Earth History

Earth History

8.E.2 Understand the history of Earth and its life forms based on evidence of change recorded in fossil records and landforms.

8.E.2.1 Infer the age of Earth and relative age of rocks and fossils from index fossils and ordering of rock layers (relative dating and radioactive dating).

8.E.2.2 Explain the use of fossils, ice cores, composition of sedimentary rocks, faults, and igneous rock formations found in rock layers as evidence of the history of the Earth and its changing life forms.

Been There, Done That

What is the principle of uniformitarianism?

- The principle of **uniformitarianism** states that geologic processes that happened in the past can be explained by current geologic processes.

- Most geologic change is slow and gradual, but sudden changes have also affected Earth's history.

How do organisms become preserved as fossils?

- **Fossils** are the traces or remains of organisms that lived long ago.

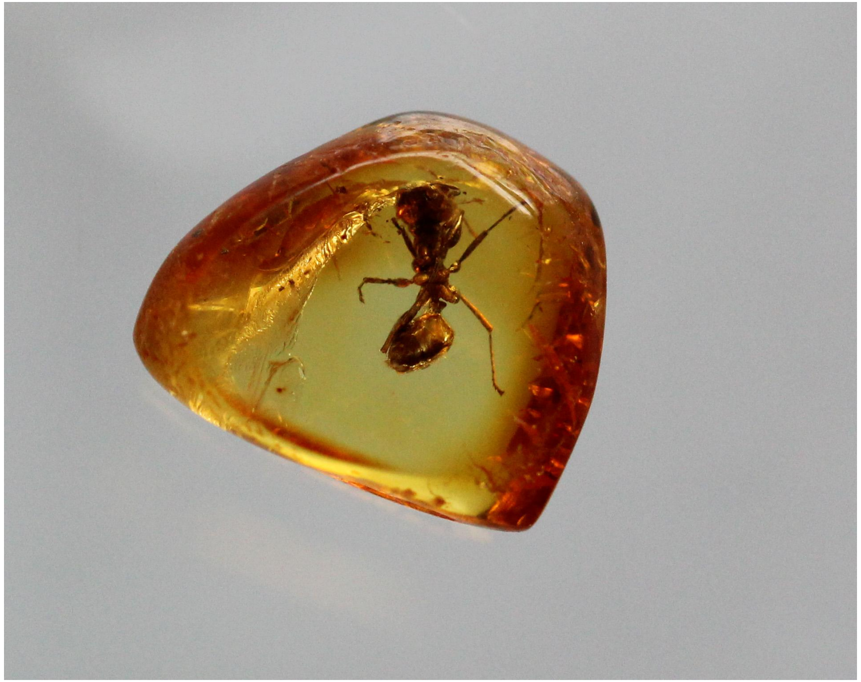
- Fossils may be skeletons or body parts, shells, burrows, or ancient coral reefs.

- Fossils form in many different ways.

How do organisms become preserved as fossils?

- Fossils can form in amber, which is formed when hardened tree sap is buried and preserved in sediment.

- In some places, asphalt wells up at Earth's surface in thick, sticky pools. These pools have trapped and preserved many fossils.



How do organisms become preserved as fossils?

- Fossils can be found buried in rock. This can happen if the organism is buried before it decays, and over time, the sediment hardens into rock.

- In very cold places, fossils can also be frozen. Because low temperatures slow decay, frozen fossils are preserved for thousands of years.

- Dead organisms may become petrified. Petrification happens when an organism’s tissues are replaced by minerals.

What are trace fossils?

- A **trace fossil** is a fossilized structure that formed in sedimentary rock by animal activity on or in soft sediment.

- Trace fossils give evidence about how some animals behaved.

- Trace fossils include tracks, burrows, and even animal dung called coprolite.

Time Is on Our Side

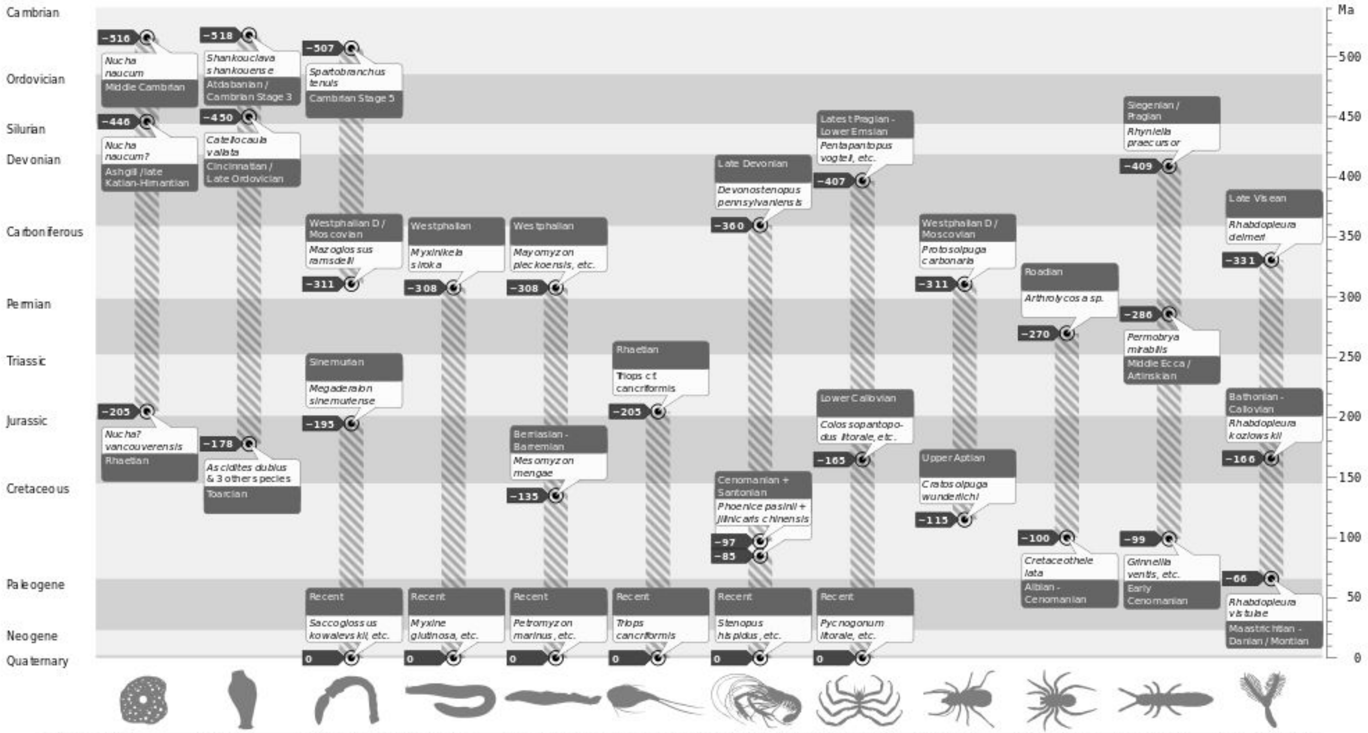
What can fossils tell us?

