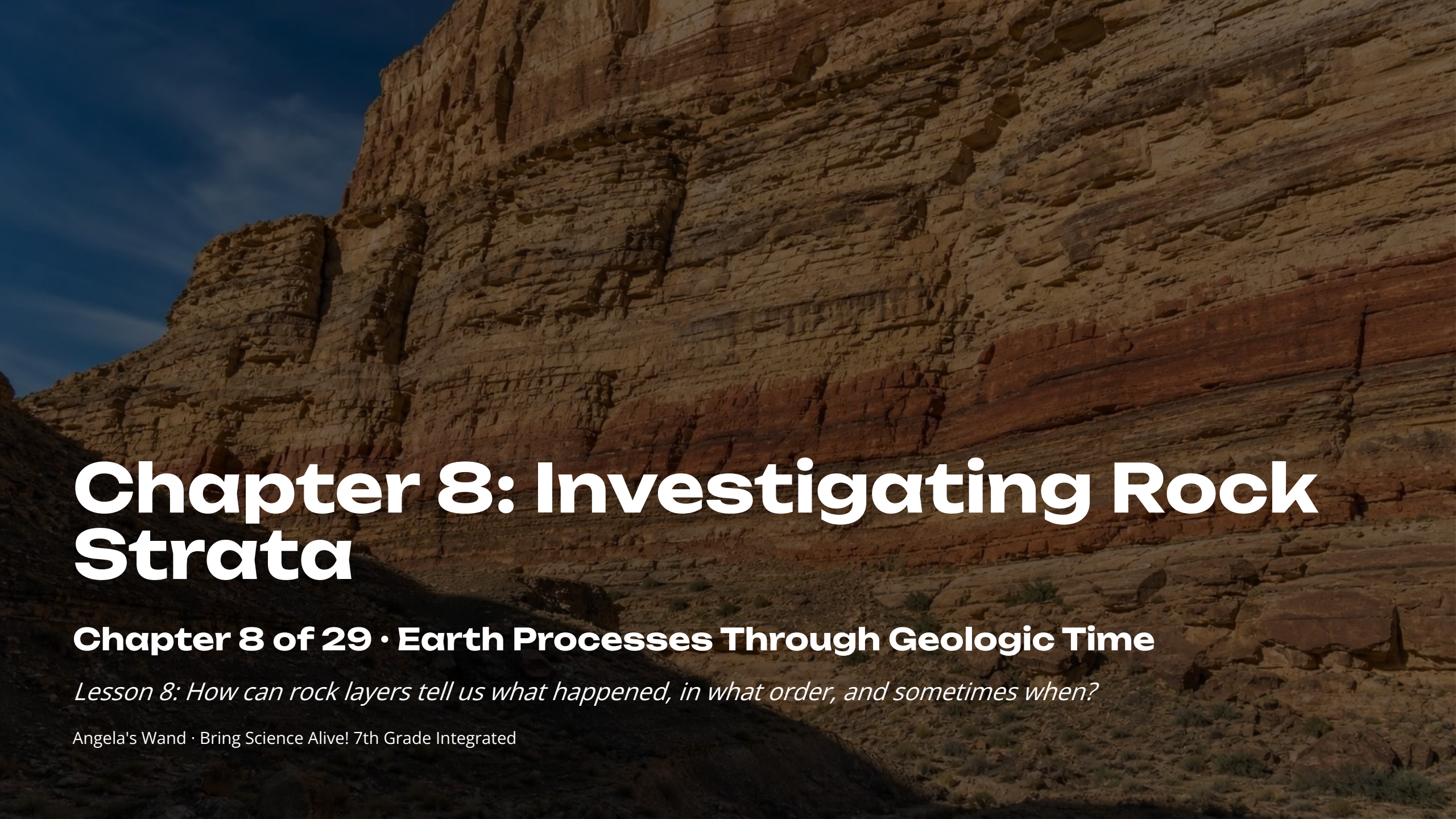




Chapter 8: Investigating Rock Strata

Chapter 8 of 29 • Earth Processes Through Geologic Time

Lesson 8: How can rock layers tell us what happened, in what order, and sometimes when?

