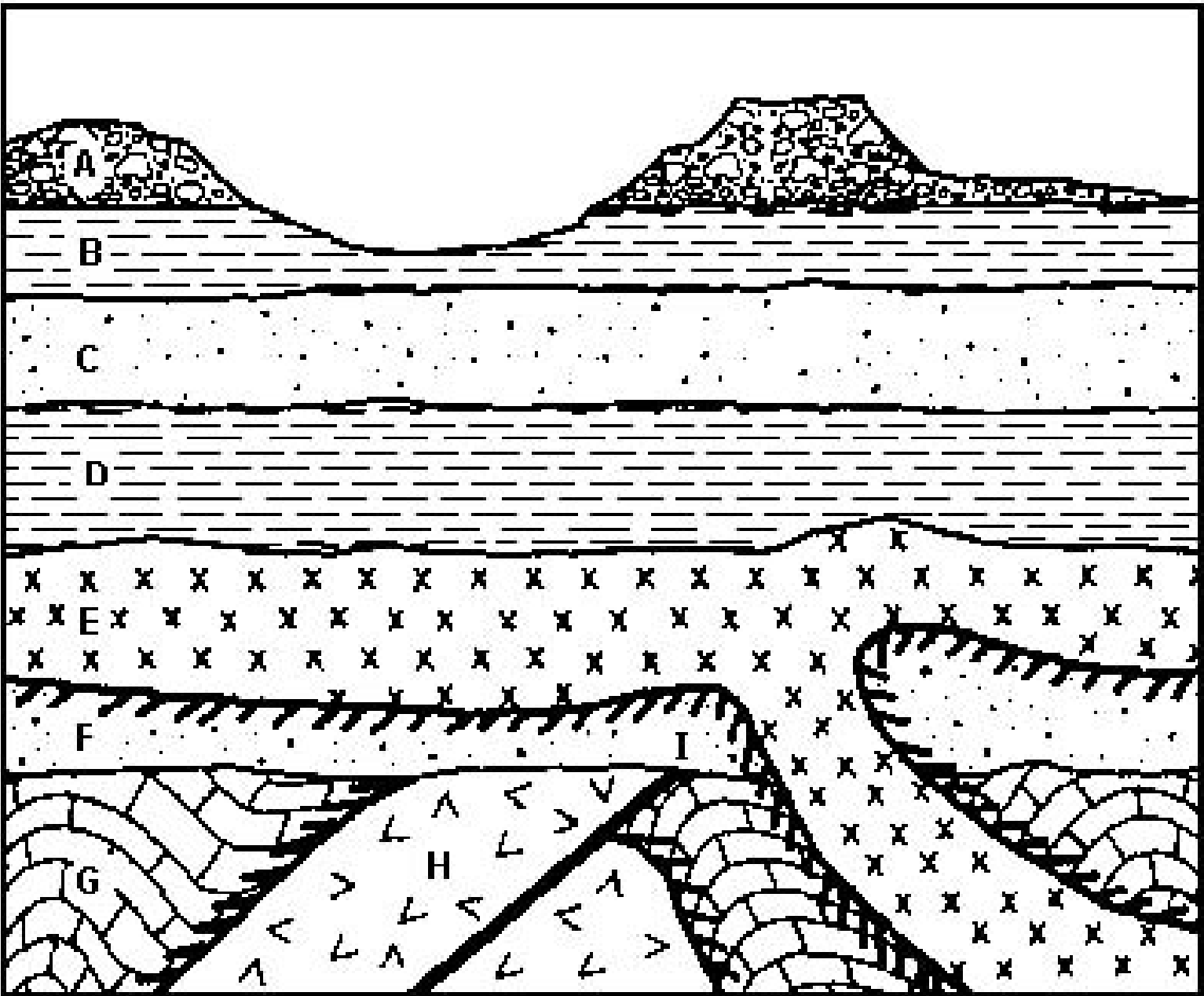


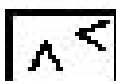
Contact metamorphism

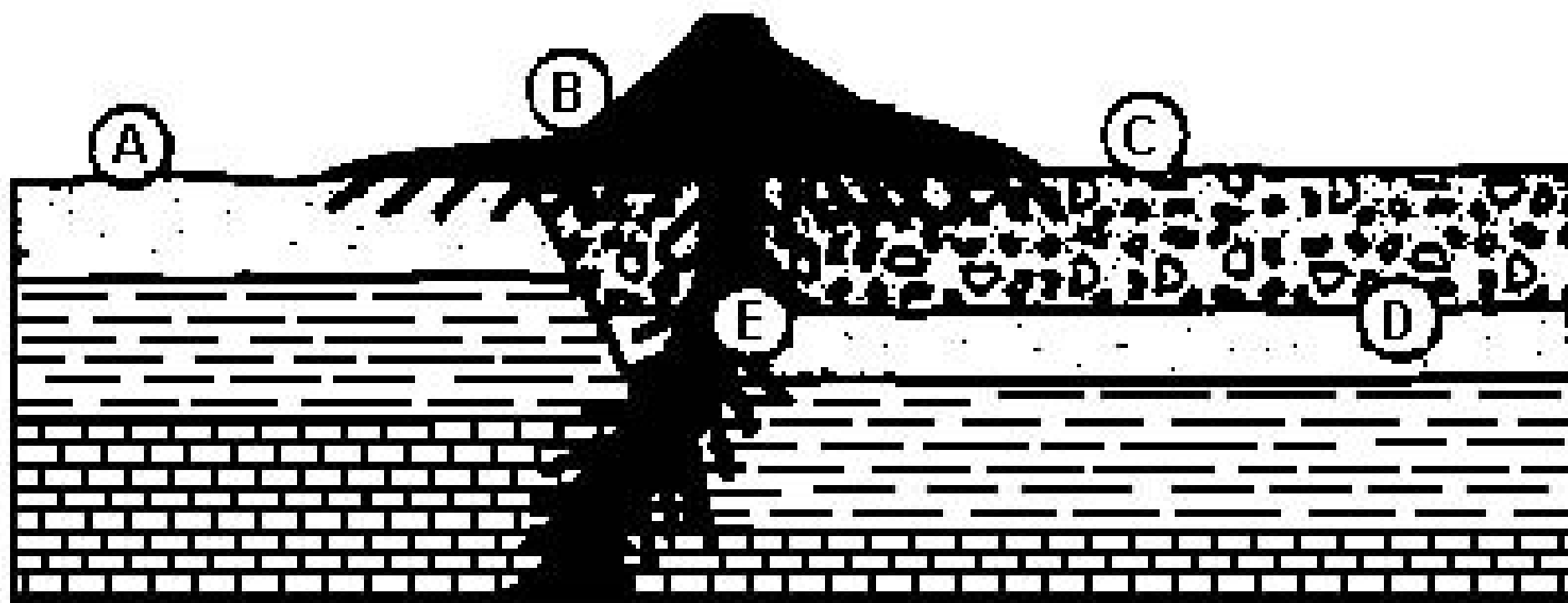


Basalt

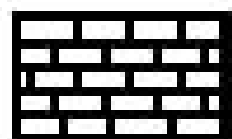
} Igneous rock



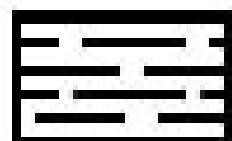
-  CONGLOMERATE
-  SHALE
-  SANDSTONE
-  BASALT
-  GRANITE
-  LIMESTONE
-  CONTACT METAMORPHISM



