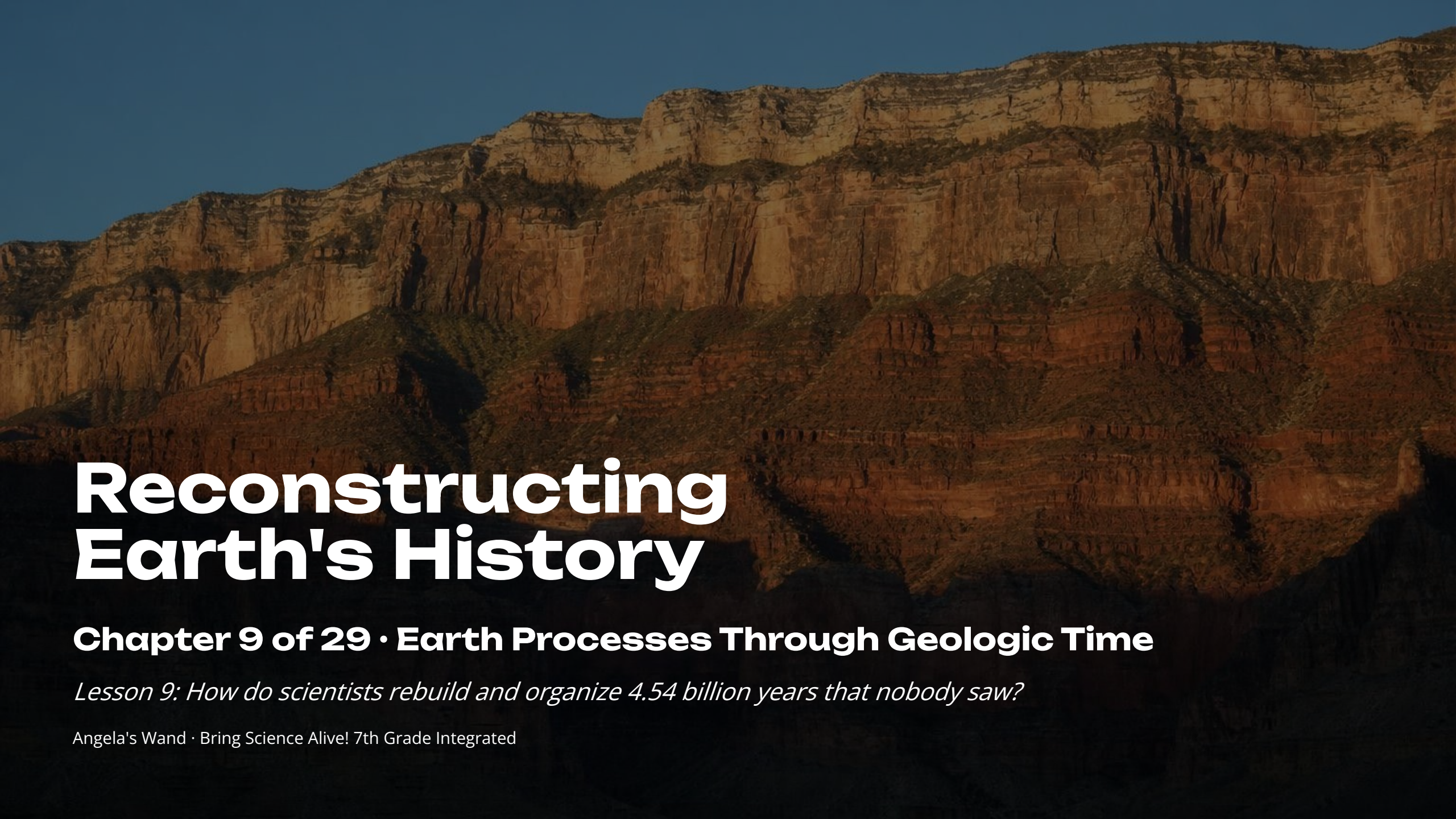




Reconstructing Earth's History

Chapter 9 of 29 • Earth Processes Through Geologic Time

Lesson 9: How do scientists rebuild and organize 4.54 billion years that nobody saw?

