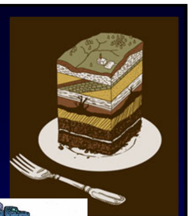
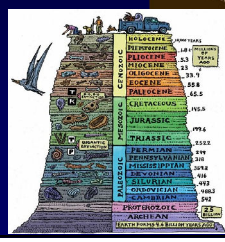
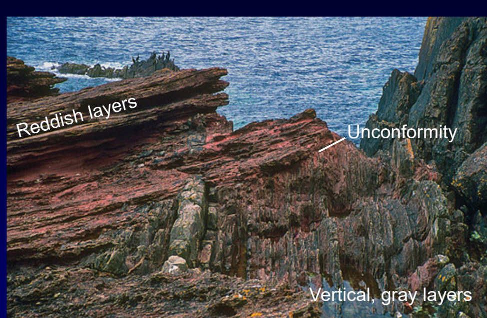
Geologic Time
Chap 9





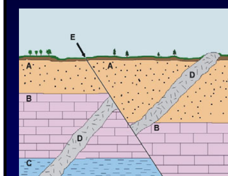
Observe the orientation of rocks at Siccar Point, Scotland

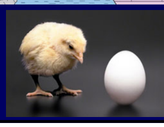


09.00.a1

Geologic Time

- Relative Time





- Absolute Time

Parent → Daughter	Half-Life (years)	Minerals Containing the Isotopes
$^{147}Sm \rightarrow ^{143}Nd$	106.0 billion	Garnets, micas
$^{87}Rb \rightarrow ^{87}Sr$	48.8 billion	Potassium-bearing minerals (mica, feldspar, hornblende)
$^{238}U \rightarrow ^{206}Pb$	4.5 billion	Uranium-bearing minerals (zircon, uraninite)
$^{40}K \rightarrow ^{40}Ar$	1.3 billion	Potassium-bearing minerals (mica, feldspar, hornblende)
$^{235}U \rightarrow ^{207}Pb$	713.0 million	Uranium-bearing minerals (zircon, uraninite)

Sm = samarium, Nd = neodymium, Rb = rubidium, Sr = strontium, U = uranium, Pb = lead, K = potassium, Ar = argon

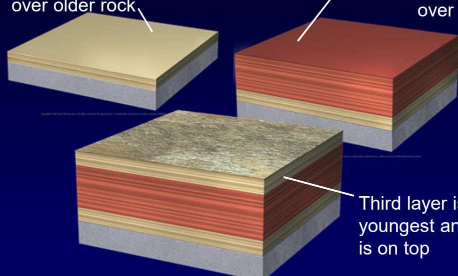
Observe the layers in these two photographs, which show the same sequence of rocks. What is different and what do you think happened?

Most sediment is deposited in horizontal layers

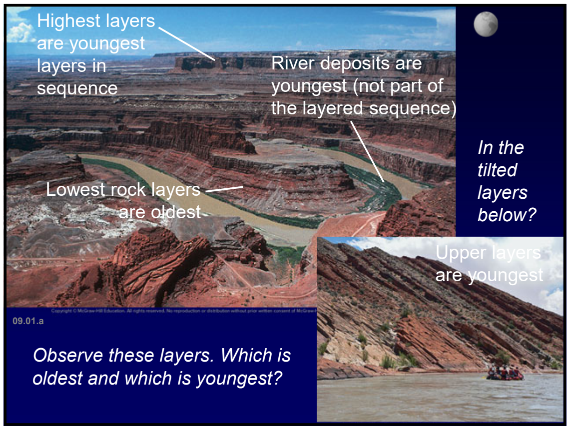
If layers are not horizontal, something has happened (deformation)

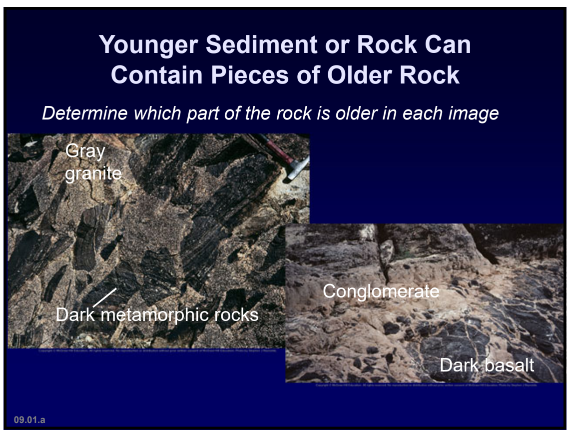
09.01.a

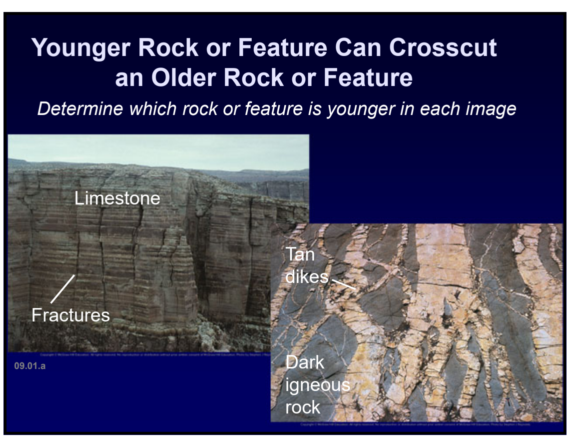
Younger Units Deposited on Older Units



09.01.a


Highest layers are youngest layers in sequence
River deposits are youngest (not part of the layered sequence)
In the tilted layers below?
Lowest rock layers are oldest
Upper layers are youngest
09.01.a
Observe these layers. Which is oldest and which is youngest?