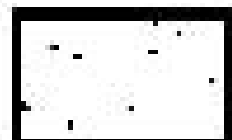
Key to Rock Type



Limestone



Shale



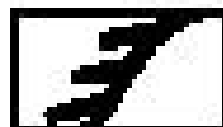
Sandstone



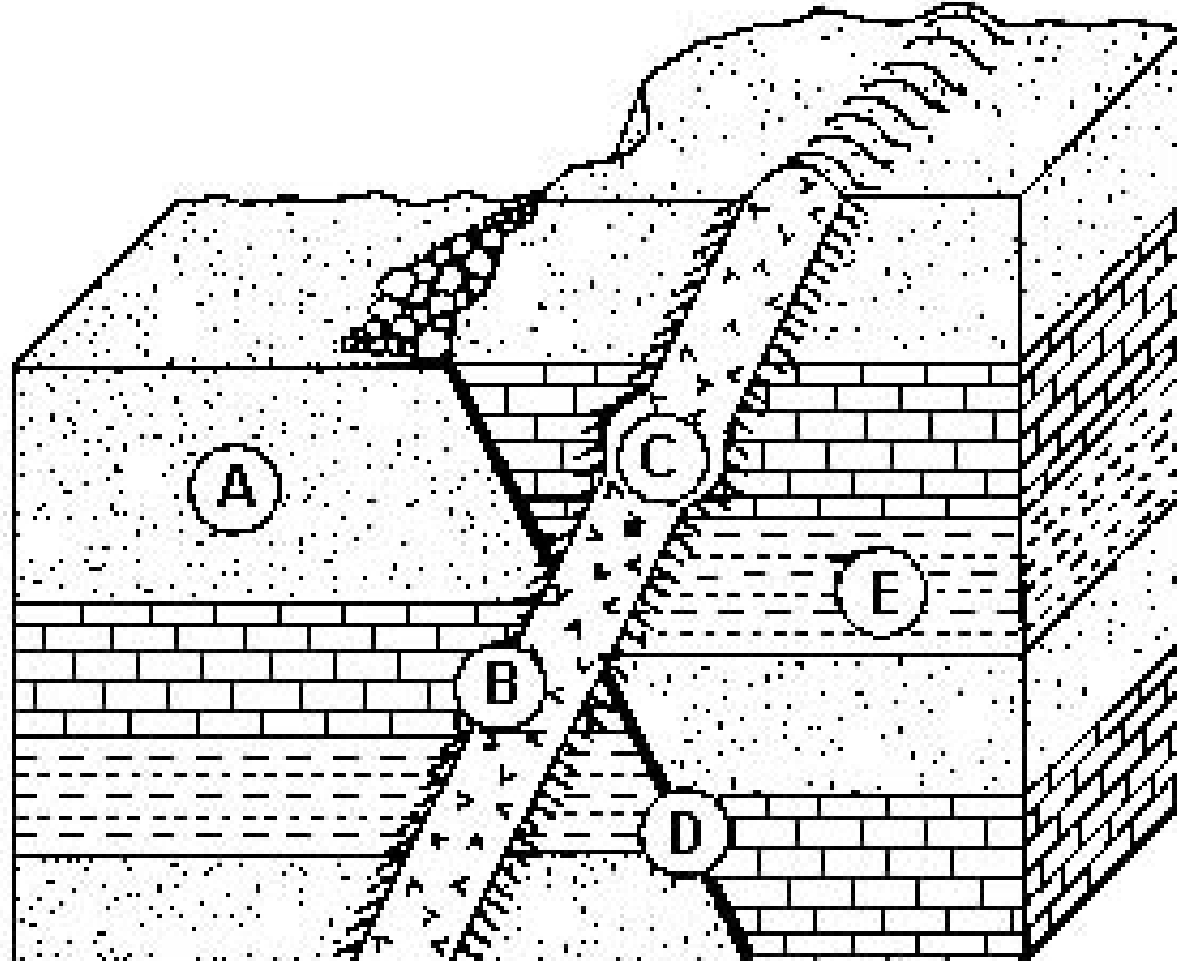
Conglomerate



Basalt



Contact Metamorphism

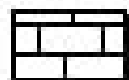


Transition zone

Key



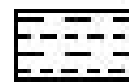
Sandstone



Limestone



Transition zone



Shale



Igneous rock



Rock Correlation

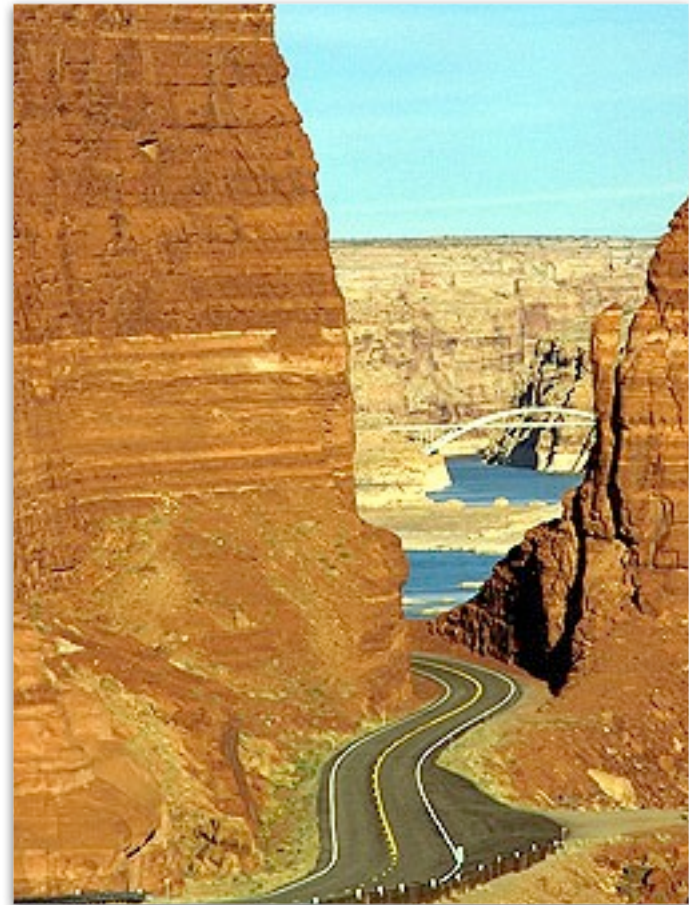
Correlation

- ▶ Matching rocks in one location to those in another location in order to determine geologic history
- ▶ Outcrops are areas of exposed bedrock which can be compared for similarities



Walking an Outcrop

- ▶ Observing and following a particular layer of rock over a long distance.
- ▶ By observing color, texture, and other characteristics, one may follow a layer over a distance

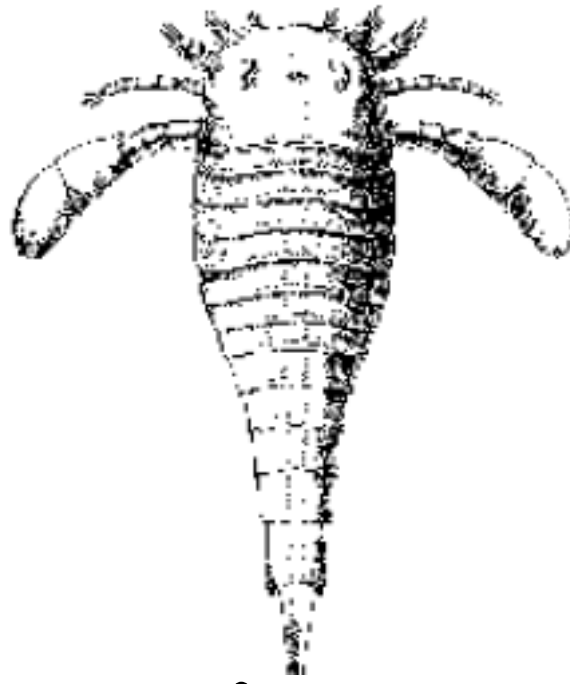
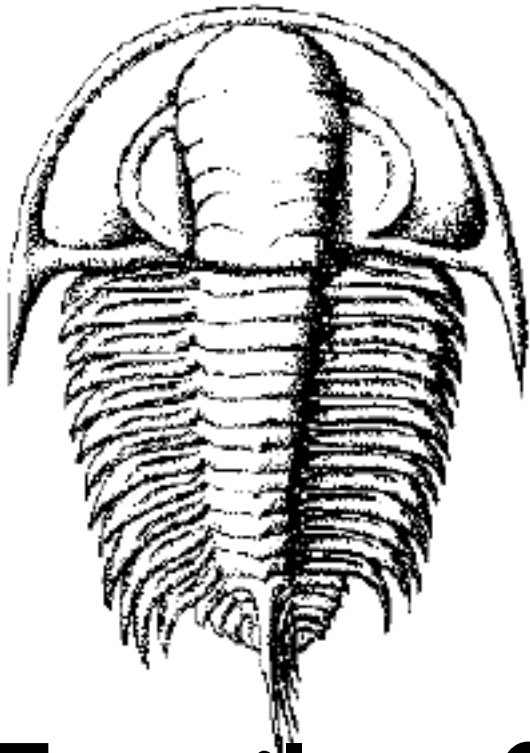


Fossil Evidence

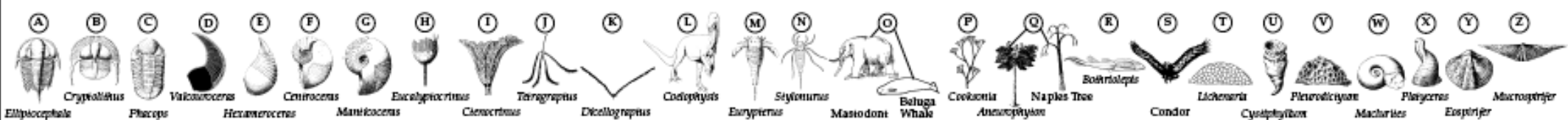
- ▶ Most reliable method of correlation
- ▶ Only found in sedimentary rocks
- ▶ Provide clues about the environment in which the rock formed