Angela's Wand • Bring Science Alive! 7th Grade Integrated

The road cut with a dark stripe

PHENOMENON

A highway crew blasts a fresh wall through a hillside. It shows striped layers of sandstone, shale and limestone, all leaning about 20 degrees. A dark band a meter wide runs diagonally through every layer. Partway along, the layers on the left sit a meter higher than the same layers on the right. Flat river gravel lies across the top, and nothing cuts it. A geologist says she can list the events in order. How?

- Notice: what is tilted, what is flat, what cuts what?
- Wonder: was the dark stripe there before the layers, or after?
- Predict: which part of the wall is oldest, and which is youngest?





What you will be able to do

LEARNING TARGETS

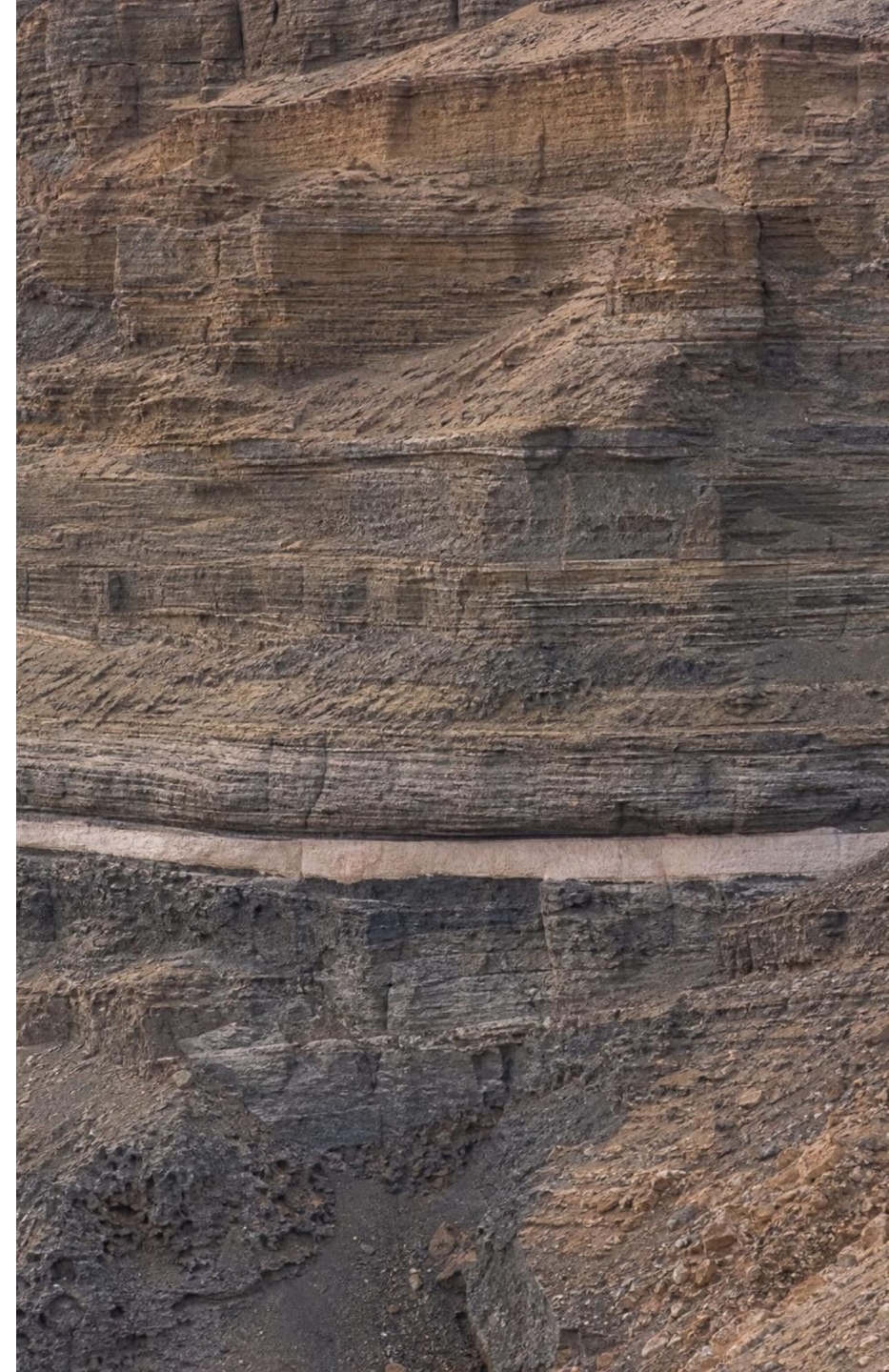
- 1 Use superposition and lateral continuity to tell which layers are older, younger or the same age.
- 2 Show that tilting, folding, faults, intrusions and erosion came after the layers they affect.
- 3 Explain how fossil succession and index fossils match layers in places far apart.
- 4 Use half-life to find an igneous rock's age, and bracket a sedimentary layer between dated ash beds.
- 5 Reconstruct the order of events in a cross section and say what the evidence cannot show.