- The *fossil record*, made of all the fossils that have been discovered, shows part of the history of life on Earth.

- The types of fossils preserved in a rock can tell scientists about how the environment changes over time.

- Fossils can also tell scientists how life forms have changed over time.

EXAMPLES OF **GAPS** (AS OF AUGUST 2015) WITHIN THE **FOSSIL RECORD** OF DELICATE AND **SOFT-BODIED** ANIMALS



NAME	*Nucha*	Tunicata	Enteropneusta	Myxinidae	Petromyzontiformes	*Triops cancriformis*	Stenopodidea	Pycnogonida	Solifugae	Mesothelae	Collembola	*Rhabdopleura*
SIZE	~ 1.5 - 6 mm	~ 0.5 - 10 cm	~ 0.1 - 2.5 m	~ 5 - 125 cm	~ 0.1 - 1 m	~ 6 - 11 cm	~ 1.5 - 8 cm	~ 0.1 - 90 cm	~ 0.6 - 15 cm	~ 11 - 35 mm	~ 0.12 - 17 mm	~ 0.5 - 2 mm
TYPE	genus	subphylum	class	family	order	species	infraorder	class	order	suborder	subclass	genus
INFO	sponge (order Octactinellida)	sac-like marine invertebrates	acorn worm, marine invertebr.	slime eels, hagfish	lamprey eels, jawless fish	horseshoe / tadpole shrimp	lobster-like decapods	sea spiders, marine arthropods	camel spiders, windscorpions	solifugid-like spiders	springtails, hexapods	worm-shaped aquatic animals
GAPS	**c. 70 Myr & c. 241 Myr**	**c. 68 Myr & c. 272 Myr**	**c. 196 Myr & c. 195 Myr**	**c. 308 Myr**	**c. 173 Myr & c. 135 Myr**	**c. 205 Myr**	**c. 263 Myr & c. 85 Myr**	**c. 232 Myr & c. 165 Myr**	**c. 196 Myr**	**c. 170 Myr**	**c. 123 Myr & c. 187 Myr**	**c. 165 Myr & c. 100 Myr**

How does sedimentary rock show Earth’s history?

- Sediment is deposited in layers that can become compacted and cemented together as sedimentary rock.

- Scientists study sedimentary rock to find evidence of the environment that the rock formed in.

How does sedimentary rock show Earth's history?

- The composition shows the source of the sediment that makes up a sedimentary rock.

- The texture, or size of the sediment making up a sedimentary rock, shows the environment in which the sediment was carried and deposited.

- Features, such as *ripple marks* and *mud cracks*, show the motion or stillness of the water where the sediment was deposited.

What do Earth’s surface features tell us?

- Earth’s surface is always changing.
- Today’s continents were once part of a landmass called *Pangaea*.
- Pangaea broke apart about 200 million years ago. Since then, the continents have been slowly moving to their present locations.

What do Earth’s surface features tell us?

- The distribution of rocks, fossils, and mountains on Earth’s surface is evidence for plate motion.

- The movement of tectonic plates has resulted in extraordinary events, such as volcanic eruptions, earthquakes, and the formation of mountain ranges.

- Other forces, such as weathering and erosion, act to break down Earth’s surface features.

Back to the Future

What other materials tell us about Earth's climate history?

- The **climate** of an area describes the weather conditions in the area over a long period of time.

- Scientists analyze fossils and other materials to learn how Earth's climate has changed over time.

- Scientists can use the thickness of tree rings to learn about the climate during the life of a tree.

What other materials tell us about Earth's climate history?

- Sea floor sediments contain fossil remains of microscopic organisms that built up in layers.

- These microorganisms can give information about the climate at a certain time.

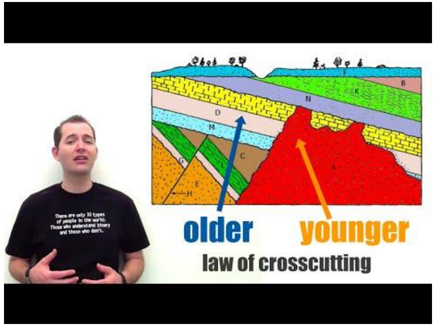
- The chemical composition of sediments can show the composition of the ocean water and atmosphere when the organisms were alive.

What other materials tell us about Earth's climate history?

- Scientists drill into icecaps to collect **ice cores**, which are long cylinders of ice.