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

PHENOMENON

Earth's oldest rocks are younger than Earth

The oldest whole rock ever found, in northern Canada, is about 4.0 billion years old. A few zircon crystals in Australia are 4.4 billion, but the sandstone holding them is far younger. Meteorites give about 4.57 billion years, and the oldest moon rocks 4.4 to 4.5 billion. Earth seems to have lost its own first chapter. How can we know how old it is, and how do we rebuild the rest?

- Notice: which objects give the oldest ages, and where did each come from?
- Wonder: what could erase a planet's earliest rocks but not a meteorite?
- Predict: if Earth and the meteorites formed together, how old is Earth?



What you will be able to do

- 1 Match rock layers from different places and combine them into one longer record.
- 2 Read the geologic time scale: its nested units, Ga/Ma/ka, and why boundaries sit at big fossil changes.
- 3 Explain from strata evidence how the time scale organizes Earth's history.
- 4 Describe the evidence for Earth's age and for the origin of its core, moon, oceans and oxygen.
- 5 Use a scaled model to compare spans of Earth's history and explain why most charts are not to scale.





A cliff is a book you read from the bottom up

- In an undisturbed stack, the lowest layer formed first and the top layer last.
- Each layer records its setting: limestone from a shallow sea, red sandstone from a desert.
- Fossils inside a layer show what lived while it formed.
- The order of layers gives relative age: older or younger, not years.
- Watch for the exceptions: tilted, folded or faulted layers must be unscrambled first.

Reading one wall: four layers, one story

Model

Model: A cliff face from the top (youngest) down (oldest)

Top to bottom:

Yellow mudstone with mammal teeth and broad leaves (a wooded floodplain) /

Thin gray clay with glassy beads, dated 66 Ma (fallout from an impact, settled in weeks) /

Gray mudstone with dinosaur bones and conifer wood (a river plain) /

Red sandstone with reptile footprints (a desert of dunes) /

Gray limestone with crinoids and trilobites (a clear shallow sea)

Reading upward, this place changed from sea to desert to river plain. The thin clay records the shortest time but the biggest event.



No single place holds the whole story

- A sediment layer spreads sideways as a wide sheet until it thins out or hits an edge.
- So the same layer can appear in cliffs many kilometers apart: lateral continuity.
- Match a shared layer, and two short records become one longer record.
- Best matches: a distinctive key bed, such as a volcanic ash with its own chemical fingerprint.
- Rock type alone can fool you; geologists also match fossils and position in the sequence.



CHECK FOR UNDERSTANDING

Quick check: stitch two sites

Site 1 (top to bottom): shale, white ash, limestone. Site 2 (top to bottom): sandstone, shale, white ash. Same ash at both sites. Which is the complete order, youngest first?

A. sandstone, shale, ash, limestone

B. shale, ash, limestone, sandstone

C. sandstone, limestone, shale, ash

D. ash, shale, sandstone, limestone



The units of deep time

geologic time scale: A model that divides Earth's whole history into named spans, built from the order of strata and fossils and pinned to years by dated layers. *A geologist who finds trilobites can place a layer on the scale before any date is measured.*