Two different questions about a rock

Question 1: Which came first?
That is relative dating. The answer is an order.

Question 2: How many years ago? That is absolute dating. The answer is a number with an uncertainty.

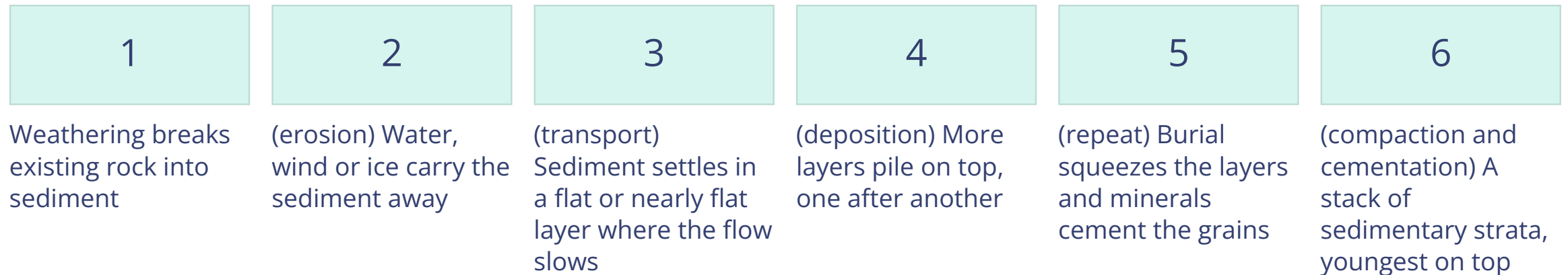
- Relative dating works on any rock you can see the arrangement of; it needs no lab.
- Absolute dating needs igneous minerals with radioactive atoms, and a laboratory.
- Most of Earth's story was worked out in order long before anyone could put years on it.





How one layer of rock comes to exist

MODEL MODEL: FROM OLD ROCK TO A NEW STRATUM



Every rule in this lesson comes from this sequence. Each new layer can only land on whatever is already there.



Superposition: reading an undisturbed stack

MODEL

Model: A stack of layers that has not been tilted, folded or broken

Top to bottom:

River gravel: youngest, deposited last

Limestone with marine shells

Gray shale

Volcanic ash bed

Tan sandstone with ripple marks

Red mudstone: oldest, deposited first

In an undisturbed stack each layer is younger than the one below and older than the one above. Age increases downward.

Three words to keep straight

VOCABULARY IN CONTEXT

strata: Layers of rock, usually sedimentary. One layer is a stratum. *The quarry wall shows nine strata; the fourth stratum from the bottom is limestone.*

relative dating: Working out the order of rocks and events without giving ages in years. *The dike is younger than the shale: that is a relative date.*

absolute dating: Finding an approximate age in years, with an uncertainty, usually from radioactive atoms in igneous minerals. *The ash bed is 150 million years old, give or take two million.*





Quick check: read the stack

CHECK FOR UNDERSTANDING

A cliff shows, from top to bottom: gravel, limestone, shale, sandstone. The layers are flat and unbroken. Which statement must be true?

- A. The sandstone is the oldest layer and the gravel is the youngest.
- B. The gravel is the oldest because it is loose and not yet rock.
- C. The limestone and the shale are the same age because they touch.
- D. You cannot tell the order without a laboratory date.