- Ice cores give a history of the precipitation and concentration of gases in the atmosphere.

Who’s First?



What is relative dating?

- Scientists try to find out the order in which events happened during Earth’s history.

- They use rocks and fossils for **relative dating**, determining whether an object or event is older or younger than other objects or events.

- Scientists use different pieces of information about rocks to determine the relative age of each rock layer.

How are undisturbed rock layers dated?

- Sedimentary rocks form when new sediments are deposited in horizontal layers on top of older rock.

- Over time, the layers pile up, with younger layers piling on top of older ones.

How are undisturbed rock layers dated?

- Scientists use the order of rock layers to date the rock in each layer.

- The law of **superposition** is the principle that states that younger rocks lie above older rocks if the layers have not been disturbed.

How Disturbing!

How are sedimentary rock layers disturbed?

- Forces in Earth can disturb rock layers in various ways.

- *Tilting* happens when Earth’s forces move rock layers up or down unevenly. The layers become slanted.

- *Folding* is the bending of rocks that can happen when rock layers are squeezed together. Older layers may end up on top of younger layers.

How are sedimentary rock layers disturbed?

- Features such as faults and intrusions can cut across existing layers of rock.

- A *fault* is a break or crack in Earth’s crust where rocks can move.

- An *intrusion* is igneous rock that forms when magma is injected into rock and then cools and becomes hard.

How are sedimentary rock layers disturbed?

- Finding the relative ages of rock layers can be even more complicated when an entire layer of rock is missing.

- A missing layer of rock is called an **unconformity**. It forms a gap in the geologic record.

- An unconformity is formed when rock layers are eroded or when sediment is not deposited for a long time.

I'm Cutting In!

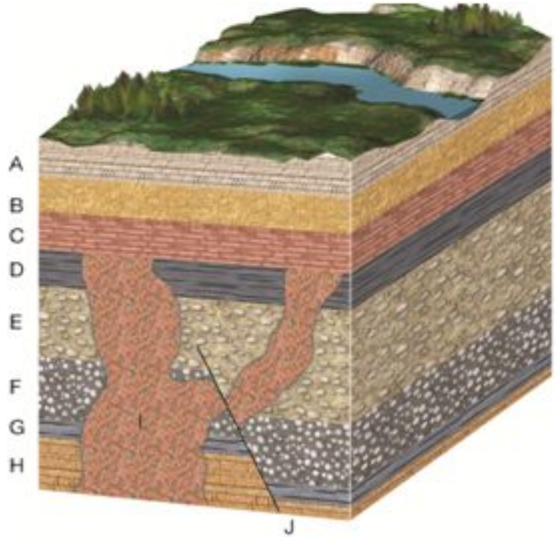
How are rock layers ordered?

- The law of crosscutting relationships states that a fault or a body of rock, such as an intrusion, must be younger than any feature or layer of rock that the fault or rock body cuts through.

- The law of superposition and the law of crosscutting relationships help scientists figure out how rock layers formed.

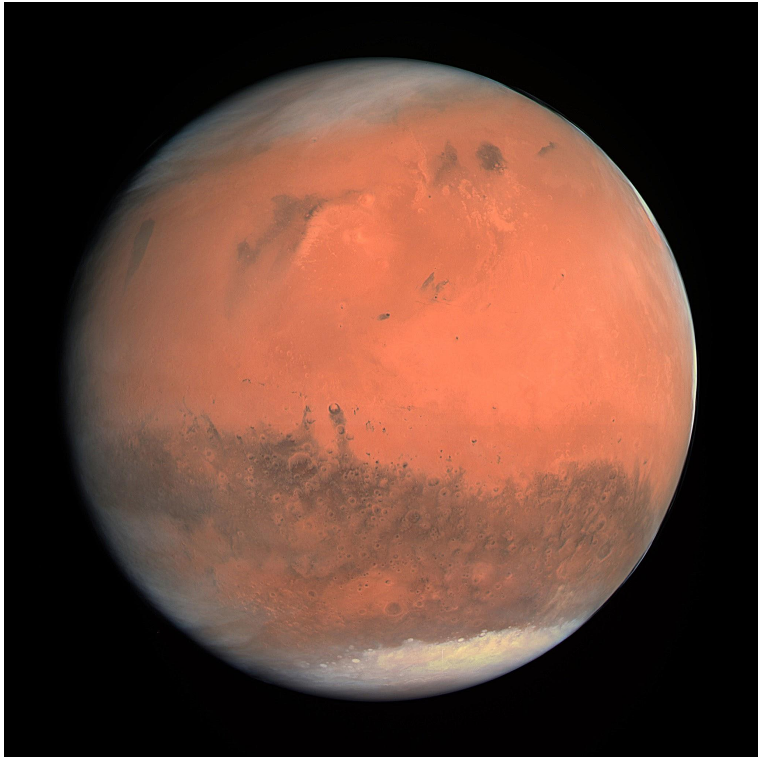
How are rock layers ordered?

- Using the laws of superposition and crosscutting relationships, determine the relative ages of rock layers and features in the image below.



Dating Mars

- The laws of superposition and crosscutting relationships are used to find the relative ages of features on Mars.
- A crater that cuts into another crater is the newer crater.
- A crater that is cut by another feature, such as a fracture, is older than the other feature.



So Far Away

How are fossils used to determine relative ages of rocks?

- **Fossils** are the traces or remains of an organism that lived long ago.

- Scientists can classify fossils based on changes over time, and they can use that classification to find the relative ages of rocks.