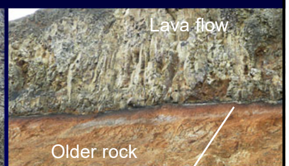

Younger Sediment or Rock Can Contain Pieces of Older Rock
Determine which part of the rock is older in each image
Gray granite
Dark metamorphic rocks
Conglomerate
Dark basalt
09.01.a


Younger Rock or Feature Can Crosscut an Older Rock or Feature
Determine which rock or feature is younger in each image
Limestone
Fractures
Tan dikes
Dark igneous rock
09.01.a

Younger Rocks and Features Can Cause Changes Along Contacts with Older Rocks

Observe the boundaries between different rock types

Baking along contact

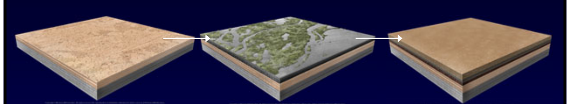


Baking along base of lava flow (but not on top)

Sill can bake rocks below and above

09.01.a

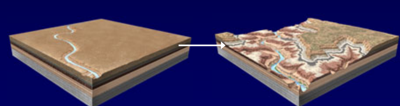
How a Typical Landscape Forms



Sediment covers preexisting rock

Environment changes, depositing more rock

Deposition stops



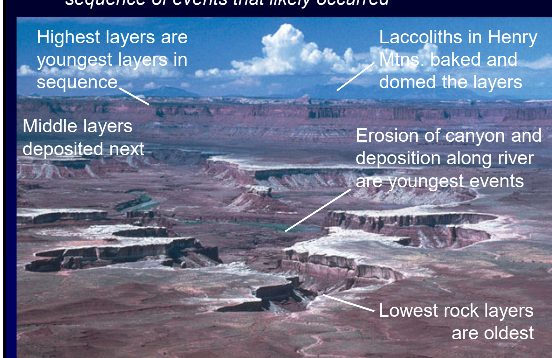
Area eroded by rivers, etc.

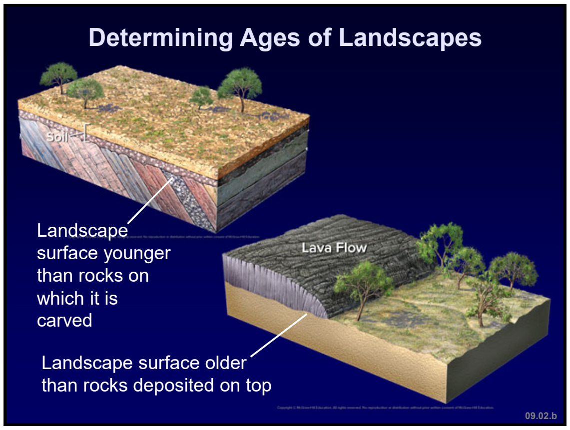
Continued erosion cuts and widens a canyon

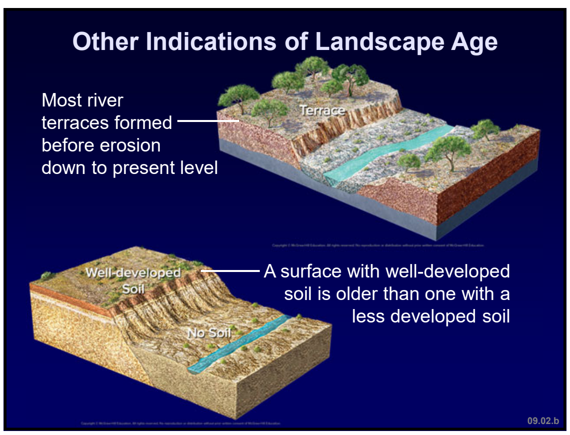
09.02.a

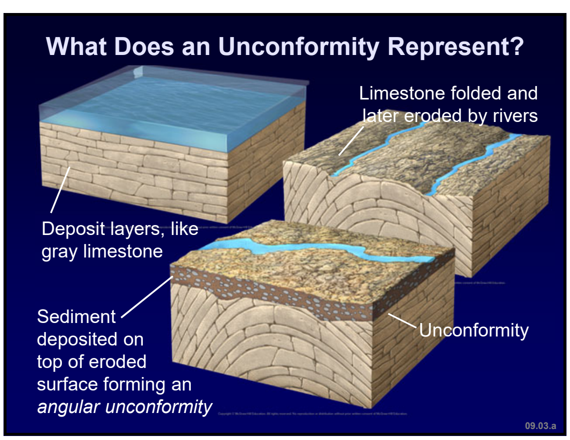
Observe this photograph and consider the sequence of events that likely occurred