Lateral continuity: matching layers across a gap

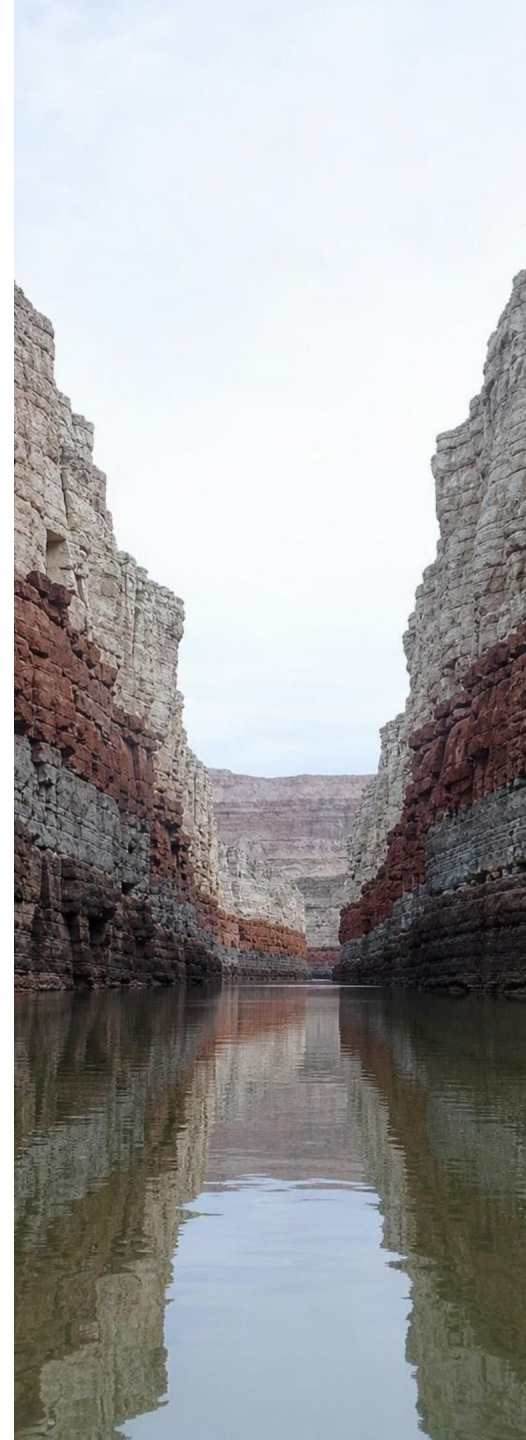
Model/Model: Two canyon walls, one original stack

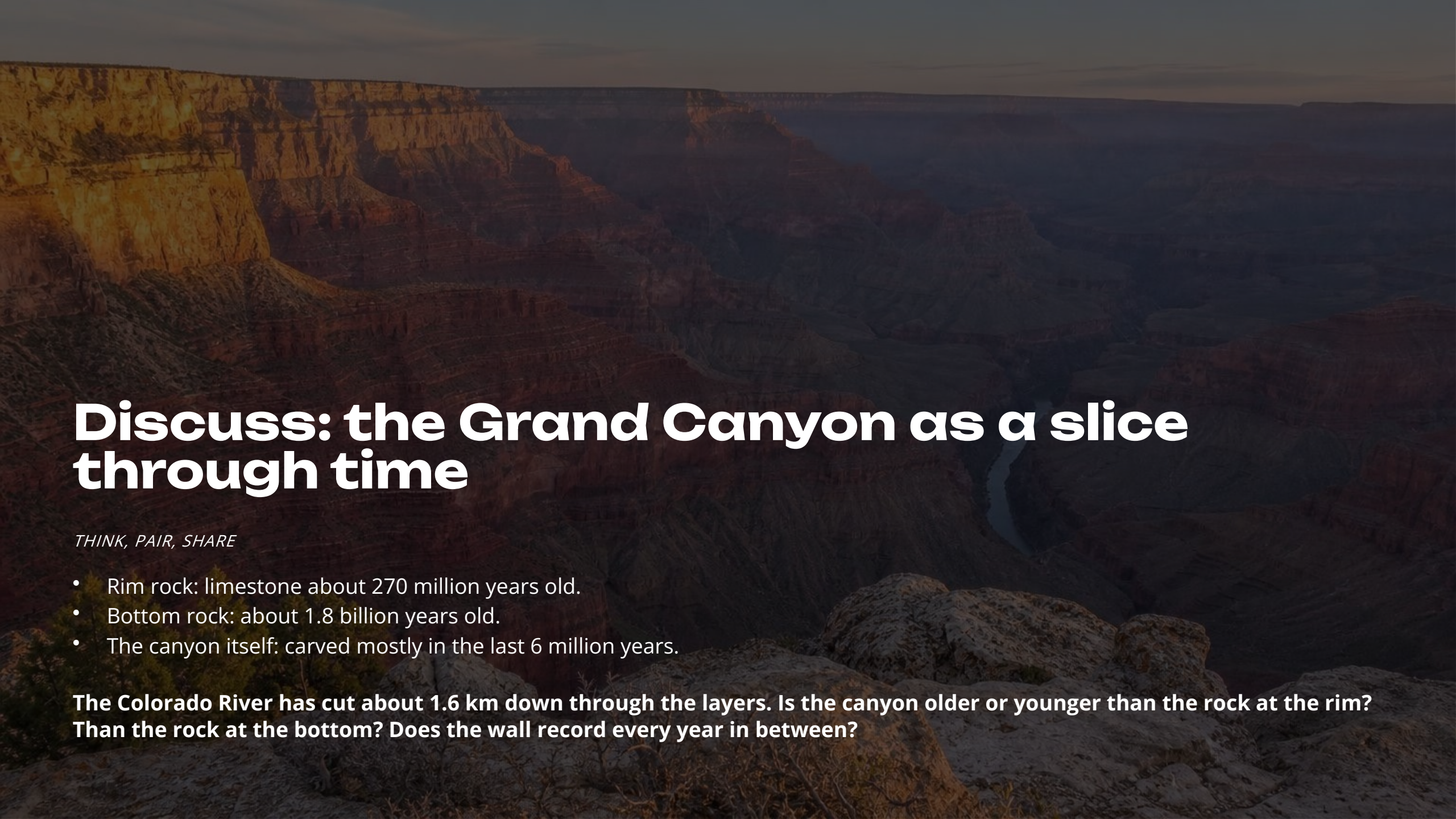
West wall, top to bottom: Pale limestone 4 m, red sandstone 10 m, gray shale 6 m, dark sandstone 8 m.