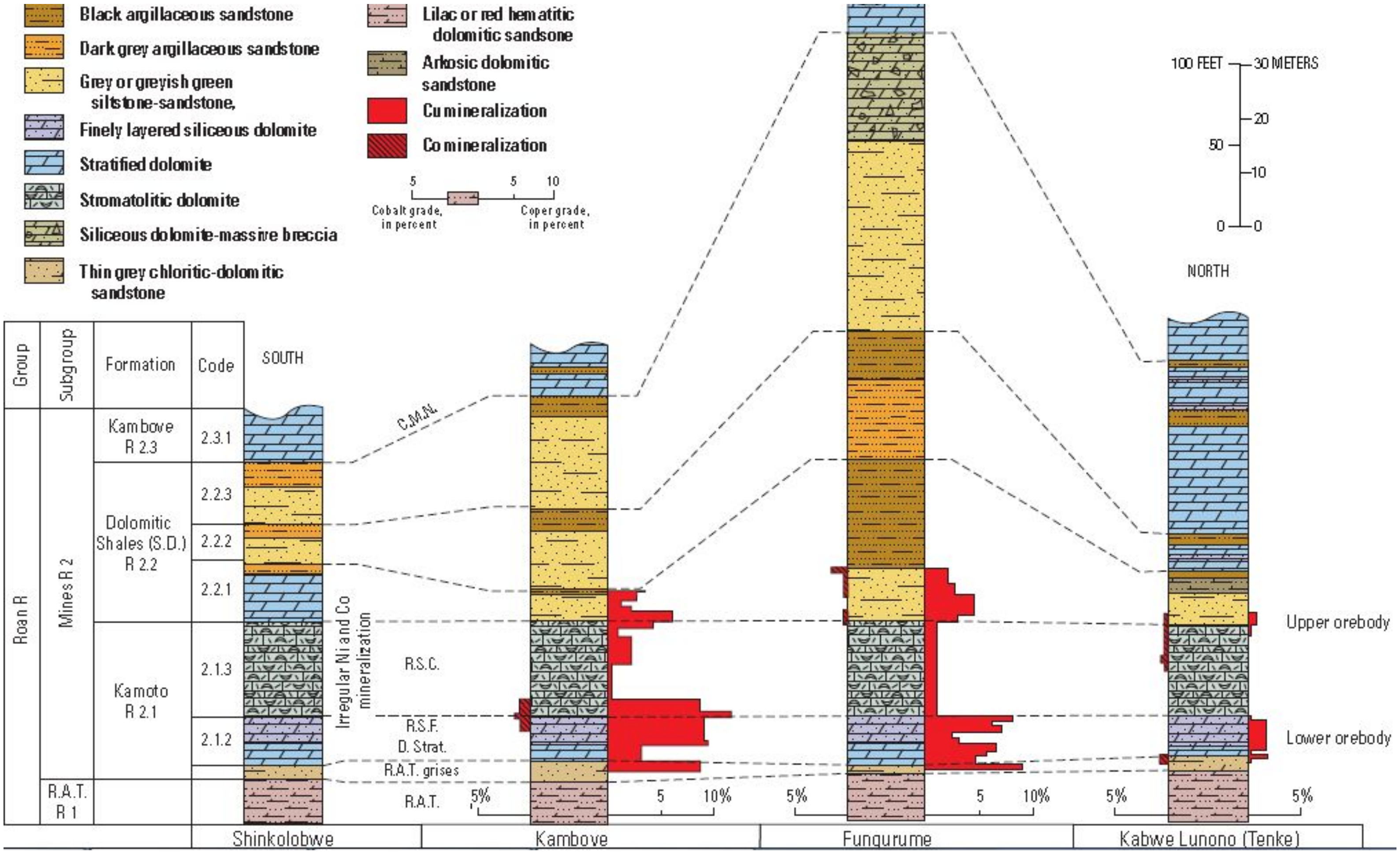
- Rocks containing fossils of organisms similar to those alive today are most likely younger than rocks containing fossils of more primitive organisms.

How are geologic columns used to compare relative ages of rocks?

- Relative dating can also be done by comparing the relative ages of rock layers in different areas.

- A **geologic column** is an ordered arrangement of rock layers based on the relative ages of the rocks, with the oldest rocks at the bottom.

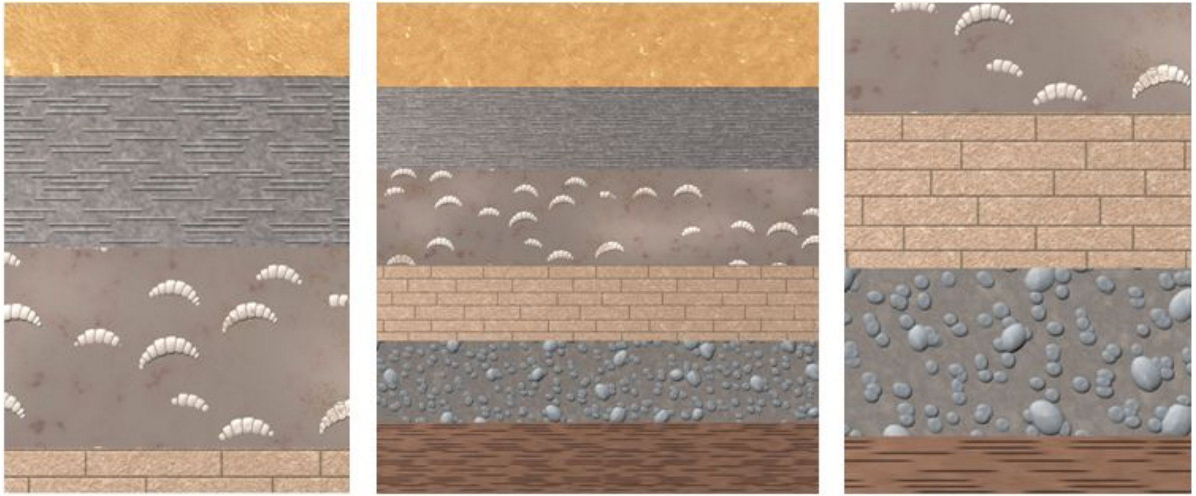
- Scientists develop geologic columns to piece together the geologic record of a large area.