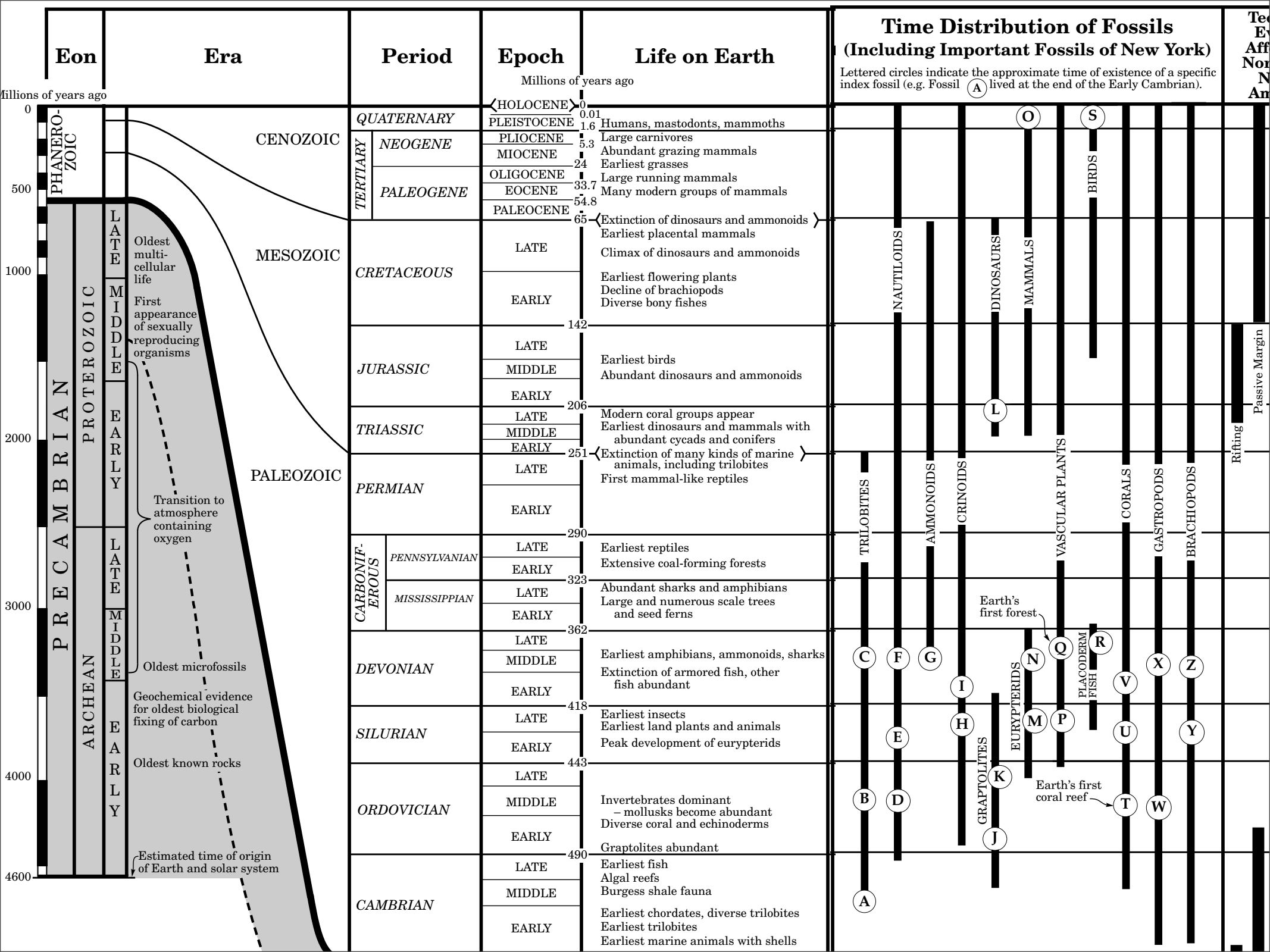


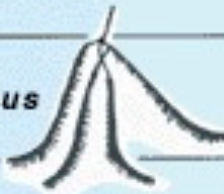
Index Fossils



Fossils of organisms that lived for a short period of time, but over a wide geographic area.



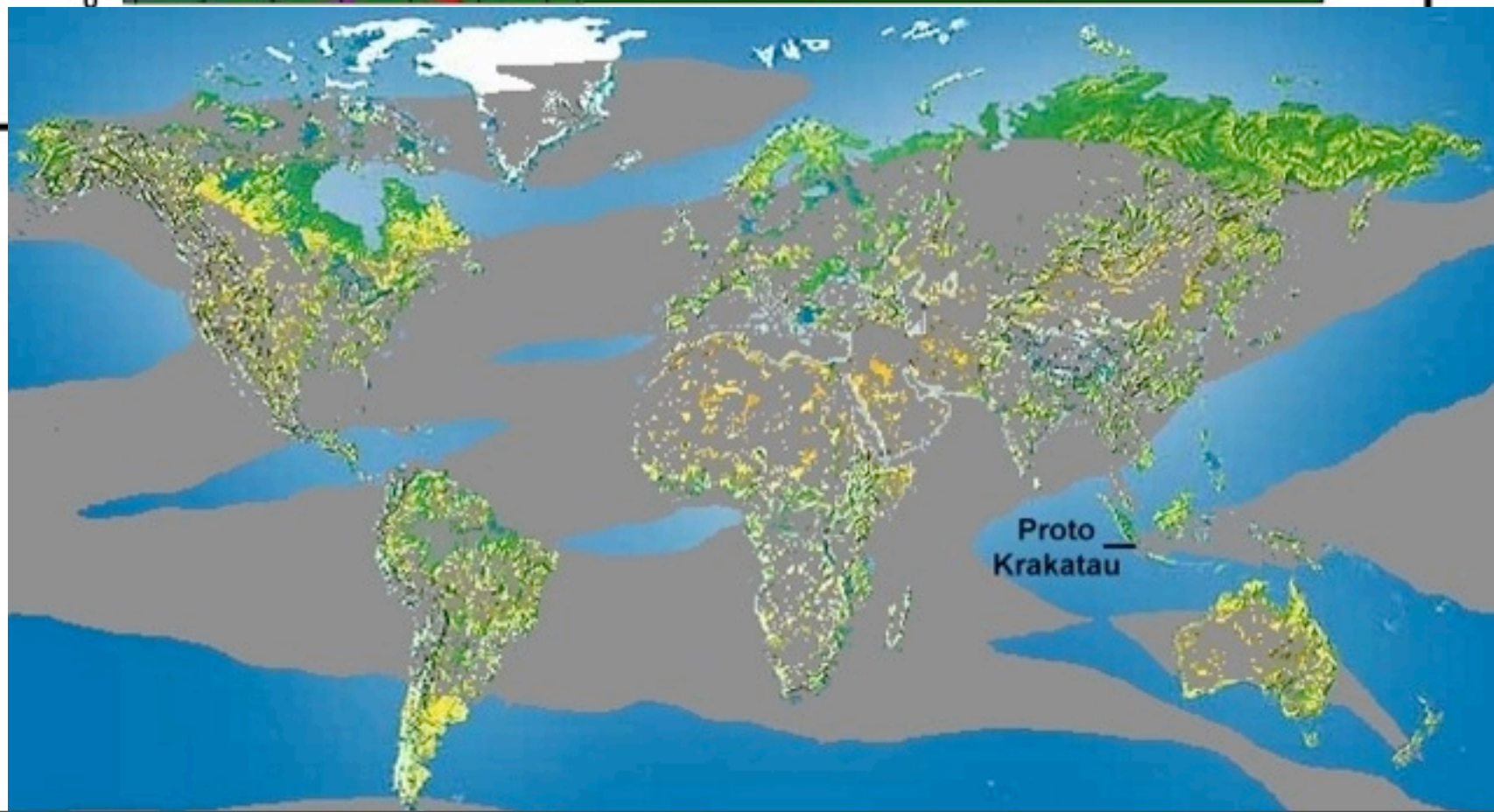
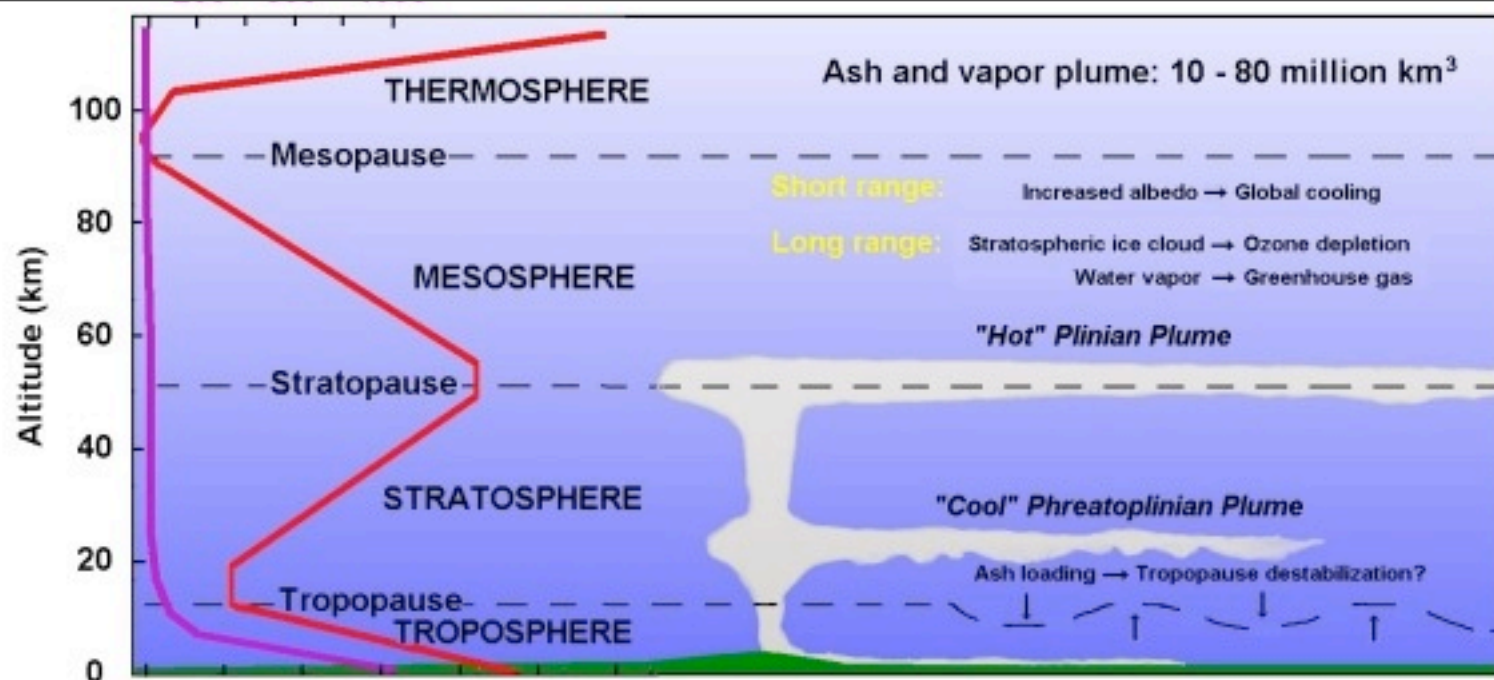