East wall, top to bottom: Pale limestone 4 m, red sandstone 10 m, gray shale 6 m, dark sandstone 8 m. Same rocks, same thicknesses, same order.

- **The gap between them:** A river has been carrying the missing rock away as sediment for a long time.
- **What the match tells you:** Each layer once stretched across the gap as one continuous sheet, so matching layers on both walls are the same age.
- **What the gap tells you:** The canyon cut through all four layers, so the canyon is younger than every one of them.
- **A caution:** Only matching layers count: same rock, same thickness, same position in the sequence. A pale limestone on one wall and a pale sandstone on the other do not match.

Sediment spreads sideways until it thins out or meets a barrier. Erosion later removes pieces, but the pieces still match.





Discuss: the Grand Canyon as a slice through time

THINK, PAIR, SHARE

- Rim rock: limestone about 270 million years old.
- Bottom rock: about 1.8 billion years old.
- The canyon itself: carved mostly in the last 6 million years.

The Colorado River has cut about 1.6 km down through the layers. Is the canyon older or younger than the rock at the rim? Than the rock at the bottom? Does the wall record every year in between?

Layers that tipped: original horizontality

Gravity settles sediment into flat or nearly flat layers. So when you find layers standing at 30, 60 or 90 degrees, or bent into arches, you know two things in order: the layers formed first, flat, and something tilted or folded them afterward. The something is almost always the slow squeeze of tectonic plates, which can bend solid rock over millions of years the way a thick rug wrinkles when you push one end.





From flat to folded: what the shape tells you

Model

Model: A stack of layers under slow tectonic squeezing

1. Layers deposited flat, oldest at the bottom
2. (time) Buried and hardened into rock
3. (pressure) Plates push; the stack tilts as one block
4. (more pressure) Pushing continues; the stack bends into an arch or trough
5. (even more) Extreme folding flips one limb: older rock now lies on top

Work out the fold first, then apply superposition to the layers as they were before folding.



Quick check: tilted layers under flat gravel

CHECK FOR UNDERSTANDING

A wall shows layers tilted 30 degrees. Their upper ends are worn flat, and a bed of flat river gravel lies across them. Which order of events fits the evidence?

- A. Gravel deposited, layers deposited, layers tilted.
- B. Layers deposited flat, layers tilted and their tops eroded, gravel deposited.
- C. Layers deposited already tilted, then gravel deposited.
- D. Layers deposited flat, gravel deposited, both tilted together.