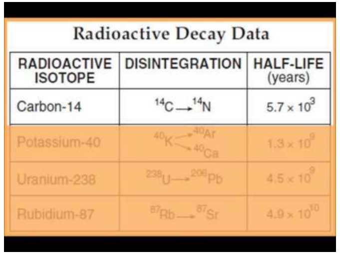
Black argillaceous sandstone
Dark grey argillaceous sandstone
Grey or greyish green siltstone-sandstone,
Finely layered siliceous dolomite
Stratified dolomite
Stromatolitic dolomite
Siliceous dolomite-massive breccia
Thin grey chloritic-dolomitic sandstone
Lilac or red hematitic dolomitic sandsone
Arkosic dolomitic sandstone
Cu mineralization
Co mineralization
5
5
10
Cobalt grade, in percent
Coper grade, in percent
100 FEET
30 METERS
20
50
10
0
0
NORTH
SOUTH
Group
Subgroup
Formation
Code
Roan R
Mines R 2
R.A.T. R 1
Kambove R 2.3
Dolomitic Shales (S.D.) R 2.2
Kamoto R 2.1
2.3.1
2.2.3
2.2.2
2.2.1
2.1.3
2.1.2
C.M.N.
Irregular Ni and Co mineralization
R.S.C.
R.S.F.
D. Strat.
R.A.T. grises
R.A.T.
5%
5
10%
Upper orebody
Lower orebody
Shinkolobwe
Kambove
Fungurume
Kabwe Lunono (Tenke)

How are geologic columns used to compare relative ages of rocks?

- Scientists can compare the rock layers of different places with similar layers in the geologic column. Two layers that match probably formed around the same time.



It’s About Time!


Radioactive Decay Data

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

How can the absolute age of rock be determined?

- Determining the actual age of an event or object in years is called **absolute dating**.

- Scientists often use radioactive isotopes to find the absolute age of rocks and other materials.

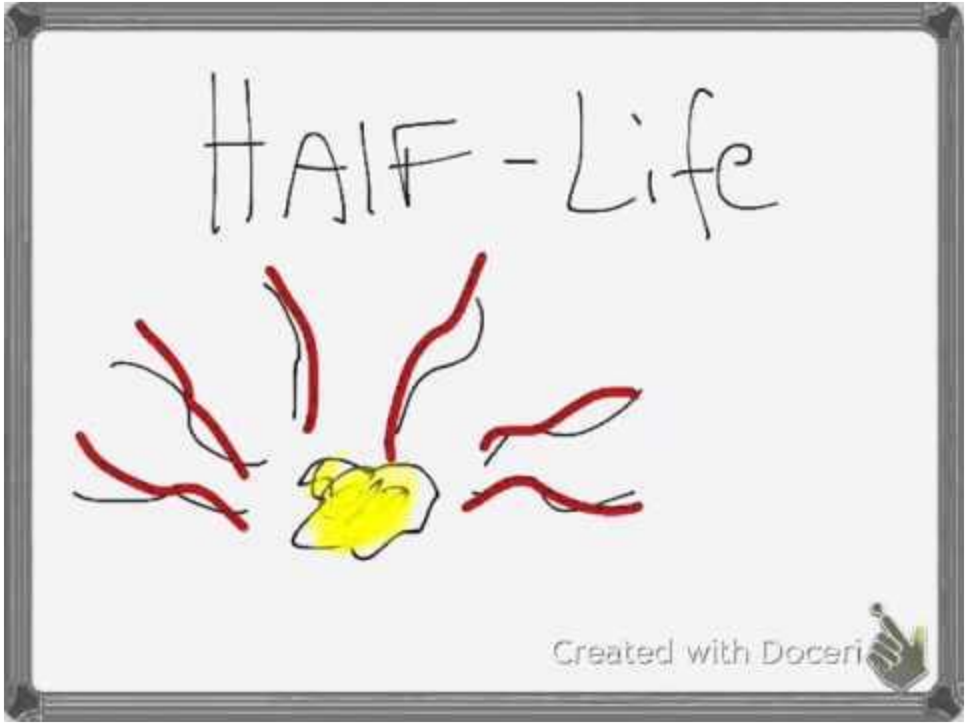
- Atoms of the same element that have a different number of neutrons are called isotopes.

How can the absolute age of rock be determined?

- Radioactive isotopes are isotopes that are unstable and break down into other isotopes by a process called **radioactive decay**.

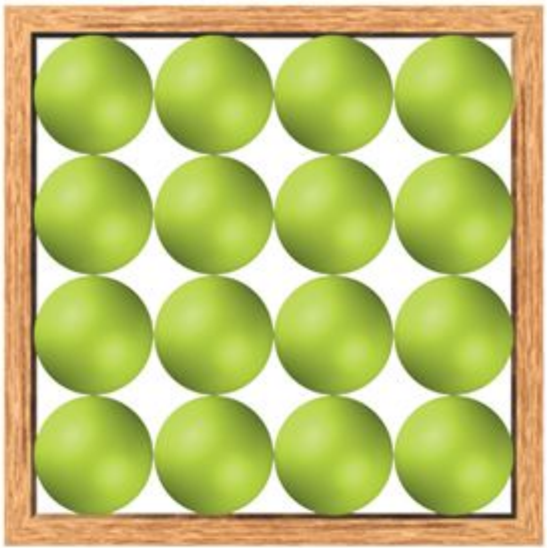
- The radioactive isotope is called the *parent isotope*, and the stable isotope formed by its breakdown is called the *daughter isotope*.