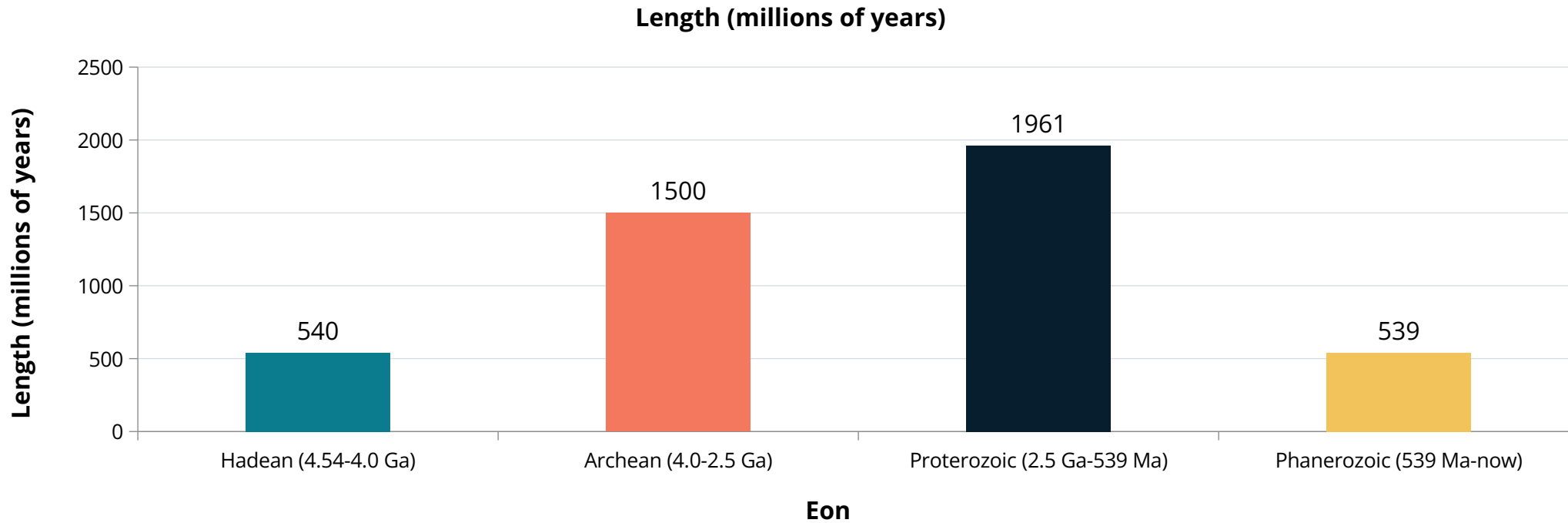
eon, era, period, epoch: The nested units, longest to shortest. Eons hold eras, eras hold periods, periods hold epochs. *We live in the Phanerozoic Eon, Cenozoic Era, Quaternary Period and Holocene Epoch.*

Ga, Ma, ka: Billions, millions and thousands of years, from the Latin annum. On a timeline, 66 Ma means 66 million years ago. *The present interglacial began 11.7 ka, which is 11,700 years ago.*



The four eons drawn to scale

Model: Length of each eon in millions of years



The eon with all the animals, plants and people is the shortest of the four. Most charts give it the most space anyway.