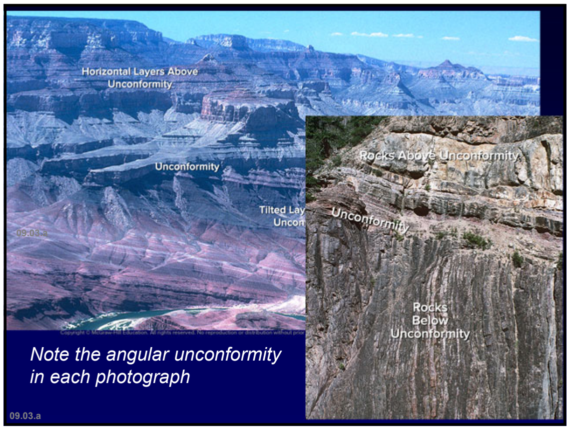
09.02.a6

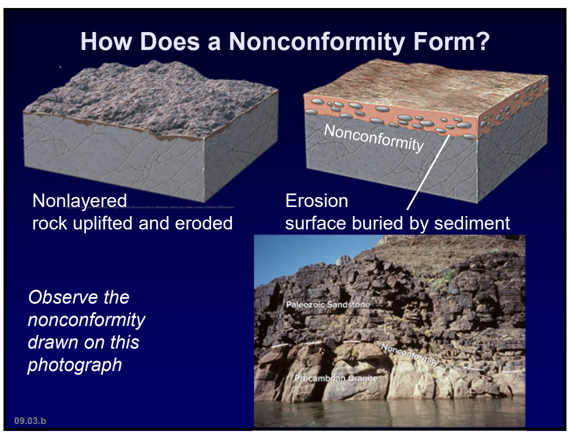


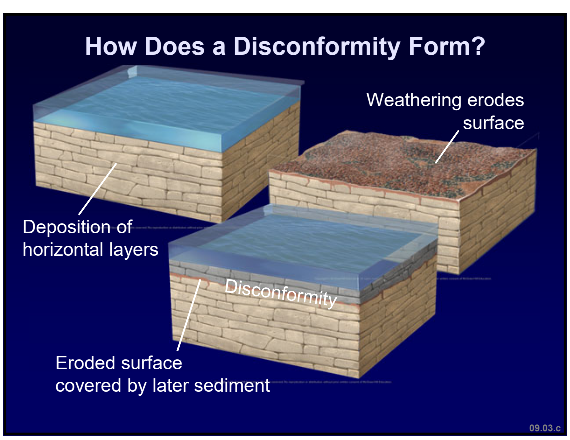

Determining Ages of Landscapes
Soil
Landscape surface younger than rocks on which it is carved
Lava Flow
Landscape surface older than rocks deposited on top
09.02.b


Other Indications of Landscape Age
Most river terraces formed before erosion down to present level
Terrace
Well-developed Soil
No Soil
A surface with well-developed soil is older than one with a less developed soil
09.02.b

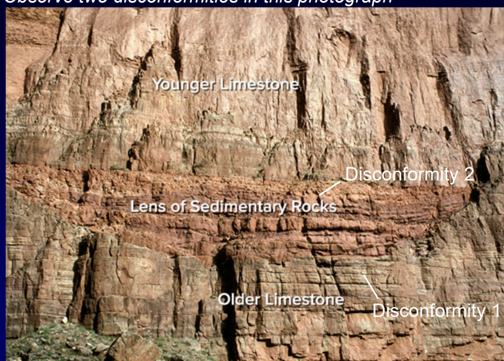

What Does an Unconformity Represent?
Limestone folded and later eroded by rivers
Deposit layers, like gray limestone
Sediment deposited on top of eroded surface forming an *angular unconformity*
Unconformity
09.03.a


Horizontal Layers Above Unconformity
Unconformity
Rocks Above Unconformity
Unconformity
Rocks Below Unconformity
Note the angular unconformity in each photograph
09.03.a


How Does a Nonconformity Form?
Nonconformity
Nonlayered rock uplifted and eroded
Erosion surface buried by sediment
Observe the nonconformity drawn on this photograph
Paleozoic Sandstone
Nonconformity
Precambrian Granite
09.03.b

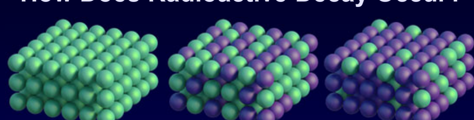

How Does a Disconformity Form?
Weathering erodes surface
Deposition of horizontal layers
Disconformity
Eroded surface covered by later sediment
09.03.c

Observe two disconformities in this photograph



09.03.c4

How Does Radioactive Decay Occur?



Before decay, unstable parent atoms

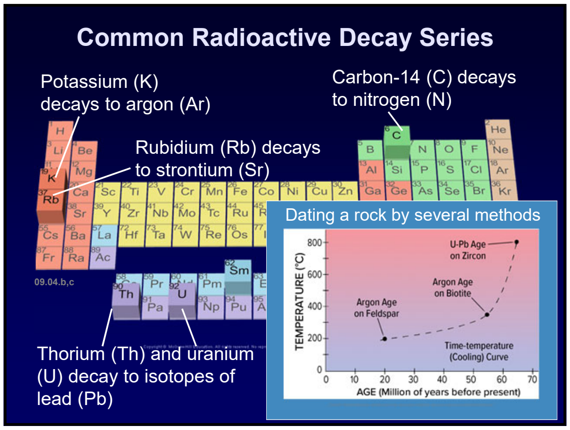
Half the parent atoms decayed to daughter atoms (time = half life)