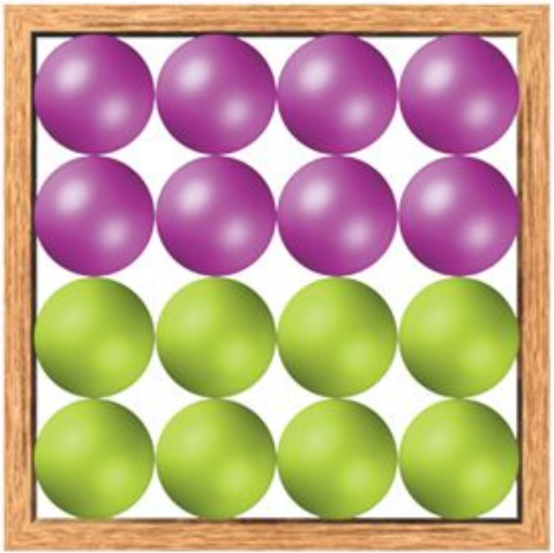
- **Half-life** is the time needed for half of a sample of a radioactive element to undergo radioactive decay and form daughter isotopes.



How can the absolute age of rock be determined?

- After one half-life has passed, one-half of the parent isotope has changed into daughter isotopes.





How can the absolute age of rock be determined?

- Scientists study the amounts of parent and daughter isotopes to date samples.

- Finding the absolute age of a sample by determining the relative percentages of a radioactive parent isotope and a stable daughter isotope is called **radiometric dating**.

What is the best rock for radiometric dating?

- Igneous rocks are the best types of rock samples to use for radiometric dating.

- When igneous rocks form, minerals in them often contain only a parent isotope and none of the daughter isotope.

- This makes the isotope percentages easier to interpret and helps dating to be more accurate.

Time for a Change

What are some radiometric dating methods?

- Scientists use many different isotopes for radiometric dating.
- The type of isotope used depends on the type of material being dated.
- The half-life of the isotope used is also very important. It can’t be too short or too long compared to the age of the sample.

What are some radiometric dating methods?

- Radiocarbon dating is a method used for dating wood, bones, shells, and other organic remains.

- All living things have a constant ratio of radioactive carbon-14 to carbon-12.

- Once a plant or an animal dies, no more carbon is taken in. The ratio between the isotopes changes because carbon-14 undergoes radioactive decay.

What are some radiometric dating methods?

- The half-life of carbon-14 is 5,730 years. The number of half-lives of carbon-14 that have passed gives the absolute age.

- Radiocarbon dating can be used to date organic matter only.

- This method is used to date things that lived in the last 45,000 years.

What are some radiometric dating methods?

- Potassium-argon dating is often used to date igneous volcanic rocks that are 100,000 years to billions of years old.

- Uranium-lead dating is based on measuring the amount of the lead-206 daughter isotope in a sample.

- Uranium-lead dating can be used to determine the age of igneous rocks that are between 100 million years and a few billion years old.

Time Will Tell

How is radiometric dating used to determine the age of Earth?

- Radiometric dating can be used to find the age of Earth. But there are no Earth rocks which can be directly studied that are as old as our planet.

- Meteorites are small, rocky bodies that have fallen from space to Earth's surface. They are the same age as the solar system, including Earth.

- The absolute age of meteorites and other rocks in the solar system is about 4.6 billion years.

Showing Your Age

How can fossils help to determine the age of sedimentary rock?

- Sedimentary rock layers and the fossils within them cannot be dated directly.

- But igneous rock layers on either side of a fossil layer can be dated radiometrically.

- Once the older and younger rock layers are dated, scientists can assign an absolute age range to the sedimentary rock layer containing the fossils.

How can fossils help to determine the age of sedimentary rock?

- *Index fossils* are fossils used to estimate the absolute age of the rock layers in which they are found.

- Once the absolute age of an index fossil is known, it can be used to determine the age of rock layers containing the same fossil anywhere on Earth.

How can fossils help to determine the age of sedimentary rock?

- To be an index fossil, the organism from which it formed must have lived during a relatively short geologic time span.

- Index fossils must be relatively common and must be found over a large area.

- Index fossils must also have features that make them different from other fossils.

How are index fossils used?

- Index fossils act as markers for the time that the organisms were alive on Earth.

- Index fossils can also be used to date rocks in separate areas.

- The appearance of the same index fossil in rock of different areas shows that the rock layers formed at about the same time.

Once Upon a Time

How have geologists described the rate of geologic change?

- **Geology** is the scientific study of the origin, history, and structure of Earth and the processes that shape it.

- Early geologists proposed different ideas to explain how Earth changes over time.

How have geologists described the rate of geologic change?

- Some early scientists used catastrophism to explain geologic changes on Earth.

- *Catastrophism* is the principle that states that all geologic change occurs suddenly.

- Supporters of catastrophism thought that Earth’s features, such as mountains and seas, formed during sudden events called catastrophes.

How have geologists described the rate of geologic change?

- About 250 years ago, James Hutton established a principle that is now known as uniformitarianism.

- *Uniformitarianism* is the idea that the same geologic processes that shape Earth today have been at work throughout Earth's history.

- The principle also states that the average rate of geologic change is slow and has remained relatively constant over time.

How have geologists described the rate of geologic change?

- Today, geologists realize that neither uniformitarianism nor catastrophism accounts for all geologic change.

- While most geologic change is gradual and uniform, catastrophes do cause some geologic change.

- For example, earthquakes, floods, volcanic eruptions, and asteroid impacts can cause sudden changes to Earth’s surface.