Three rules, three names

VOCABULARY IN CONTEXT

principle of original horizontality: Sediment settles in flat or nearly flat layers, so steep tilting or folding came later. *Layers standing on end in the Mojave were laid down flat in an ancient lake and tipped afterward.*

principle of lateral continuity: A layer spreads sideways until it thins out or meets a barrier, so matching layers across a gap were once one layer. *The same limestone on both rims of a canyon is one sheet the river cut through.*

law of cross-cutting relationships: Anything that cuts through rock, such as an intrusion, a fault or an erosion surface, must be younger than whatever it cuts through. *A dark dike through three layers is younger than all three.*



Features that cut across strata, and the rule for each

Model

Model: Three kinds of cutting feature

Igneous intrusion (dike): Magma pushed into cracks in existing rock and cooled. Younger than every layer it crosses. A dike cannot form in rock that is not there yet.

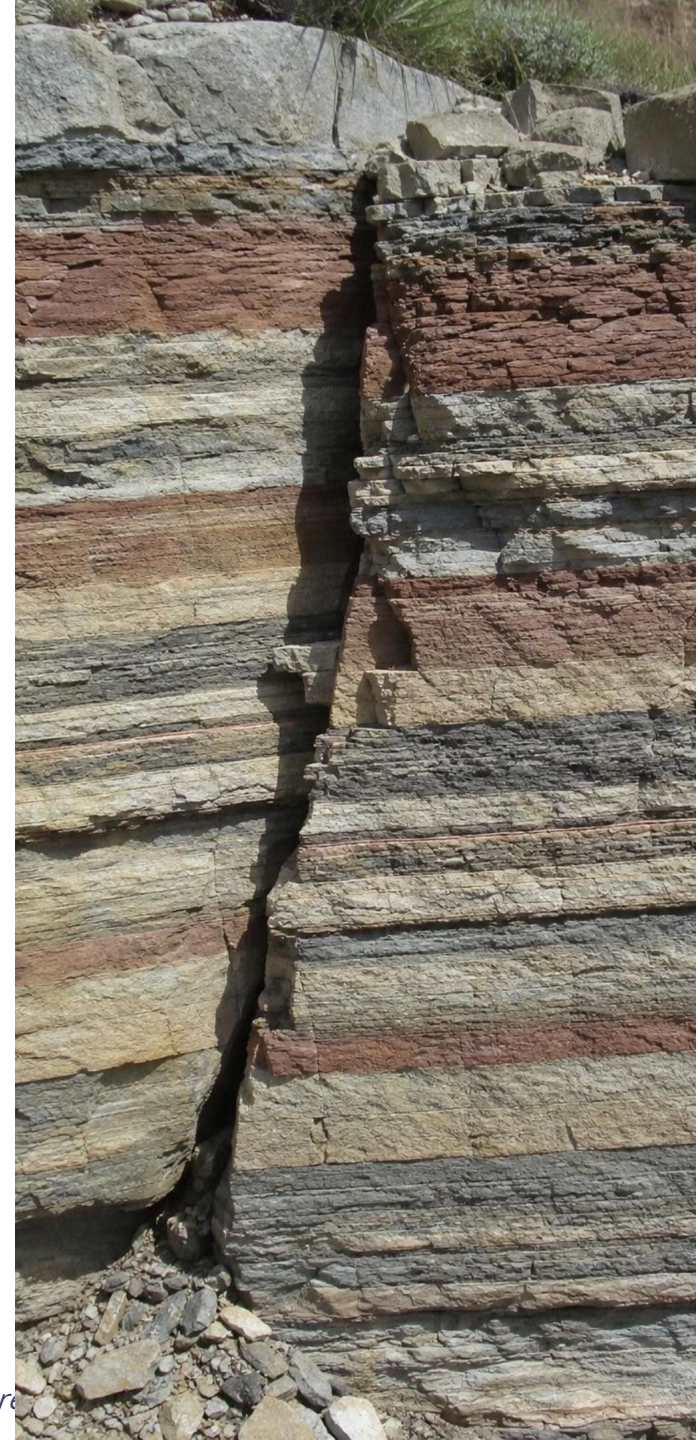
Erosion surface: A surface where layers were worn away before new ones were deposited. Younger than the layers it cuts, older than the layers on top of it.

A fault cut by another fault: The fault that is broken is older; the fault that breaks it is younger. Same for a dike cut by a fault, or a fault cut by a dike.