After a second half life, only ¼ parent atoms remain

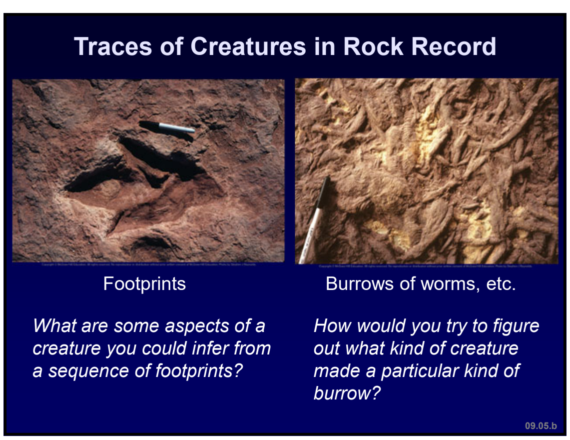
Example for 1000 atoms

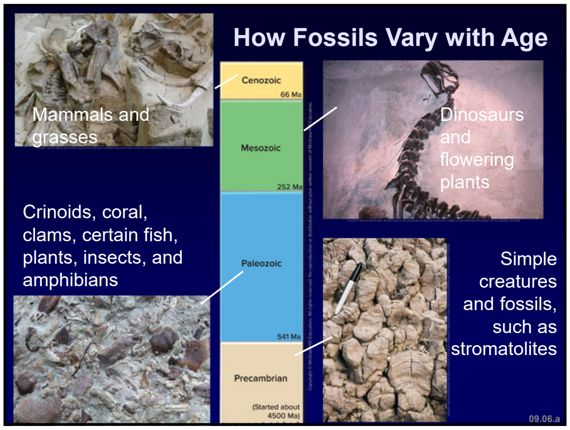
	Before Any Decay	After One Half-Life	After Two Half-Lives
Atoms of Parent	1,000	500	250
Atoms of Daughter	0	500	750

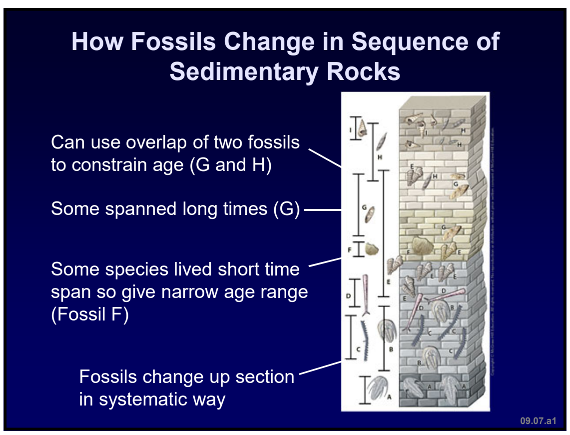
09.04.a

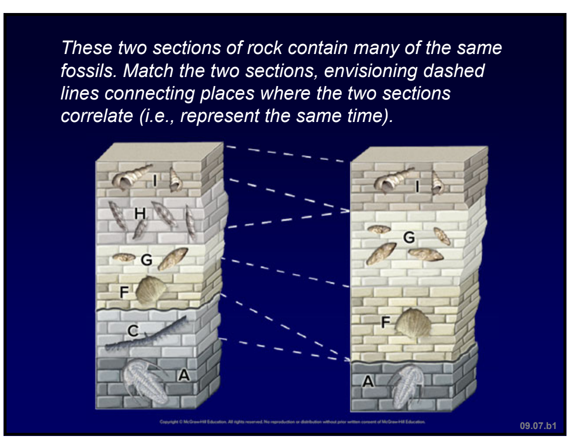

Common Radioactive Decay Series
Potassium (K) decays to argon (Ar)
Carbon-14 (C) decays to nitrogen (N)
Rubidium (Rb) decays to strontium (Sr)
Thorium (Th) and uranium (U) decay to isotopes of lead (Pb)
Dating a rock by several methods
U-Pb Age on Zircon
Argon Age on Biotite
Argon Age on Feldspar
Time-temperature (Cooling) Curve
TEMPERATURE (°C)
AGE (Million of years before present)
09.04.b,c

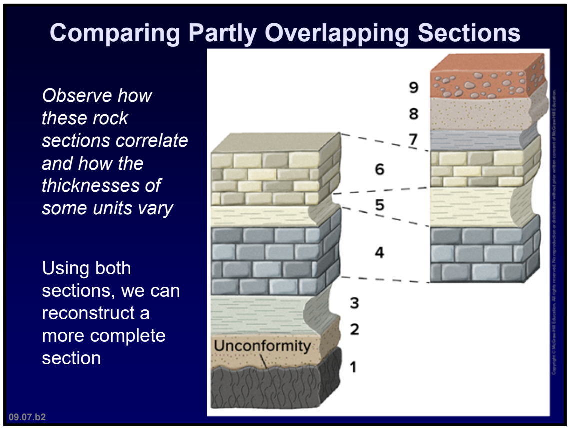

How Are Fossils Preserved?
Shells/hard parts
Bones
Replacement
Cast or mold
Thin film of material
Impressions
Amber
Constructed feature
09.05.a

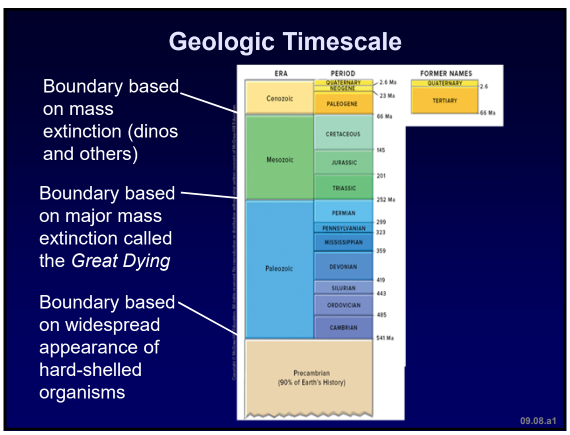

Traces of Creatures in Rock Record
Footprints
Burrows of worms, etc.
What are some aspects of a creature you could infer from a sequence of footprints?
How would you try to figure out what kind of creature made a particular kind of burrow?
09.05.b