CENOZOIC ERA (Age of Recent Life)	Quaternary Period	<i>Pecten gibbus</i>		<i>Neptunea tabulata</i>	
	Tertiary Period	 <i>Calyptraphorus velatus</i>		 <i>Venericardia planicosta</i>	
MESOZOIC ERA (Age of Medieval Life)	Cretaceous Period	<i>Scaphites hippocrepis</i>		<i>Inoceramus labiatus</i>	
	Jurassic Period	 <i>Perisphinctes tiziani</i>		 <i>Nerinea trinodosa</i>	
	Triassic Period	<i>Trophites subbullatus</i>		<i>Monotis subcircularis</i>	
	Permian Period	 <i>Leptodus americanus</i>		 <i>Parafusulina bosei</i>	
PALEOZOIC ERA (Age of Ancient Life)	Pennsylvanian Period	<i>Dictyoclostus americanus</i>		<i>Lophophyllidium proliferum</i>	
	Mississippian Period	 <i>Cactocrinus multibrachiatus</i>		 <i>Prolecanites gurleyi</i>	
	Devonian Period	<i>Mucrospirifer mucronatus</i>		<i>Palmatolepus unicornis</i>	
	Silurian Period	 <i>Cystiphyllum niagarensense</i>		 <i>Hexamoceras hertzeri</i>	
	Ordovician Period	<i>Bathyrurus extans</i>		<i>Tetragraptus fructicosus</i>	
	Cambrian Period	 <i>Paradoxides pinus</i>		 <i>Billingsella corrugata</i>	
PRECAMBRIAN					

Volcanic Time Markers

Volcanic eruptions spread a thin layer of ash over the earth's surface.

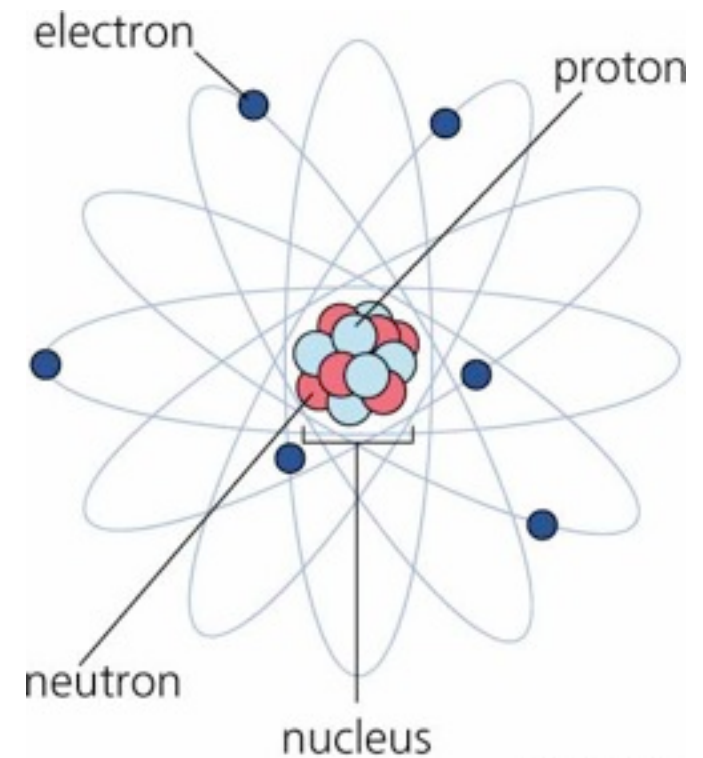
The ash covers a wide area in a short period of time.



Absolute Dating
with
Radioactive Decay

We start with an atom...

- An atom is the smallest piece of an element that still has all the same properties of the element.
- Atoms are made of protons and neutrons in the center (nucleus) and electrons flying around the center. (we are not concerned with electrons right now)



Isotopes

- Atoms get their identity from the number of protons in the nucleus (Carbon always has 6 protons, oxygen has 8, etc.)
- In general, stable atoms have equal numbers of neutrons and protons.
- However, sometimes atoms have too many neutrons. This throws the atom out of balance and makes it unstable. These unstable atoms are called are ***isotopes***.

Radioactivity

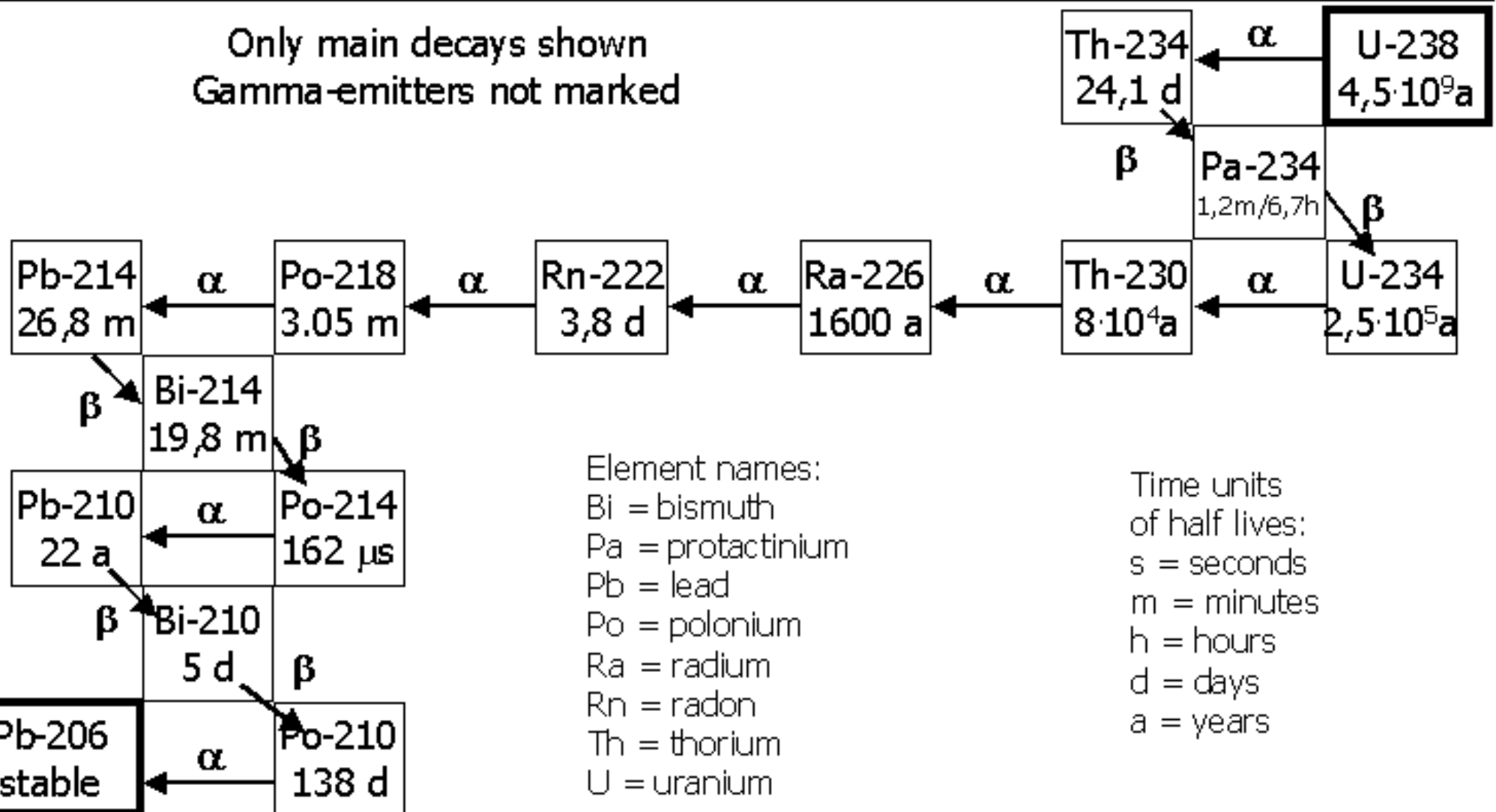
- If **isotopes** are very unstable, they are said to be **radioactive** (they are then called **radioisotopes**).
- These radioactive isotopes are so unstable that they **decay** or give off radiation.
- During decay, the nucleus breaks down giving the atom a new identity (a new number of neutrons).