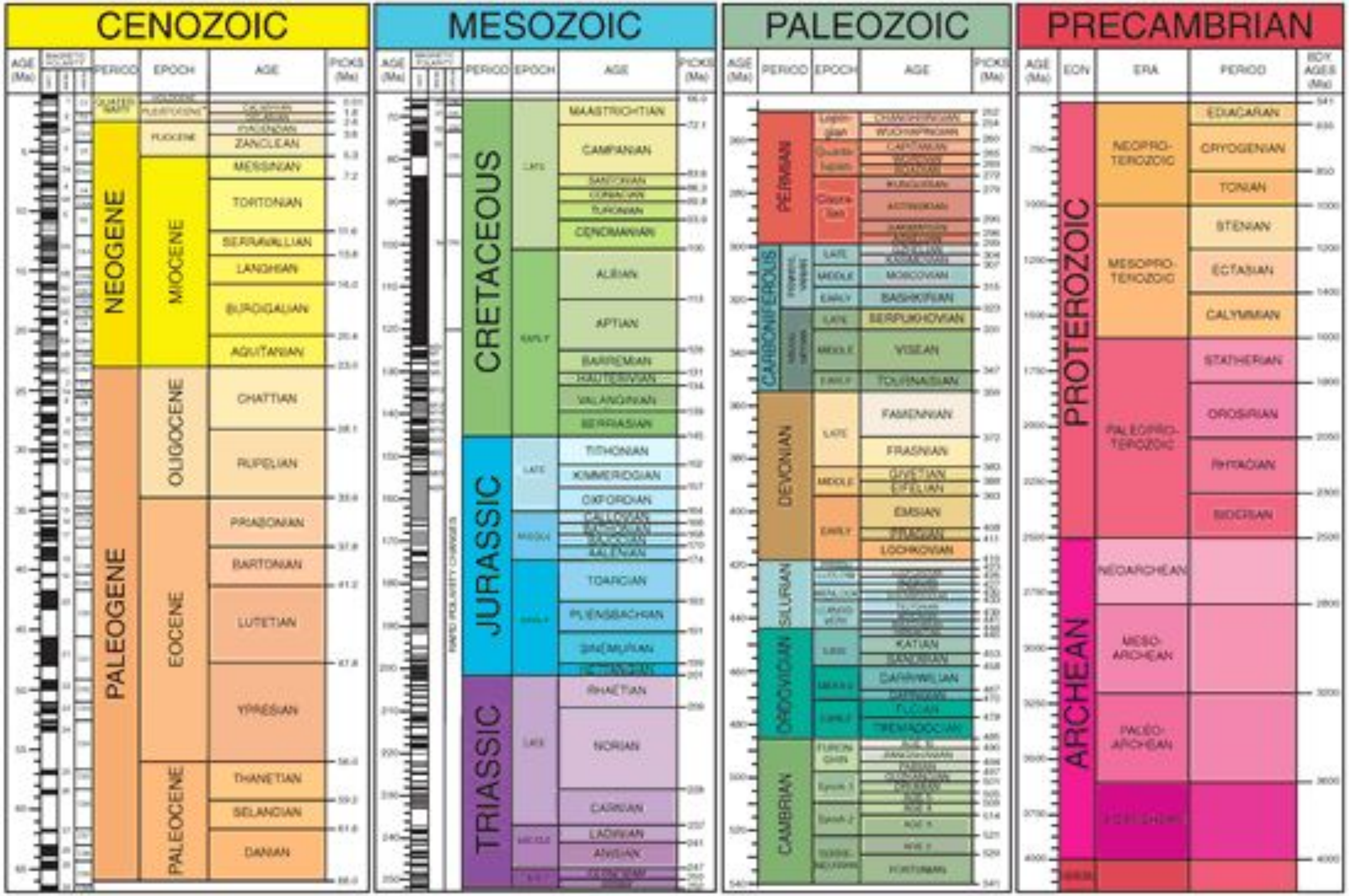
It's About Time

How do geologists use the geologic time scale?

- The **geologic time scale** divides Earth's geologic history into intervals of time defined by major events or changes on Earth.

- The largest unit of geologic time is an *eon*.

- Earth's 4.6-billion-year history is divided into four eons: the Hadean, Archean, Proterozoic, and Phanerozoic.



CENOZOIC
MESOZOIC
PALEOZOIC
PRECAMBRIAN
AGE (Ma)
PERIOD
EPOCH
AGE
PICKS (Ma)
EON
ERA
BDY. AGES (Ma)
NEOGENE
PALEOGENE
PLIOCENE
MIOCENE
OLIGOCENE
EOCENE
PALEOCENE
ZANCLEAN
MESSINIAN
TORTONIAN
SERRAVALLIAN
LANGHIAN
BURDIGALIAN
AQUITANIAN
CHATTIAN
RUPELIAN
PRIABONIAN
BARTONIAN
LUTETIAN
YPRESIAN
THANETIAN
SELANDIAN
DANIAN
CRETACEOUS
JURASSIC
TRIASSIC
LATE
EARLY
MIDDLE
MAASTRICHTIAN
CAMPANIAN
SANTONIAN
CONIACIAN
TURONIAN
CENOMANIAN
ALBIAN
APTIAN
BARREMIAN
HAUTERIVIAN
VALANGINIAN
BERRIASIAN
TITHONIAN
KIMMERIDGIAN
OXFORDIAN
CALLOVIAN
BAJOCIAN
AALENIAN
TOARCIAN
PLIENSBACHIAN
SINEMURIAN
HETTANGIAN
RHAETIAN
NORIAN
CARNIAN
LADINIAN
ANISIAN
RAPID POLARITY CHANGES
PERMIAN
CARBONIFEROUS
DEVONIAN
SILURIAN
ORDOVICIAN
CAMBRIAN
CHANGHSINGIAN
WUCHIAPINGIAN
CAPITANIAN
KUNGURIAN
ARTINSKIAN
MOSCOVIAN
BASHKIRIAN
SERPUKHOVIAN
VISEAN
TOURNAISIAN
FAMENNIAN
FRASNIAN
GIVETIAN
EIFELIAN
EMSIAN
PRAGIAN
LOCHKOVIAN
KATIAN
SANDBIAN
DARRIWILIAN
DAPINGIAN
FLOIAN
TREMADOCIAN
FORTUNIAN
PROTEROZOIC
ARCHEAN
NEOPRO-TEROZOIC
MESOPRO-TEROZOIC
PALEOPRO-TEROZOIC
NEOARCHEAN
MESO-ARCHEAN
PALEO-ARCHEAN
EDIACARAN
CRYOGENIAN
TONIAN
STENIAN
ECTASIAN
CALYMMIAN
STATHERIAN
OROSIRIAN
RHYACIAN
SIDERIAN