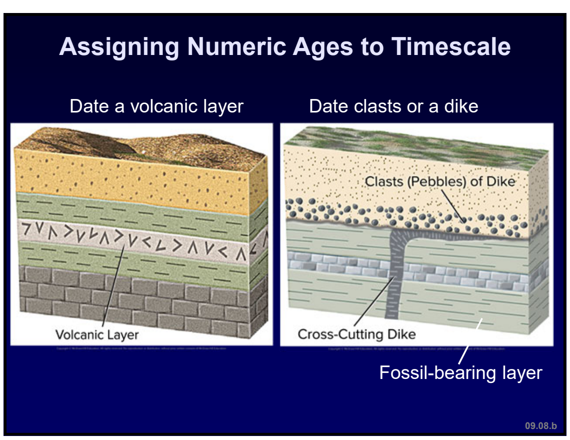

How Fossils Vary with Age
Cenozoic
66 Ma
Mesozoic
252 Ma
Paleozoic
541 Ma
Precambrian
(Started about 4500 Ma)
Mammals and grasses
Dinosaurs and flowering plants
Crinoids, coral, clams, certain fish, plants, insects, and amphibians
Simple creatures and fossils, such as stromatolites
09.06.a


How Fossils Change in Sequence of Sedimentary Rocks
Can use overlap of two fossils to constrain age (G and H)
Some spanned long times (G)
Some species lived short time span so give narrow age range (Fossil F)
Fossils change up section in systematic way
09.07.a1


These two sections of rock contain many of the same fossils. Match the two sections, envisioning dashed lines connecting places where the two sections correlate (i.e., represent the same time).
I
H
G
F
C
A
I
G
F
A
09.07.b1


Comparing Partly Overlapping Sections
Observe how these rock sections correlate and how the thicknesses of some units vary
Using both sections, we can reconstruct a more complete section
9
8
7
6
5
4
3
2
1
Unconformity
09.07.b2

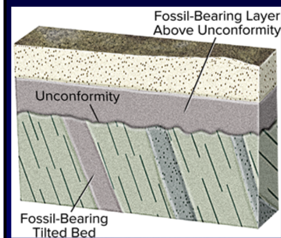

Geologic Timescale
Boundary based on mass extinction (dinos and others)
Boundary based on major mass extinction called the *Great Dying*
Boundary based on widespread appearance of hard-shelled organisms
ERA
PERIOD
FORMER NAMES
Cenozoic
Mesozoic
Paleozoic
Precambrian
(90% of Earth's History)
QUATERNARY
NEOGENE
PALEOGENE
CRETACEOUS
JURASSIC
TRIASSIC
PERMIAN
PENNSYLVANIAN
MISSISSIPPIAN
DEVONIAN
SILURIAN
ORDOVICIAN
CAMBRIAN
2.6 Ma
23 Ma
66 Ma
145
201
252 Ma
299
323
359
419
443
485
541 Ma
QUATERNARY
TERTIARY
2.6
66 Ma
09.08.a1

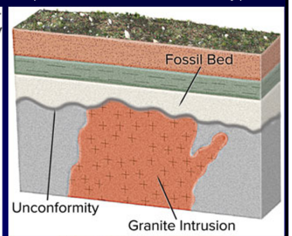

Assigning Numeric Ages to Timescale
Date a volcanic layer
Date clasts or a dike
Volcanic Layer
Clasts (Pebbles) of Dike
Cross-Cutting Dike
Fossil-bearing layer
09.08.b

Using Timescale to Assign Numeric Ages

Bracket using ages of fossils from geologic timescale

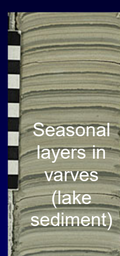
Use fossils and timescale to assign numeric age (like for this unconformity)



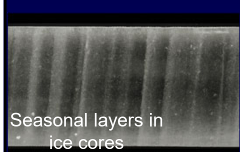


09.08.c

Evidence that Earth's History is Not Short



Measured rates of modern plate movement are consistent with long-term rates



09.09.b

Where Age of Earth Comes From

Age of meteorites

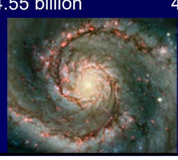
4.55 billion

Dated Moon rocks

4.5 billion

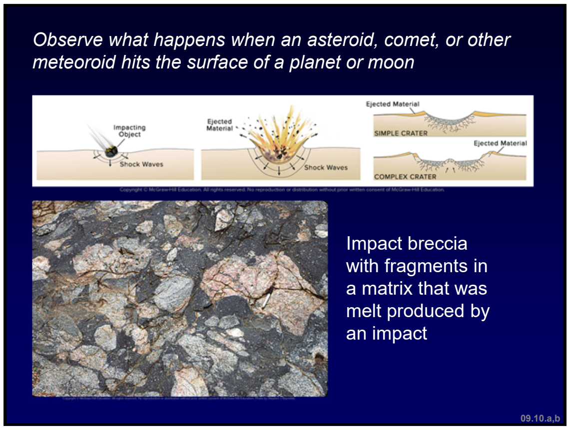
Oldest dates on Earth rocks

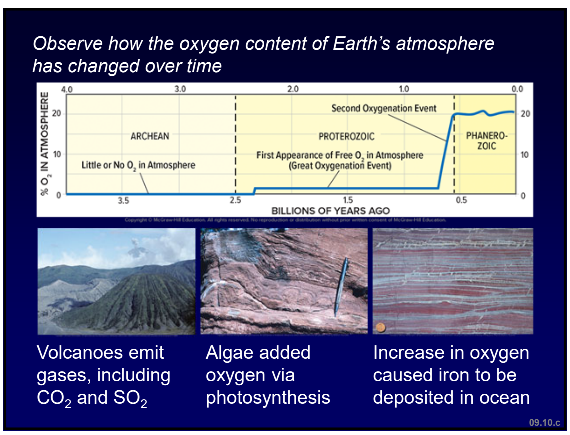
3.9 to > 4.0 b.y. (rock) to 4.3 b.y. (grains)