The uranium-238 decay chain

Atomic number

82 83 84 85 86 87 88 89 90 91 92

Only main decays shown
Gamma-emitters not marked



So what...

- These radioisotopes happen to decay at a steady, predictable rate.
- The amount of time it takes for half (50%) of the atoms of a radioisotope to decay is called the ***half-life***.

Radioactive Decay Data

RADIOACTIVE ISOTOPE	DISINTEGRATION	HALF-LIFE (years)
Carbon-14	$C^{14} \rightarrow N^{14}$	5.7×10^3
Potassium-40	$K^{40} \rightarrow \begin{matrix} Ar^{40} \\ Ca^{40} \end{matrix}$	1.3×10^9
Uranium-238	$U^{238} \rightarrow Pb^{206}$	4.5×10^9
Rubidium-87	$Rb^{87} \rightarrow Sr^{87}$	4.9×10^{10}

Rubidium-87	$Rb^{87} \rightarrow Sr^{87}$	4.9×10^{10}
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Red- Blastonium (unstable parent)
Green- Happystone (stable daughter)

54321



100% Blastonium
0% Happystone

Red- Blastonium (unstable parent)
Green- Happystone (stable daughter)

54321



50% Blastonium
50% Happystone

Red- Blastonium (unstable parent)
Green- Happystone (stable daughter)

54321



25% Blastonium
75% Happystone

Red- Blastonium (unstable parent)
Green- Happystone (stable daughter)

54321



12.5% Blastonium
87.5% Happystone

Red- Blastonium (unstable parent)
Green- Happystone (stable daughter)

54321



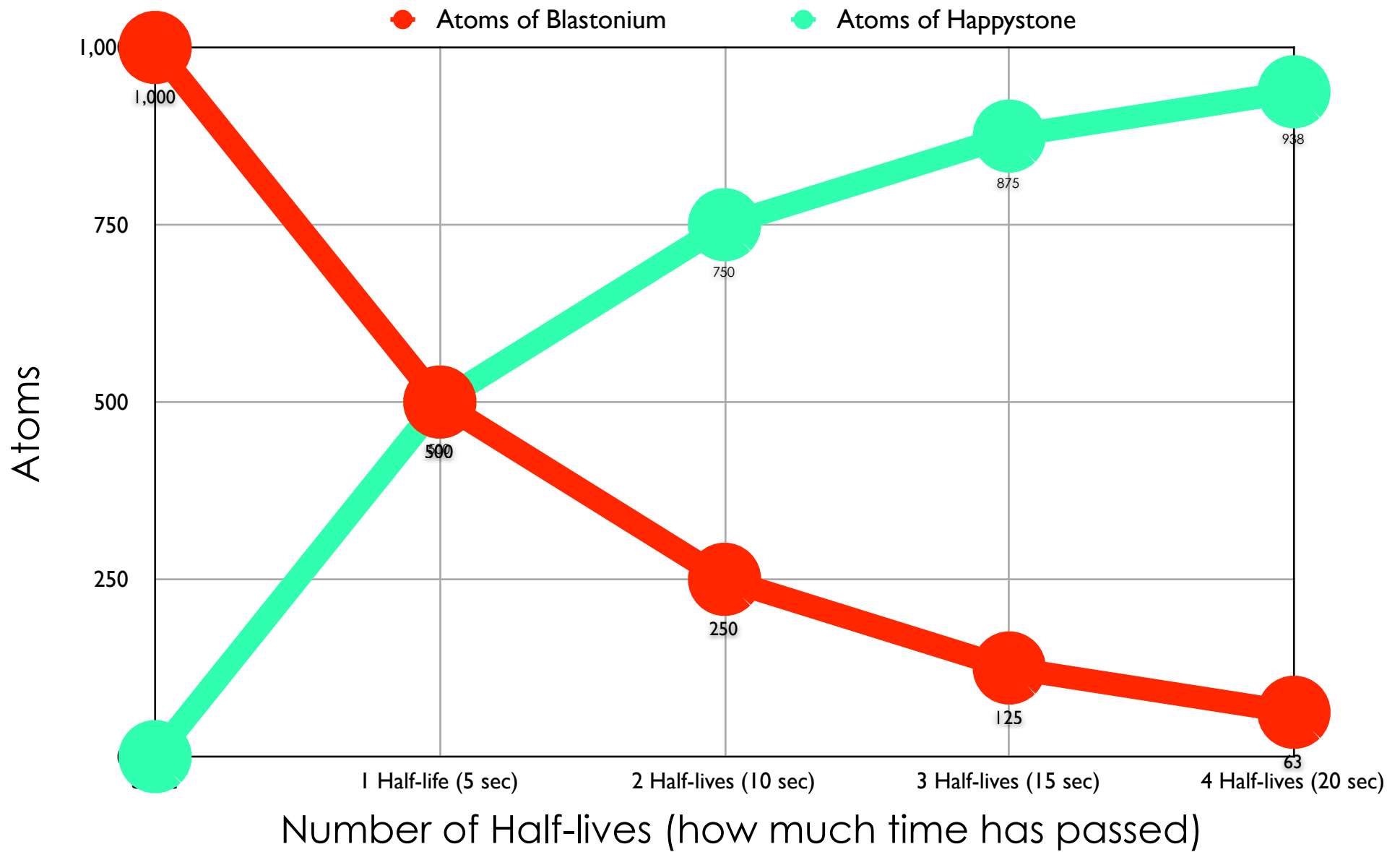
6.25% Blastonium
93.75% Happystone

Red- Blastonium (unstable parent)
Green- Happystone (stable daughter)

54321



3.125% Blastonium
96.875% Happystone

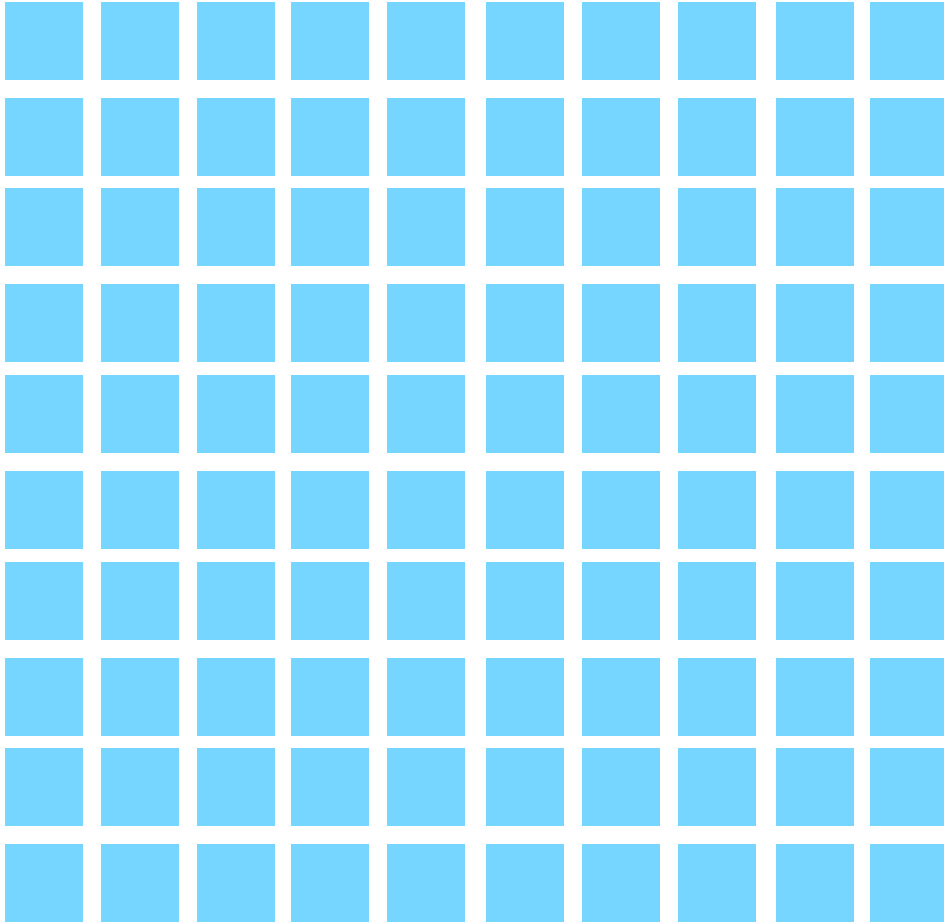


So?