How do geologists use the geologic time scale?

- The Hadean, Archean, and Proterozoic eons together are called *Precambrian time*.
- Precambrian time makes up almost 90 percent of Earth’s history.
- Eons may be divided into smaller units of time called *eras*.

How do geologists use the geologic time scale?

- The Phanerozoic Eon, the present eon, is divided into three eras: the Paleozoic, Mesozoic, and Cenozoic.

- Each era is subdivided into a number of *periods*.

- The periods of the Cenozoic, the present era, are further divided into *epochs*.

How do geologists use the geologic time scale?

- Many divisions of the geologic time scale are based on events in Earth's geologic history.
- Some divisions are based entirely on the fossil record.
- At least five divisions of geologic time have ended in large mass extinction events.

How do geologists use the geologic time scale?

- The Cenozoic Era is only a tiny fraction of Earth's geologic history.

Time After Time … After Time

What were some defining events of Precambrian time?

- Precambrian time began with the formation of Earth about 4.6 billion years ago.

- Massive supercontinents, the first oceans, and the early atmosphere formed during this time.

- Toward the end of Precambrian time, much of Earth's land surfaces were located near the poles and covered in ice.

What were some defining events of the Paleozoic Era?

- The Paleozoic Era began about 540 million years ago. The supercontinent Pannotia was breaking up and the supercontinent Pangaea began forming.

- Life diversified quickly and dramatically during the Cambrian Explosion, during which most major groups of organisms first evolved.

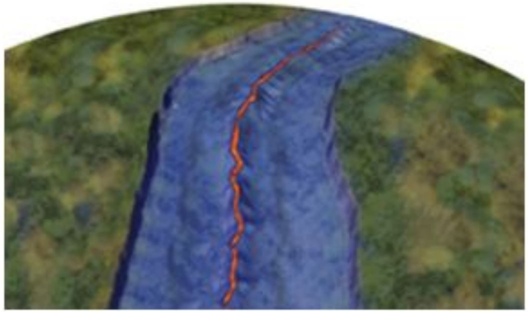
- The era ended about 250 million years ago with a huge mass extinction event.

What were some defining events of the Paleozoic Era?

- During the Cambrian Explosion, new species evolved rapidly in Earth's shallow seas.

What were some defining events of the Mesozoic Era?

- During the Mesozoic Era, which began about 250 million years ago, Pangaea began breaking up.
- The Atlantic Ocean began to open up, the Mid-Atlantic Ridge formed, sea levels rose, and shallow seas covered much of the land.



What were some defining events of the Mesozoic Era?

- Along the western edge of North America, tectonic activity began to fold Earth’s crust, forming mountains. The climate was likely warm, as periods of heavy volcanism added carbon dioxide to the atmosphere.

- Life during the Mesozoic was dominated by dinosaurs. The few mammals were very small.

- A mass extinction event about 65 million years ago marked the end of the era, and the end of dinosaurs.

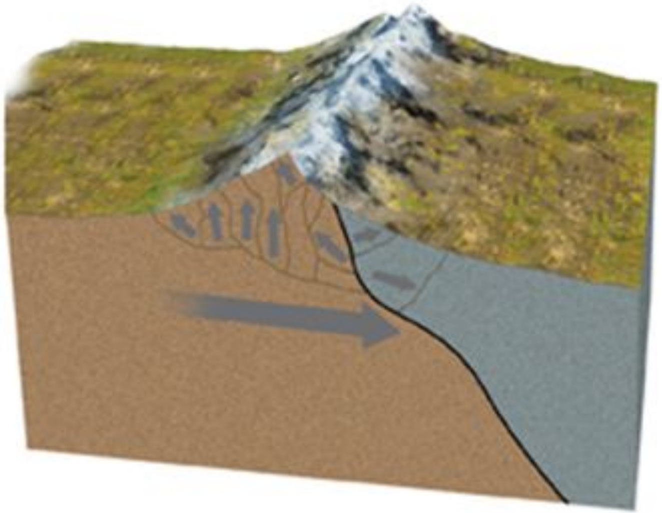
What have been some defining events of the Cenozoic Era?

- The Cenozoic Era began about 65 million years ago with the Cretaceous mass extinction and continues to the present.

- Greenland split apart from North America and Europe, and the continents assumed their current positions.

What have been some defining events of the Cenozoic Era?

- The Indian subcontinent collided with Eurasia to form the Himalayas. The collision of Africa and Europe resulted in the Alps.



What have been some defining events of the Cenozoic Era?

- The Cenozoic Era is divided into two periods: the Tertiary and the Quaternary. The latter stretches from about 2.6 million years ago to the present.

- The Quaternary has been characterized by an ice age, with much of Europe, North America, and Asia having been covered in thick sheets of ice.

- The evolution of modern humans occurred during the late Quaternary.