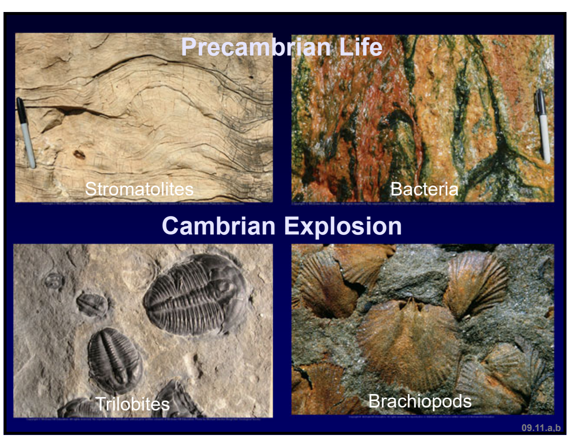


Data from astronomy on age of Solar System and Universe

09.09.t


Observe what happens when an asteroid, comet, or other meteoroid hits the surface of a planet or moon
Impacting Object
Shock Waves
Ejected Material
Shock Waves
Ejected Material
SIMPLE CRATER
Ejected Material
COMPLEX CRATER
Impact breccia with fragments in a matrix that was melt produced by an impact
09.10.a,b


Observe how the oxygen content of Earth's atmosphere has changed over time
% O_2 IN ATMOSPHERE
4.0
3.0
2.0
1.0
0.0
20
10
0
ARCHEAN
Little or No O_2 in Atmosphere
PROTEROZOIC
Second Oxygenation Event
First Appearance of Free O_2 in Atmosphere (Great Oxygenation Event)
PHANERO-ZOIC
3.5
2.5
1.5
0.5
BILLIONS OF YEARS AGO
Volcanoes emit gases, including CO_2 and SO_2
Algae added oxygen via photosynthesis
Increase in oxygen caused iron to be deposited in ocean
09.10.c


Precambrian Life
Stromatolites
Bacteria
Cambrian Explosion
Trilobites
Brachiopods
09.11.a,b