- By examining the percentage of different isotopes found in a rock or a fossil, we can determine how many half-lives have gone by which will tell us precisely how old the rock or fossil is.
- This is ***absolute dating***

An example...

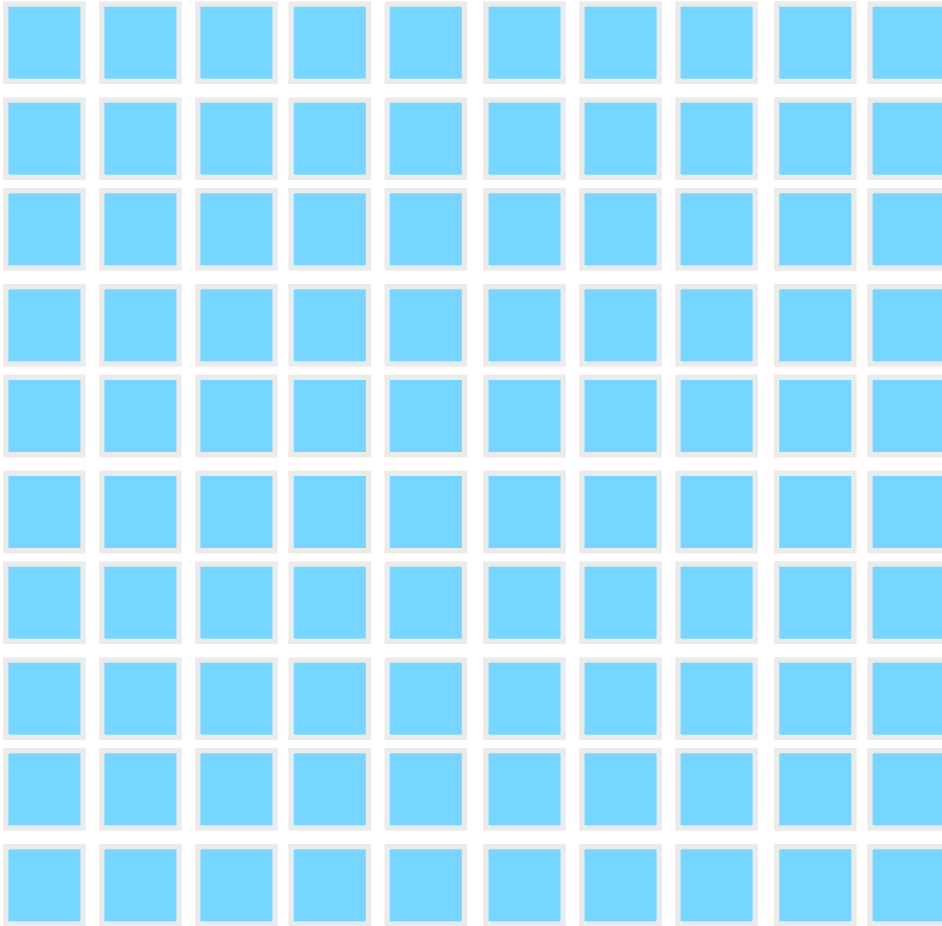
 Carbon-14
 Nitrogen-14



Imagine 100 atoms of
Carbon-14

An example...

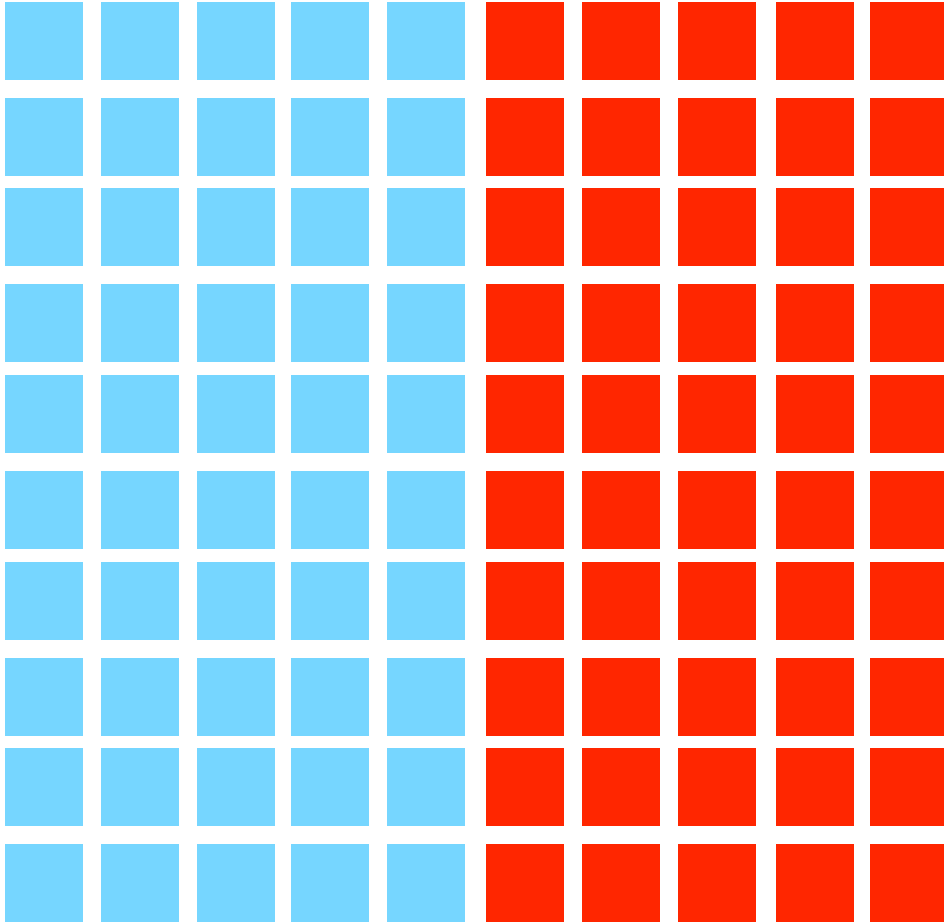
■ Carbon-14
■ Nitrogen-14



Number of Years	0
Number of half-lives	0
Atoms of C-14	100
% made up by C-14	100%
Atoms of N-14	0
% made up by N-14	0

An example...

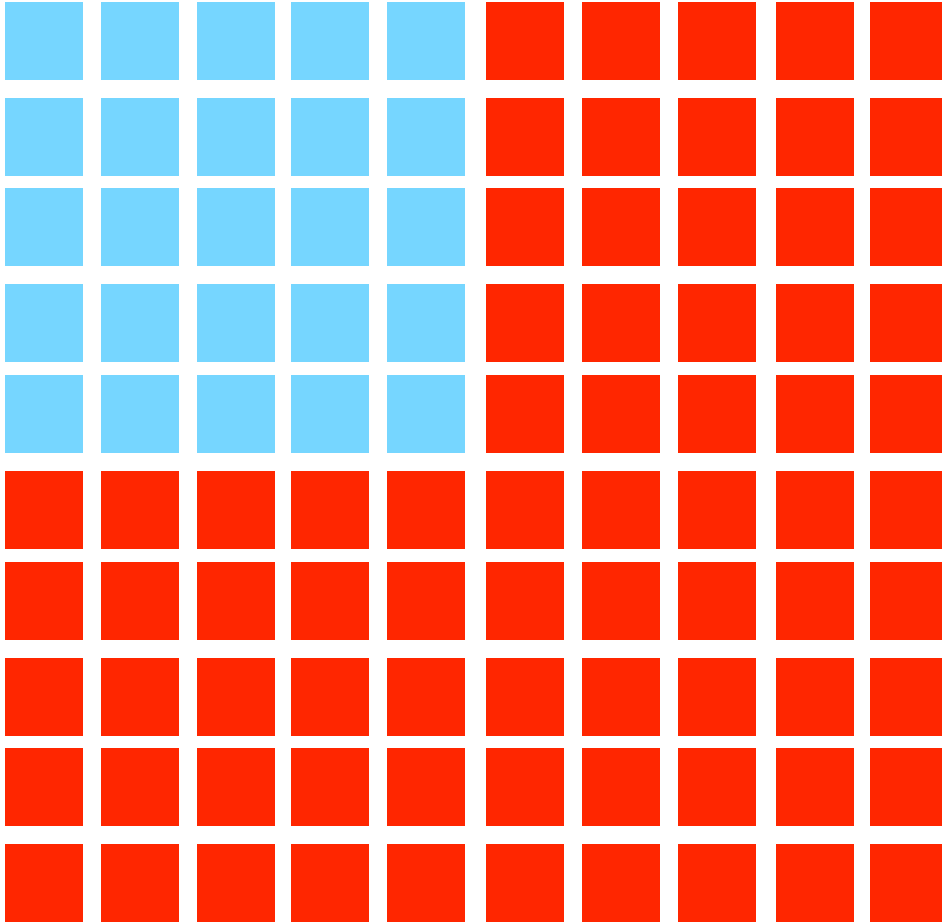
 Carbon-14
 Nitrogen-14



Number of Years	5,700
Number of half-lives	1
Atoms of C-14	50
% made up by C-14	50%
Atoms of N-14	50
% made up by N-14	50%

An example...

