

The Oldest Rocks on Earth Did Not Form on Earth

Learning target: I can describe a puzzling pattern in the ages of the oldest rocks, connect it to what I already know about rock layers, and write a first explanation that I can test later in the chapter.

Phenomenon exploration

About 25 min

Pairs

MS-ESS1-4 · practice

MS-ESS2-2 · supports

discussion

writing

Standards connections

MS-ESS1-4 (practice, the evidence half: what rocks can and cannot tell us about Earth's age): MS-ESS1-4 is a California Grade 8 performance expectation (geologic time from rock strata); this Grade 7 lesson previews it. Students begin reasoning about why Earth's own rocks cannot record its first half-billion years, the problem the geologic time scale has to solve.

MS-ESS2-2 (supports): The initial explanations students write usually invoke weathering, erosion and plate motion recycling the surface over very long time scales, which is the Grade 7 idea that surface processes act across huge spans of time.

Purpose: activate · **Time:** about 25 minutes · **Format:** pairs

Answers with reasoning

The phenomenon

Between 1969 and 1972, Apollo astronauts carried about 382 kilograms of moon rock back to Earth. When laboratories measured the ages of the oldest pieces, the answer was about 4.4 to 4.5 billion years. Meteorites, which are pieces of asteroids that fall to Earth, measure even older: about 4.56 billion years. Scientists use those numbers to say the solar system, and Earth with it, formed about 4.5 to 4.6 billion years ago.

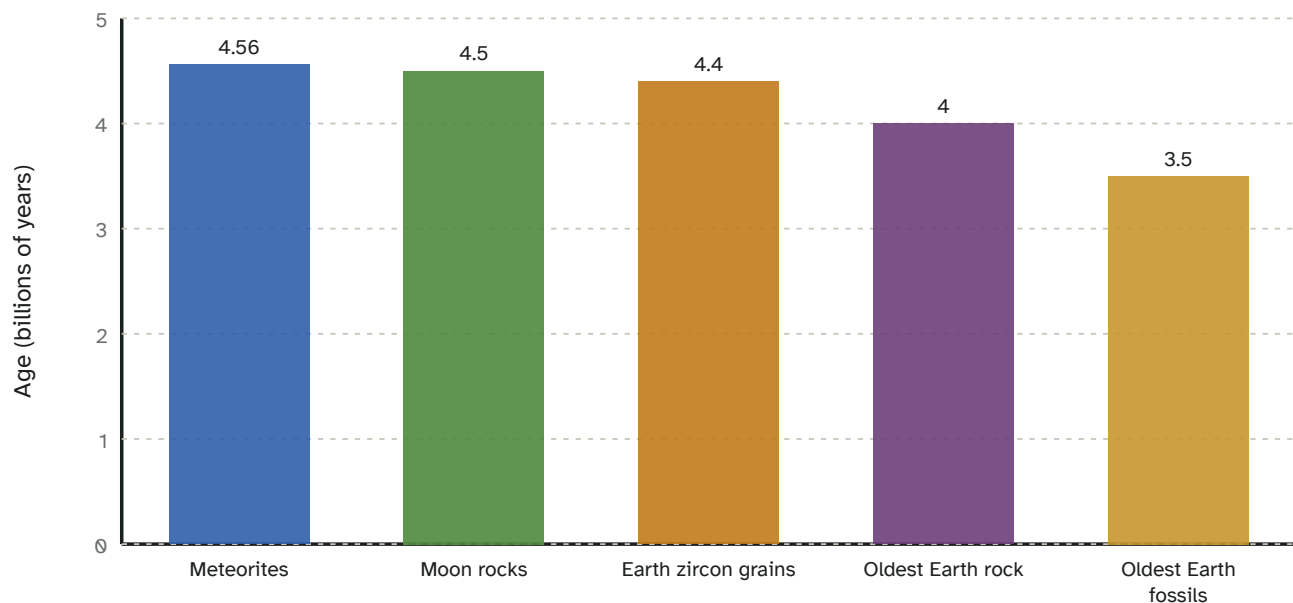
Here is the puzzle. Nobody has ever found a rock on Earth that old. The oldest known Earth rock, a gray banded rock from northern Canada called the Acasta Gneiss, is about 4.0 billion years old. The oldest known Earth *mineral grains*, tiny zircon crystals from the Jack Hills in Western Australia, are about 4.4 billion years old, but the sandstone they sit in is far younger: the grains were washed out of some older rock that no longer exists. The oldest widely accepted fossils, layered microbial mounds called stromatolites, are about 3.5 billion years old. If Earth, the moon and the asteroids formed at nearly the same time, why are Earth's oldest rocks the youngest of the group?

How an age in years is measured — Some minerals contain atoms that change into other kinds of atoms at a steady, known rate, like a clock that starts ticking when the mineral forms. Counting how far the change has gone gives an age in years. This is called **absolute dating**. It only works on certain minerals, usually ones that formed from cooling molten rock, and the clock resets if the rock melts again.

Oldest measured ages (real reference values, rounded)

Sample	Oldest measured age	Where it came from
Meteorites (pieces of asteroids)	about 4.56 billion years	Fell to Earth; the Canyon Diablo meteorite from Arizona is a famous example
Moon rocks (oldest Apollo samples)	about 4.4 to 4.5 billion years	Collected on the moon's surface by astronauts
Zircon mineral grains (Jack Hills, Australia)	about 4.4 billion years	Single grains inside a much younger sandstone
Acasta Gneiss (northern Canada)	about 4.0 billion years	The oldest known whole rock on Earth
Stromatolite fossils (Western Australia)	about 3.5 billion years	The oldest widely accepted evidence of life
Earth itself (accepted age)	about 4.54 billion years	Worked out from meteorites and moon rocks, not from any Earth rock

How far back each kind of sample reaches



Real rounded ages from the table. Notice the staircase: the bars get shorter as you move from space rocks to Earth rocks to Earth fossils.