Life in the Paleozoic


Early Paleozoic


Middle Paleozoic


Late Paleozoic

09.11.c

Life in the Mesozoic


Early Mesozoic: Triassic

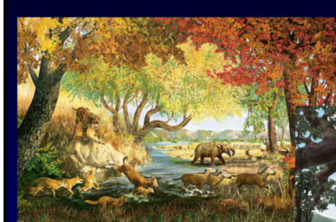

Middle Mesozoic: Jurassic



Late Mesozoic: Cretaceous

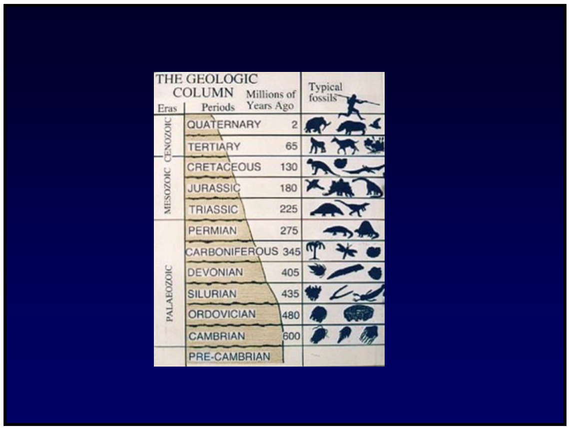
09.12.a

Life in the Cenozoic


Early Cenozoic

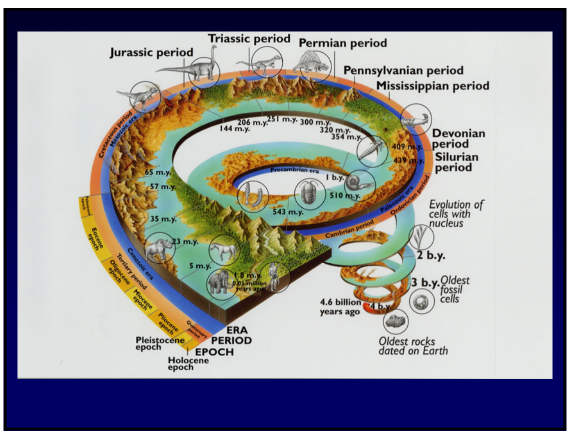

Late Cenozoic

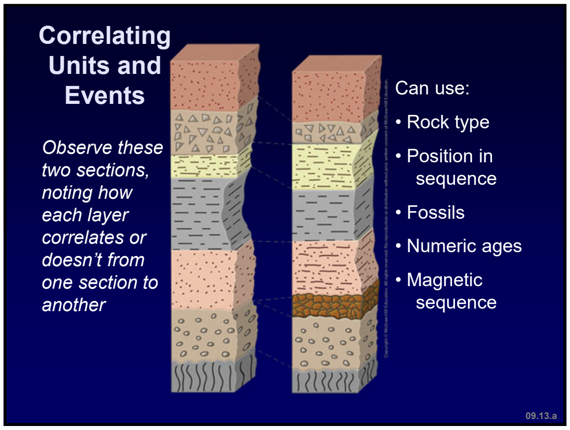
09.12.c

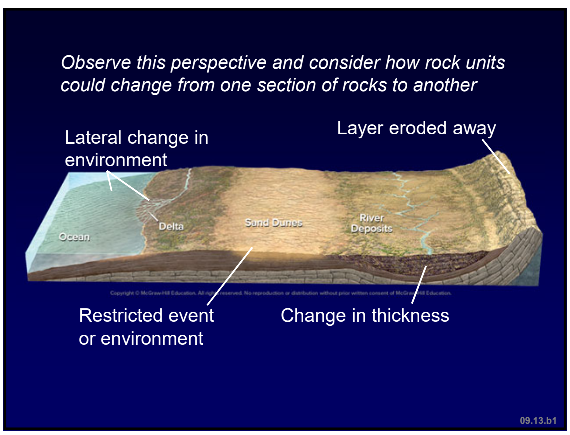


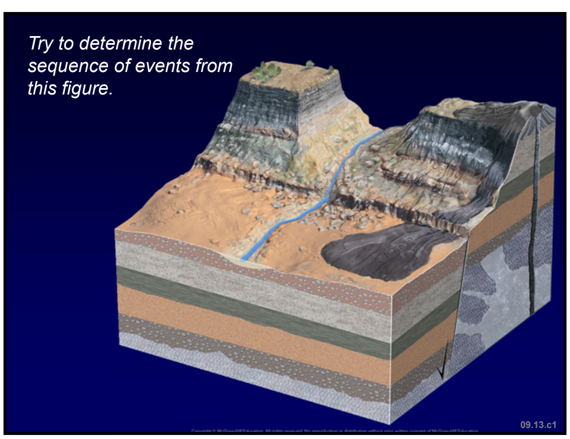
THE GEOLOGIC COLUMN

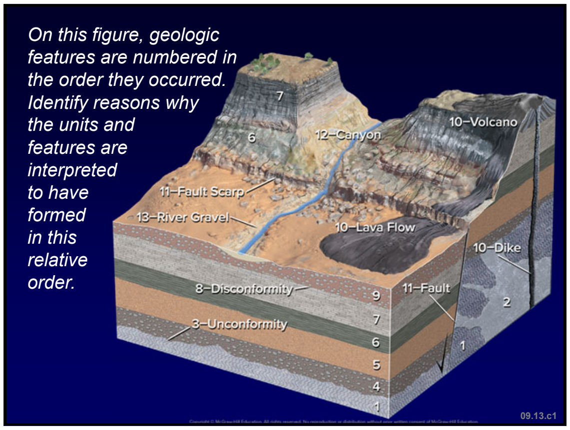
Eras	Periods	Millions of Years Ago	Typical fossils
CENOZOIC	QUATERNARY	2	
	TERTIARY	65	
MESOZOIC	CRETACEOUS	130	
	JURASSIC	180	
	TRIASSIC	225	
PALAEOZOIC	PERMIAN	275	
	CARBONIFEROUS	345	
	DEVONIAN	405	
	SILURIAN	435	
	ORDOVICIAN	480	
	CAMBRIAN	600	
	PRE-CAMBRIAN		

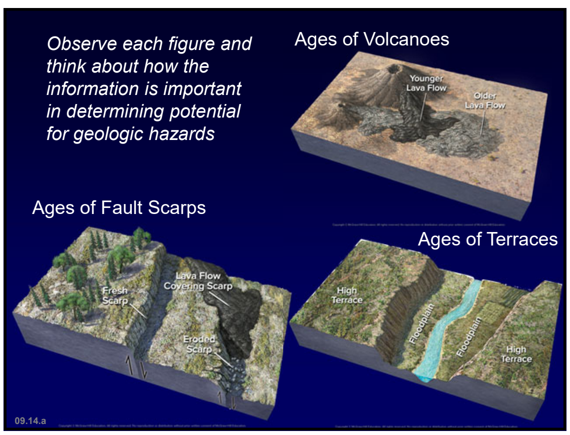


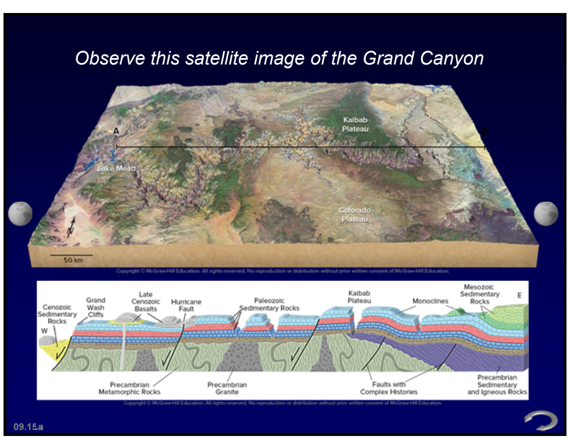

Correlating Units and Events
Observe these two sections, noting how each layer correlates or doesn't from one section to another
Can use:
• Rock type
• Position in sequence
• Fossils
• Numeric ages
• Magnetic sequence
09.13.a


Observe this perspective and consider how rock units could change from one section of rocks to another
Lateral change in environment
Layer eroded away
Ocean
Delta
Sand Dunes
River Deposits
Restricted event or environment
Change in thickness
09.13.b1