Fault: A break where rock on one side moved past the other, so layers no longer line up. Younger than every layer it offsets.

Fault with unbroken layers above it: If a layer lies across a fault without being offset, that layer formed after the fault stopped moving.

Scale: Some faults fit in a hand sample. The San Andreas runs about 1,200 km and offsets stream channels by more than 100 m near Wallace Creek.





Task: put the events in order

Apply it · Simulated data for practice.

A quarry wall shows the features below. Using the rules, list the events from oldest to youngest and name the rule for each step.

Feature	What you observe
Layer A, sandstone	Lowest layer. Cut by fault F and by dike D.
Layer B, shale	Lies on A. Cut by fault F and by dike D.
Fault F	Offsets A and B by 2 m. Stops at the base of layer C.
Layer C, limestone	Lies flat across the top of F, unbroken. Cut by dike D.
Dike D, dark igneous rock	Cuts A, B and C. Its top is sliced off by surface E.
Surface E	A flat erosion surface truncating A, B, C and D.
Layer G, river gravel	Lies on E. Nothing cuts it.

Quick check: which is youngest?

CHECK FOR UNDERSTANDING

A fault offsets layers A and B. Layer C lies flat across the fault, unbroken. A dark dike cuts A, B and C. Which feature is the youngest?

- A. The fault
- B. Layer C
- C. The dike
- D. Layer A





Fossils as time markers

- Life on Earth changed over time, and the changes happened in one order that never repeated.
- So fossil species appear in rock layers in the same order everywhere: the law of fossil succession.
- A species' fossils occur only in layers from the span of time it was alive.
- The best markers, index fossils, lived a short time, spread widely and are easy to identify.
- Matching fossils mean about the same age: within the species' lifespan, never an exact year.

What makes a fossil a good time marker?

Model

Model: Good index fossil versus poor index fossil

Good index fossil	Poor index fossil
Species existed for a short span of geologic time	Species lasted hundreds of millions of years, so its window is huge
Spread across a wide area, often by ocean currents	Lived in one small region or one rare habitat
Common and well preserved, so it is found often	Rarely preserved, so finds are scarce
Distinctive shape that is easy to tell from relatives	Looks like many other species, so misidentified

A short lifespan narrows the age; a wide range lets distant layers be matched; easy identification avoids mistakes.





Discuss: same fossil, same age?

THINK, PAIR, SHARE

Two quarries 500 km apart each have a shale layer with the same ammonite species. A student says the two shales formed in the same year. How close in age can you honestly claim? What would make you more confident?

California connection: Rainbow Basin near Barstow

REAL-WORLD CONNECTION

In the Mojave Desert north of Barstow, Rainbow Basin shows layers of ancient lake and stream sediment bent into a huge trough and tilted on edge, with faults slicing through them. Ash beds between the layers have been radiometrically dated to roughly 13 to 19 million years, and the layers hold fossils of early horses, camels and other land mammals. Every rule in this lesson is on display along one short loop road.