Why the boundaries sit where they do

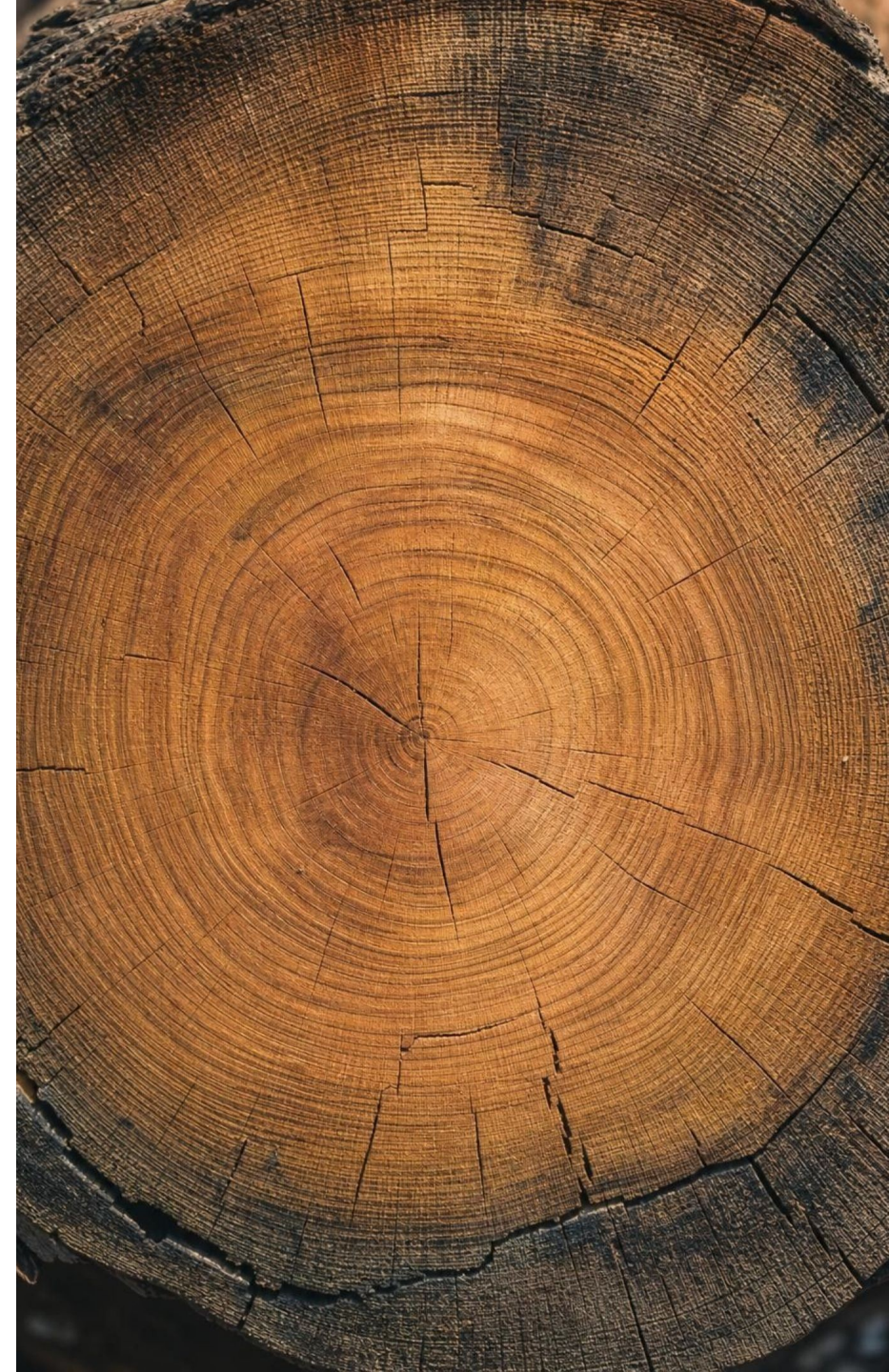
- Geologists draw a boundary where the rock and fossil record shows a big change.
- The biggest changes: mass extinctions, when many fossil types vanish at the same level.
- Others: the first appearance of a new kind of fossil, such as animals with hard shells.
- Because those changes came at irregular times, the units have uneven lengths.
- The scale was built from relative order first; dated layers added the years later.

THINK, PAIR, SHARE

Discuss: where would you draw the lines in your own life?

- Pick changes that left a visible mark: a move, a new school, a new sibling.
- Would a stranger looking at your photos be able to find your boundaries?
- Which of your spans has the most 'records' (photos, drawings, grades)? Is it the longest?

If you had to split your life into four spans using only big changes as boundaries, which events would you pick, and why would the spans not be equal?



Dating the beginning: the answer to the missing chapter

- Meteorites are leftover pieces of the cloud that made the planets; they were never recycled.
- Dated by the slow decay of atoms inside them, the oldest give about 4.57 billion years.
- Earth's own age, 4.54 billion years, comes from meteorites plus lead in Earth rocks and moon rocks.
- Earth's oldest whole rocks (4.0 Ga) are younger because plate tectonics recycled the first crust.
- The oldest zircon grains (4.4 Ga) survived their parent rock and were buried in younger sand.



Earth's first chapter, rebuilt from evidence

Model

Model: From a cloud of dust to a planet with oceans

1

A spinning cloud of gas and dust contracts; the sun forms at its center → (gravity)

2

Dust clumps into pebbles, boulders and planets; leftovers become asteroids → (collisions)

3

Young Earth is largely molten; dense iron sinks to make the core → (melting)

4

A Mars-sized body strikes Earth; debris from both forms the moon → (impact)

5

The surface cools; the first crustal rocks form → (cooling)

6

Volcanoes vent water vapor and carbon dioxide; rain fills the first oceans

Each step is an explanation built to fit evidence, from meteorite ages to the near-match between moon rock and Earth's mantle.





CHECK FOR UNDERSTANDING

Quick check: evidence or explanation?

- Moon rocks have a chemical makeup very close to Earth's mantle.
- A Mars-sized body struck young Earth and the debris formed the moon.
- Meteorites give ages of about 4.57 billion years.
- Earth's first crust was recycled by plate tectonics.
- The oldest Earth rocks are about 4.0 billion years old.