Try to determine the sequence of events from this figure.
09.13.c1


On this figure, geologic features are numbered in the order they occurred. Identify reasons why the units and features are interpreted to have formed in this relative order.
7
6
12–Canyon
10–Volcano
11–Fault Scarp
13–River Gravel
10–Lava Flow
10–Dike
8–Disconformity
3–Unconformity
11–Fault
9
7
6
5
4
1
2
1
09.13.c1


Observe each figure and think about how the information is important in determining potential for geologic hazards
Ages of Volcanoes
Younger Lava Flow
Older Lava Flow
Ages of Fault Scarps
Fresh Scarp
Lava Flow Covering Scarp
Eroded Scarp
Ages of Terraces
High Terrace
Floodplain
Floodplain
High Terrace
09.14.a


Observe this satellite image of the Grand Canyon
Kaibab Plateau
A
Lake Mead
Colorado Plateau
50 km
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W
Cenozoic Sedimentary Rocks
Grand Wash Cliffs
Late Cenozoic Basalts
Hurricane Fault
Paleozoic Sedimentary Rocks
Kaibab Plateau
Monoclines
Mesozoic Sedimentary Rocks
E
Precambrian Metamorphic Rocks
Precambrian Granite
Faults with Complex Histories
Precambrian Sedimentary and Igneous Rocks
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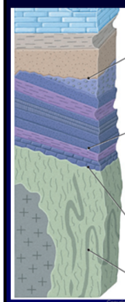
Geologic History of Grand Canyon, Part 1



4. *Tilting and Upper Unconformity*—Layers in the Late Precambrian rocks were gently to moderately tilted and then beveled by erosion. This produced the *upper unconformity*. As this unconformity is followed west, it truncates the *lower unconformity* beneath the Kaibab Plateau (see the cross section A–B). To the west, these combined unconformities represent even more missing time (from 1.7 billion years to 540 million years, or more than 1.1 billion years); it is appropriately called the *Great Unconformity* and can be followed eastward to the Great Lakes region.

3. *Late Precambrian Rocks and Lower Unconformity*—In the Late Precambrian, sedimentary and volcanic rocks accumulated in horizontal layers across the upturned basement layers. This formed the *lower unconformity* (above the metamorphic rocks). The lower parts of these late Precambrian rocks are dated by several isotopic methods at 1.1 billion years. Since the underlying basement rocks are 1.7 billion years old, the lower unconformity represents 600 million years of time not recorded by any rocks!

2. *Uplift and Erosion of the Basement*—After the metamorphism, the basement rocks cooled as they were uplifted and eroded over a period that lasted for hundreds of millions of years. Erosion beveled across the steep metamorphic layers.

1. *Basement Rocks*—Metamorphic and plutonic rocks in the bottom of the canyon represent the oldest events. They were formed, metamorphosed, and deformed to near-vertical orientations, all between 1.76 and 1.70 billion years ago.

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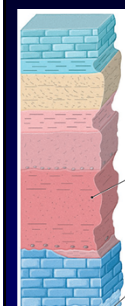
Geologic History of Grand Canyon, Part 2



The sequence of events in the Grand Canyon has been reconstructed using relative dating, fossils, and many different isotopic dating methods. The geologic history resulting from these studies is summarized below, which should be read from bottom to top (oldest to youngest).

7. *Deformation, Uplift, and Erosion*—The Paleozoic strata largely escaped deformation and remain nearly flat, except near a few faults and folds, including some monoclines visible in cross section A–B. The age of the monoclines, using relative-dating methods, is between 80 and 40 million years ago. The region was uplifted by some amount at this same time, but the modern canyon carved into the landscape much later, mostly within the last 5 million years. Some faults, like the Hurricane fault, remain active.

6. *Deposition of Late Paleozoic Layers*—Overlying sedimentary layers (shown in red, pink, tan, and blue-green) record a wide range of environments, including shallow marine, shorelines, rivers, and a dune-covered desert. These rocks contain marine and nonmarine fossils of late Paleozoic age (Pennsylvanian and Permian). Disconformities (mostly not shown) separate some of the formations and represent time when the region was above sea level.

5. *Deposition of Early and Middle Paleozoic Units*—After erosion carved the upper unconformity, seas covered the land and deposited sandstone, shale, and limestone (shown in brown and blue). These sedimentary units contain trilobites and other fossils of early and middle Paleozoic age (Cambrian, Devonian, and Mississippian). Later, the seas left and in several instances formed disconformities within the limestones.

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Observe this stratigraphic section and match the main units and unconformities between the section and the photographs

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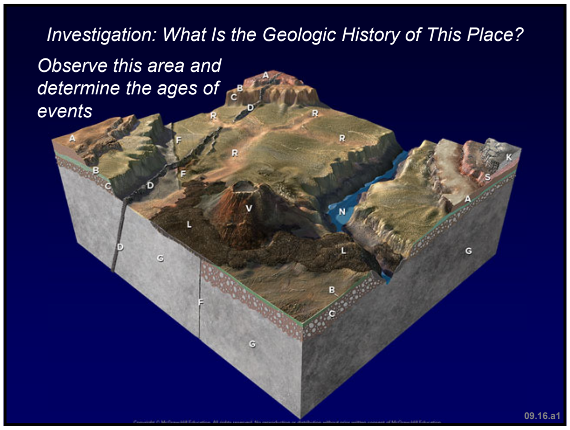
Investigation: What Is the Geologic History of This Place?
Observe this area and determine the ages of events
09.16.a1