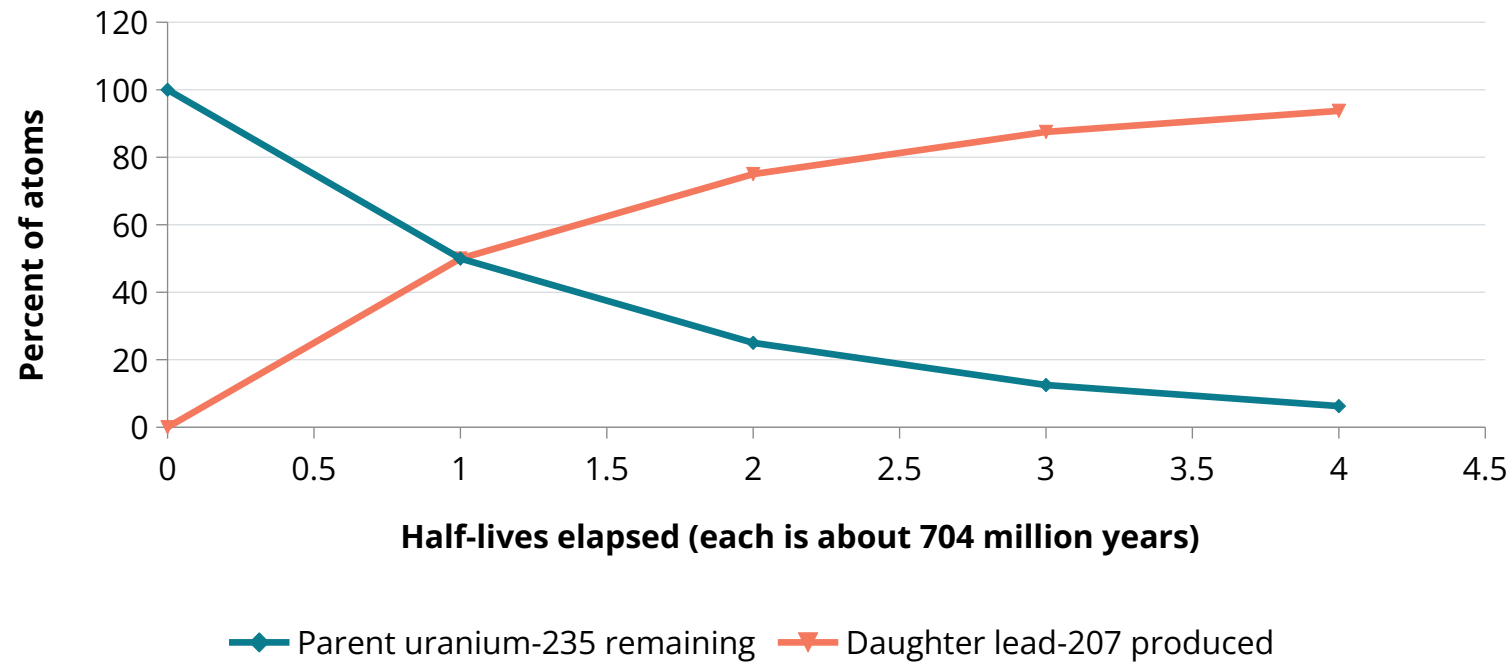


Clocks inside crystals

- When magma cools, minerals crystallize and trap radioactive atoms inside, like starting a stopwatch.
- Those parent atoms decay into daughter atoms at a steady rate that heat and pressure cannot change.
- Measure the ratio of parent to daughter in a crystal, and you can calculate when it formed.
- Works on igneous rock: lava flows, ash beds, dikes. Not on the sedimentary layers themselves.
- Why not? Sand grains are pieces of older rock; their clocks started in a different rock, long before.

Half-life: each step halves what is left

Model · **Model: Uranium-235 decaying to lead-207 in a crystal**



After one half-life half the parent is left; after two, a quarter; after three, an eighth. The parent never reaches zero in a fixed number of steps.





Quick check: how old is the lava flow?

CHECK FOR UNDERSTANDING

A zircon crystal in a lava flow has 12.5% of its original uranium-235 left. The half-life of uranium-235 is about 704 million years. How old is the flow?

- A. 704 million years
- B. 1,408 million years
- C. 2,112 million years
- D. 5,632 million years

Putting years on layers that cannot be dated

Ash from an eruption settles in hours into a flat layer of fresh crystals, so an ash bed can be dated. A limestone between an ash bed dated at 150 million years and one dated at 140 million must be 140 to 150 million years old. Layers below the lower ash are older than 150 million; layers above the upper ash are younger than 140 million. Relative dating gives the order; dated igneous layers add the numbers.



140 million

150 million



True or false? Deeper is always older

MISCONCEPTION CHECK

"In any cliff, the deepest layer is always the oldest, and a thick layer always took longer to form than a thin one."

True or false? Explain your reasoning.

Putting it together

PUTTING IT TOGETHER



Sediment settles flat, each layer on the last: in an undisturbed stack, deeper is older.



Matching layers across a gap were once one layer; the gap is younger than all of them.



Tilting, folding, faults, dikes and erosion surfaces all come after the rock they change.

Fossils appear in one worldwide order; short-lived, widespread species mark narrow time windows.



Radioactive atoms in igneous crystals give ages in years; dated ash beds bracket the layers between.





Exit ticket

EXIT TICKET

- A dike cuts three flat layers and is itself offset by a fault. List the four features from oldest to youngest.
- A layer with a certain fossil is found in two places. Finish the sentence: 'The two layers formed within...'
- A crystal has 25% of its uranium-235 left (half-life 704 million years). How old is it? Show the steps.
- Name one thing relative dating can tell you and one thing it cannot.