Label each statement E (evidence, something measured or observed) or X (explanation, an idea built to account for evidence).

Air without oxygen, then an ocean that rusted

- Volcanoes vent water vapor, carbon dioxide and sulfur gases, but no free oxygen.
- The early air was mostly nitrogen and carbon dioxide; oxygen atoms were locked in water and CO₂.
- Microbial mats were thriving by 3.5 billion years ago; stromatolites are their fossil mounds.
- Cyanobacteria were the first organisms known to release oxygen by photosynthesis.
- For a very long time that oxygen reacted with iron in seawater: banded iron formations.
- Only after the dissolved iron ran low did oxygen build up in the air, about 2.4 billion years ago.

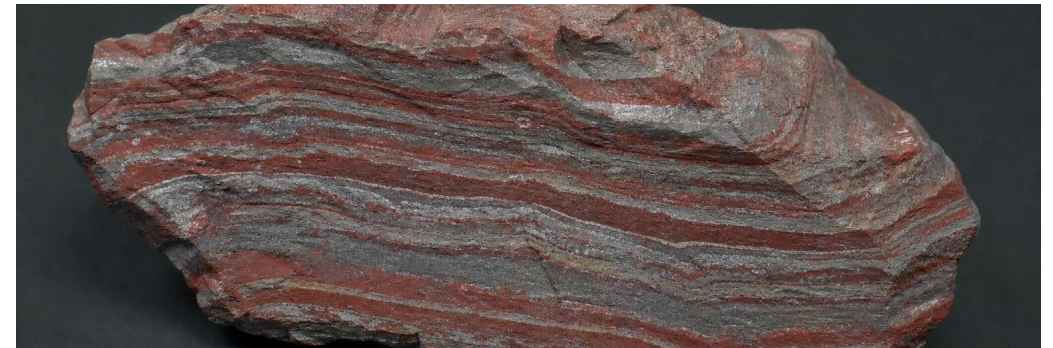


How oxygen reached the air: a cause-and-effect chain

Model: From the first oxygen-releasing microbes to breathable air

- 1 Cyanobacteria in shallow seas release oxygen → (releases)
- 2 Oxygen reacts with iron dissolved in seawater → (reacts)
- 3 Rusty iron minerals settle in bands on the seafloor → (settles)
- 4 Dissolved iron runs low; oxygen starts to escape into the air → (saturates)
- 5 Oxygen rises in the atmosphere over hundreds of millions of years → (accumulates)
- 6 Animals that need oxygen can finally evolve and grow large

The rock evidence for this chain is the banded iron formations: thin alternating iron-rich and iron-poor layers on ancient seafloors.



Three words for the record of life

stromatolite: A layered mound built by mats of microbes that trap sediment; fossil mounds are among the oldest signs of life. *Stromatolites still grow today in a salty bay in Western Australia, the same state where 3.5-billion-year-old fossil ones are found.*

mass extinction: A large share of Earth's kinds of living things dying out within a geologically short time. *In a rock sequence, a mass extinction shows up as many fossil types vanishing at the same level.*

Cambrian explosion: A burst of animal evolution starting about 539 million years ago when early relatives of most major animal groups appear in the fossil record. *Trilobites with hard shells show up in Cambrian rocks worldwide, which makes the boundary easy to find.*



Life gets big: the Cambrian explosion and a shale in Canada

For about three billion years nearly all life was microscopic. Then, from about 539 million years ago, early relatives of most major animal groups appear in the rocks within a few tens of millions of years, many with shells that fossilize well. The Burgess Shale in British Columbia preserved even soft-bodied animals from about 508 million years ago: around 200 species from well over 150,000 specimens.





Pangaea, three extinctions and the rise of the dinosaurs

- Moving plates assembled the supercontinent Pangaea by about 300 million years ago.
- About 252 Ma, enormous long-lasting eruptions in Siberia line up with the worst extinction ever.
- Most species died, especially in the oceans; trilobites and most crinoids vanished for good.
- Survivors diversified; the first dinosaurs appear about 230 Ma, dominant after the 201 Ma extinction.
- Pangaea began splitting about 200 to 180 Ma, separating populations that evolved apart.
- 66 Ma: an asteroid struck at Chicxulub, Mexico; the non-bird dinosaurs died out. Birds lived on.