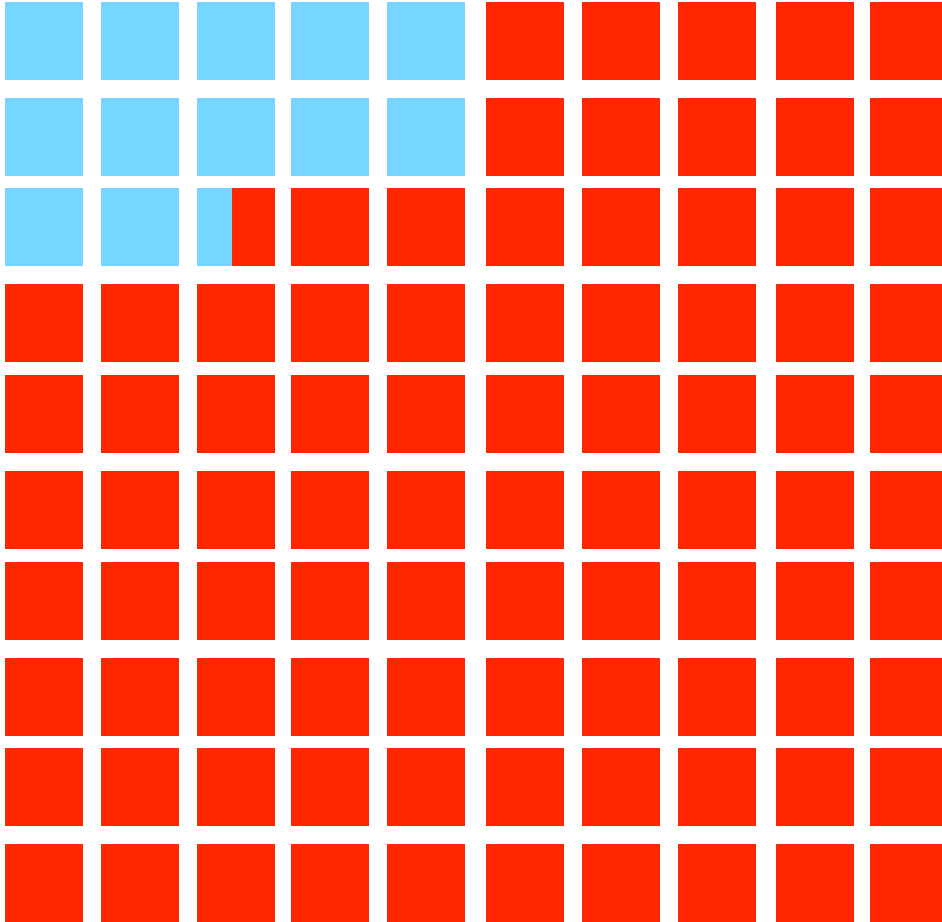
■ Carbon-14
■ Nitrogen-14



Number of Years	11,400
Number of half-lives	2
Atoms of C-14	25
% made up by C-14	25%
Atoms of N-14	75
% made up by N-14	75%

An example...

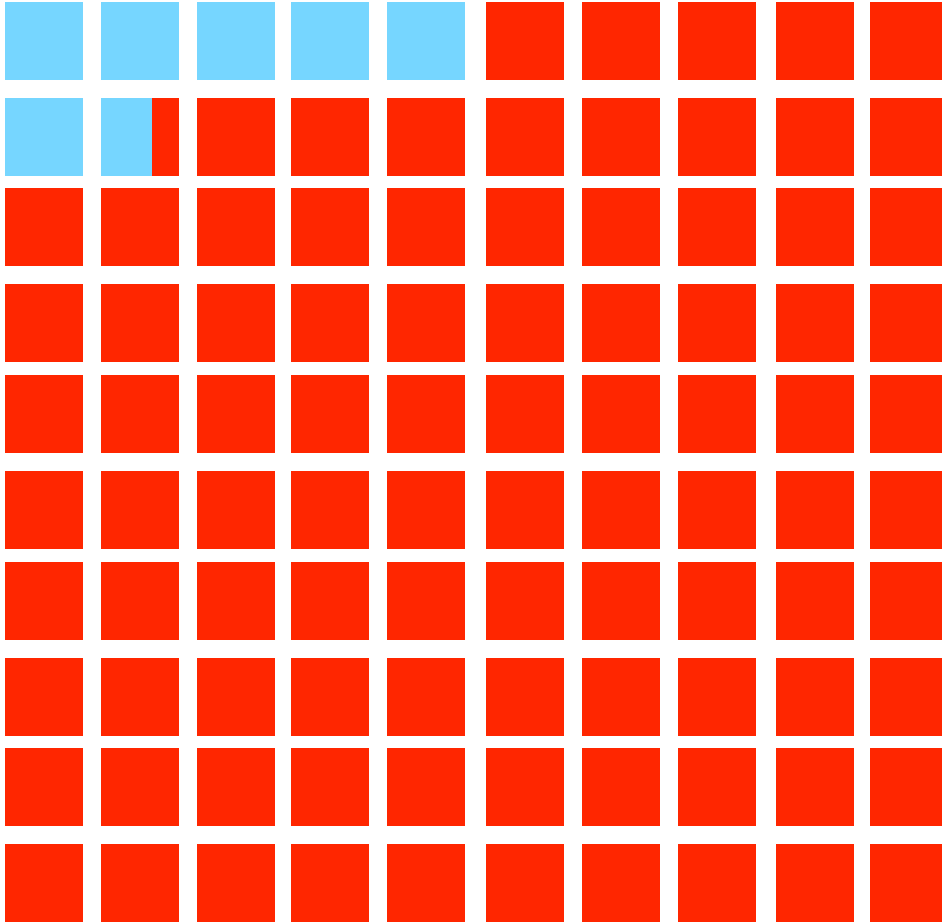
■ Carbon-14
■ Nitrogen-14



Number of Years	17,100
Number of half-lives	3
Atoms of C-14	12.5
% made up by C-14	12.5%
Atoms of N-14	87.5
% made up by N-14	87.5%

An example...