Task: where do the boundaries go?

Simulated data for practice.

A team logged which fossil groups appear in each layer of a cliff (bottom layer first). Decide where you would draw era-level boundaries, and justify each with a number.

Layer (1 = oldest)	Fossil groups present	Number of groups	Groups lost since layer below	Percent lost
1	A, B, C	3	-	-
2	A, B, C, D, E	5	0	0%
3	A, B, C, D, E, F	6	0	0%
4	C, D, F	3	?	?
5	C, D, F, G, H	5	0	0%
6	C, F, G, H	4	?	?
7	C, F, G, H, I	5	0	0%



CHECK FOR UNDERSTANDING

Quick check: say it in years

Which pair is correct?

A. 66 Ma = 66,000 years ago; 11.7 ka = 11,700 years ago

B. 66 Ma = 66,000,000 years ago; 2.58 Ma = 2,580,000 years ago

C. 4.54 Ga = 454,000,000 years ago; 66 Ma = 66,000,000 years ago

D. 2.58 Ma = 258,000 years ago; 4.54 Ga = 4,540,000,000 years ago





REAL-WORLD CONNECTION

California connection: ice-age Los Angeles at Rancho La Brea

In the middle of Los Angeles, natural asphalt still seeps up through the ground. For about 50,000 years it trapped animals that wandered in: mammoths, saber-toothed cats, dire wolves, ground sloths, birds and insects. Their bones, dated to roughly 50,000 to 11,000 years ago, record the last glacial period in Southern California. The big mammals vanished from the region as the present interglacial began.

After the dinosaurs: mammals rise, continents keep moving

- With the big reptiles gone, mammals diversified into forms from bats to whales within 20 million years.
- Fully marine whales appear by about 40 Ma; the first primates about 55 Ma.
- India collided with Eurasia about 50 Ma; the Himalayas are still rising, up to about 1 cm a year in places.
- About 34 Ma, Antarctica iced over as carbon dioxide fell and ocean currents around it changed.
- About 30 to 25 Ma, East Africa began splitting apart along the Great Rift Valley.
- Same planet, very different speeds: an impact in a day, a mountain range over 50 million years.





We live in an ice age

- An ice age is a long stretch of cool climate with lasting ice at the poles; Earth is in one now.
- Northern ice sheets have grown and shrunk in cycles for about the last 2.6 million years.
- Glacial periods: ice sheets spread toward the equator. Interglacials: they shrink back.
- The present interglacial, the Holocene, began about 11,700 years ago.
- Moving ice gouged and deepened the Great Lakes basins; meltwater filled them.
- Natural interglacial warming takes thousands of years; today's human-caused warming is far faster.

THINK, PAIR, SHARE

Discuss: is the geologic time scale discovered or invented?

The rocks and fossils are real. The names, the unit boundaries and the chart were made by people. So is the geologic time scale a discovery, an invention, or both? Defend your answer with one example.





MISCONCEPTION CHECK

True or false? Most of Earth's history came after the Cambrian

"Because the geologic time scale chart gives the Phanerozoic Eon most of the space, most of Earth's history happened after animals appeared, and the dinosaurs must have lived not long before the first humans."

True or false? Explain your reasoning.

PUTTING IT TOGETHER

Putting it together

- Layers and fossils give the order of events; dated ash, meteorites and moon rocks give the years.
- Matching a key bed across sites stitches short records into one long one.
- Boundaries on the time scale sit where the fossil record changes most, so the units are uneven.
- Earth is 4.54 billion years old; its core, moon, oceans and oxygen each left evidence.
- The Phanerozoic is only about one-eighth of the story; we live in its ice age, in a warm interglacial.



EXIT TICKET

Exit ticket

- 1 Name one material suited to absolute dating and one thing that can only be dated relatively.
- 2 Two cliffs share a white ash bed. In one sentence, explain what the ash lets a geologist do.
- 3 About what fraction of Earth's history is the Phanerozoic: half, one-quarter, or one-eighth?
- 4 Write one piece of evidence and one explanation about how the moon formed, labeled E and X.