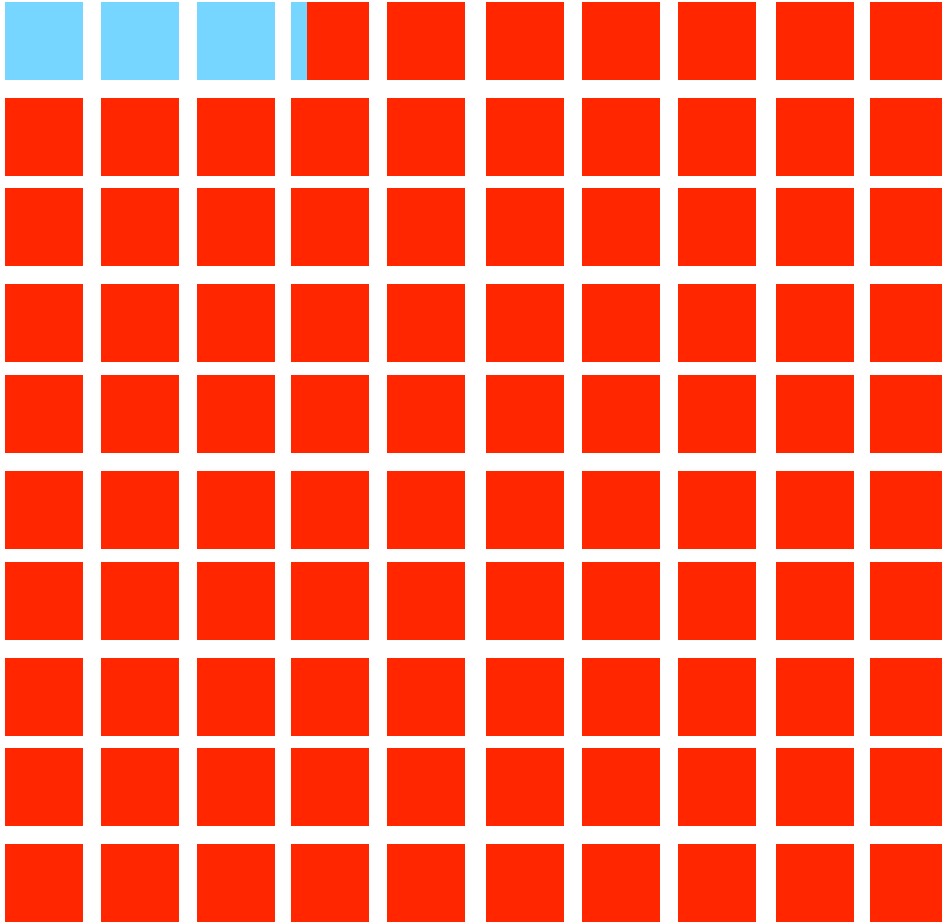
■ Carbon-14
■ Nitrogen-14



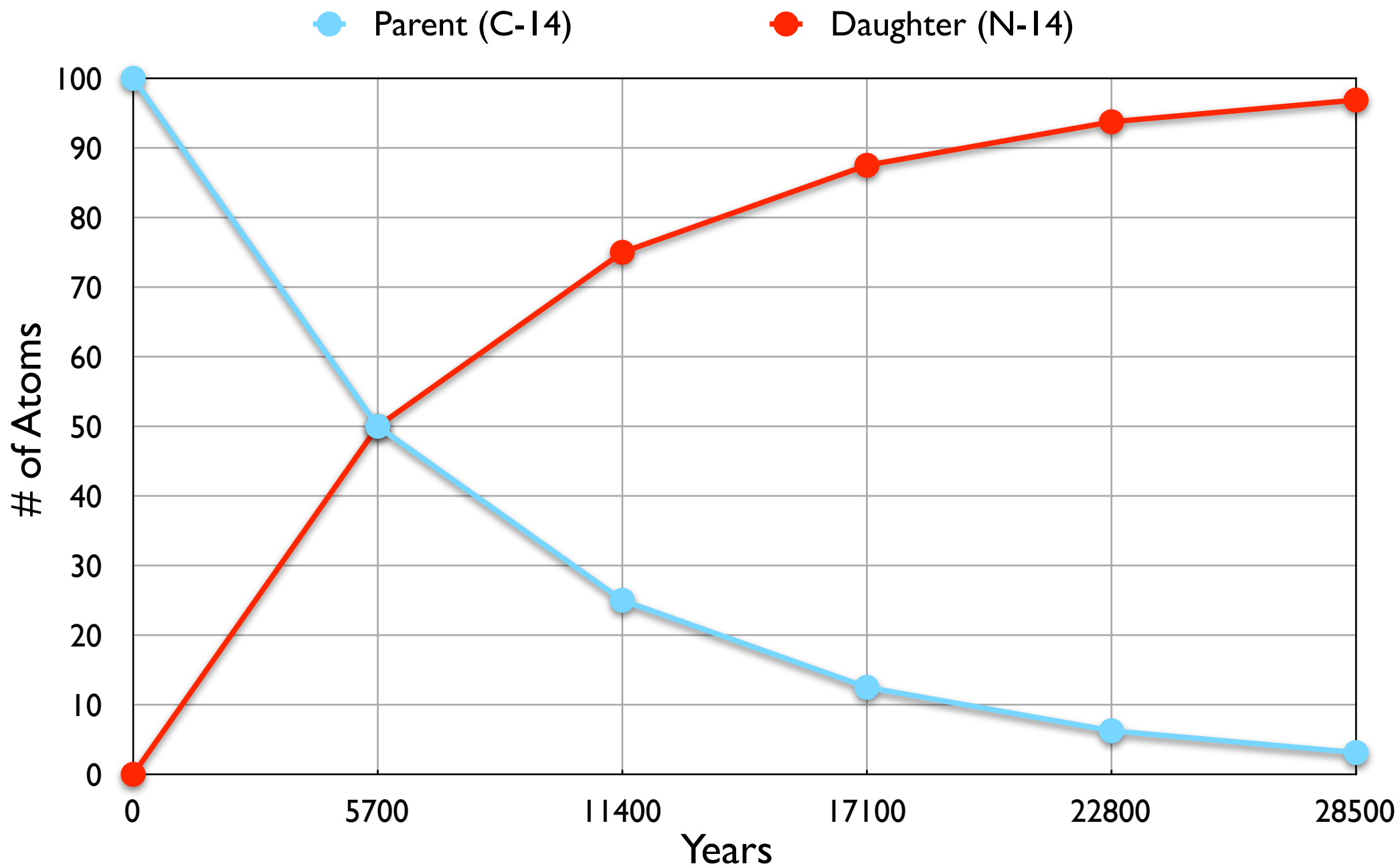
Number of Years	22,500
Number of half-lives	4
Atoms of C-14	6.25
% made up by C-14	6.25%
Atoms of N-14	93.75
% made up by N-14	93.75%

An example...

■ Carbon-14
■ Nitrogen-14



Number of Years	28,200
Number of half-lives	5
Atoms of C-14	3.125
% made up by C-14	3.125%
Atoms of N-14	96.875
% made up by N-14	96.875%



Carbon-14

- Half-life is 5,700 years
- Used to date relatively young materials, from 0 to 50,000 years old
- Used only to date organic material such as wood and mummies

Potassium-40, Uranium-238, and Rubidium-87

- Used to date very old materials such as rocks and fossils
- The half-lives are so long, they remain in rock layers for a long time

Carbon-14, an isotope used to date recent organic remains, would most likely be useful in determining the age of a fossil

- A) armored fish
- B) Beluga whale

- C) *Coelophysis*
- D) trilobite

If a sample of a radioactive substance is crushed, the half-life of the substance will

- A) increase
- B) decrease
- C) remain the same

A student filled a graduated cylinder with 1,000 milliliters of water to represent a radioactive substance. After 30 seconds, the student poured out one-half of the water in the cylinder to represent the decay occurring within the first half-life. The student repeated the process every 30 seconds. How much water did the student pour from the cylinder at the 2-minute mark?

A) 125.0 mL

C) 250.0 mL

B) 62.5 mL

D) 12.5 mL

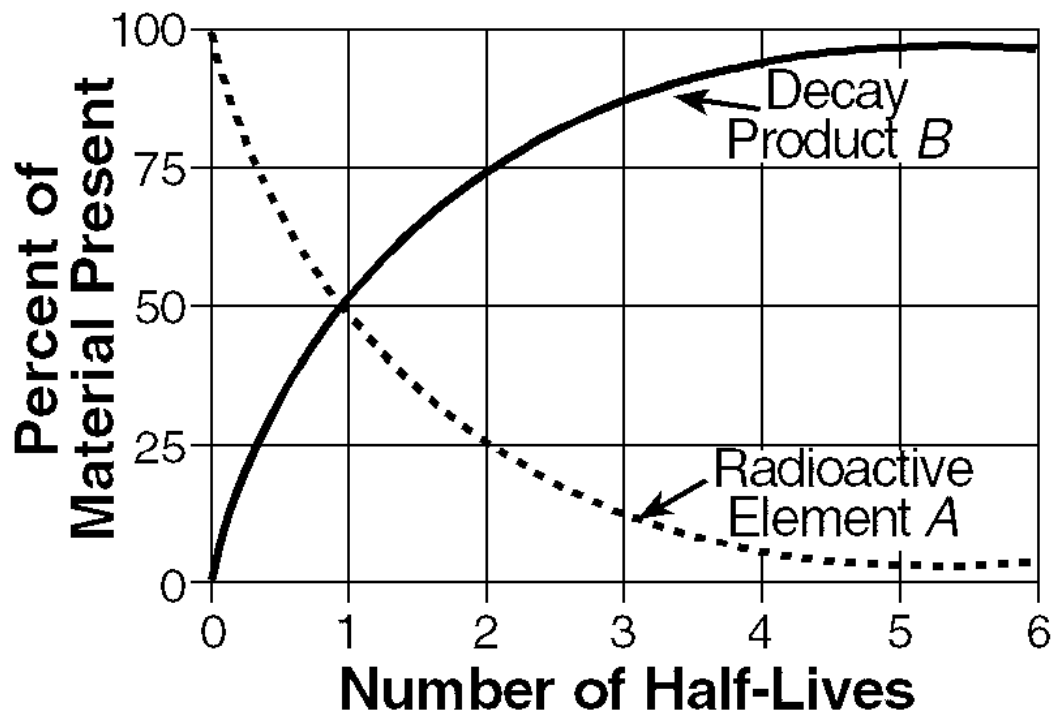
One half of the radioactive potassium-40 (^{40}K) in an igneous rock has decayed to argon-40 (^{40}Ar). According to the *Earth Science Reference Tables*, about how many years ago was this rock formed?

A) 1.3×10^9

C) 2.8×10^9

B) 4.2×10^9

D) 9.8×10^9



An igneous rock contains 2 grams of radioactive element A and 2 grams of decay product B. How old is the rock sample?

- A) 3 half-lives
- B) 2 half-lives
- C) less than 1 half-life
- D) 1 half-life

According to the graph, what is the total percentage of radioactive element A present after 3 half-lives?

- | | |
|----------|----------|
| A) 25.0% | C) 75.0% |
| B) 87.5% | D) 12.5% |