Notice and wonder (on your own)

1. Record three things you notice and three things you wonder. A notice must be something you can point to in the table or chart; a wonder must end with a question mark.

Answer: Any three observations tied to the text, table or chart (for example: meteorites are the oldest samples; Earth's own age is not measured from Earth rock; the zircon grains are older than their sandstone; the bars step down in order; the oldest fossils are about a billion years younger than Earth) and three questions that end with a question mark (for example: What destroyed the oldest Earth rocks? Why did the moon keep its old rocks? How can a mineral clock be trusted?).

Why: This is a warm-up; grade for completion and for notices that are genuinely visible in the materials, not for correctness of the wonders.

Also acceptable: Accept a notice about the method (absolute dating needs certain minerals) as long as it comes from the callout.

- Three notices that point to specific content in the text, table or chart
- Three wonders written as questions

2. How much older are the oldest meteorites than the oldest known Earth rock? Show the subtraction, in billions of years and then in millions of years.

Answer: 4.56 billion years – 4.0 billion years = 0.56 billion years, which is 560 million years ($0.56 \times 1,000$ million = 560 million).

Why: The point is the size of the missing span: more than half a billion years of Earth's history has no surviving whole rock. Students must convert billions to millions by multiplying by 1,000.

Also acceptable: Accept 0.5 billion or 500 million years if the student rounded 4.56 to 4.5 and said so.

What you already know (with your partner)

3. In the last lesson you learned ways to tell which rock layer is older. Write two rules or clues you already know for putting rocks in order, and say whether each one gives an age in years or only an order (older than, younger than).

Answer: Examples: in undisturbed layers the lowest layer is oldest (superposition) gives order only; a layer that cuts across others is younger than what it cuts (cross-cutting) gives order only; fossils that appear in a known sequence can match layers between places (fossil order) gives order only; absolute dating of certain minerals gives an age in years. Any two with the correct order-versus-years label earn full credit.

Why: This activates the relative-dating ideas from the previous lesson and sets up the lesson's point that rock strata give relative order while absolute ages come from a smaller set of datable rocks.

Also acceptable: A student who lists two relative rules and notes that neither gives years has answered fully.

- Two valid rules or clues
- Each labeled correctly as order-only or age-in-years

4. First explanation: Earth formed about 4.54 billion years ago, yet no Earth rock older than about 4.0 billion years has been found. Write your best explanation for where the first half-billion years of Earth rock went. Use at least one of these words: *melted, recycled, worn away, buried*.

Answer: A strong first explanation: Earth's early surface was melted or re-melted (the young planet was largely molten, and later heat and impacts re-melted rock, which resets the mineral clock); since then the surface has been recycled by plate motion (old crust is pushed back into the mantle) and worn away by water, ice and wind, with the pieces buried as new sediment. The moon and asteroids have no water, air or moving plates, so their old rocks survived.

Why: Accept any reasonable mechanism; this is a pre-assessment. Look for the idea that Earth's surface is active and the moon's is not. Record common ideas to revisit with W7 and the synthesis slide.

Also acceptable: A student who says 'the old rocks are still there but deep underground where nobody has drilled' has a testable idea; accept it and flag it for the follow-up discussion (deep drilling and uplifted deep rocks have not found rock older than about 4.0 billion years).

- Names at least one process that destroys or resets old rock (melting, recycling by plates, erosion, burial)
- Uses at least one of the required words
- Explanation is consistent with the data (it must explain why Earth, not the moon, lost its old rock)

5. If Earth's own rocks cannot give Earth's age directly, why might scientists trust the ages of meteorites to stand in for the age of Earth? Write your best idea, even if you are not sure.

Answer: Meteorites are pieces of asteroids, and asteroids are leftovers from the same cloud of dust and gas that formed Earth and the other planets at the same time. Because they formed together but the asteroid pieces were never melted or recycled afterward, their ages record when the whole solar system, including Earth, formed.

Why: Students may not yet know the nebular hypothesis; credit any answer that links meteorites and Earth to a shared origin or the same formation event.

Also acceptable: Accept 'the moon rocks are almost as old, which backs up the meteorites' as supporting reasoning.

- States that meteorites and Earth formed at the same time or from the same material
- Gives a reason meteorites kept their original age (not melted, not recycled)

6. The zircon grains are 4.4 billion years old, but the sandstone they sit in is much younger. Explain how a single grain can be older than the rock around it. (Think about where sand comes from.)

Answer: Sand is made of pieces of older rocks that were broken down by weathering and carried away by water or wind. A zircon grain formed inside an ancient rock 4.4 billion years ago; that rock was later worn away, the tough grain survived, and it was deposited with other sand that hardened into a much younger sandstone. The grain's clock records when the grain formed, not when the sandstone formed.

Why: This connects the rock cycle from earlier lessons to the phenomenon and explains why the zircon bar is taller than the whole-rock bar.

Also acceptable: Accept 'the grain was recycled into a new rock' with the idea that the grain is tougher than its original rock.

- Says sand grains come from older rocks that were broken down
- Says the grain's age records the grain's formation, not the sandstone's

7. Write two questions you would need answered to test your explanation in q4. Each question should name something a scientist could actually look for or measure.

Answer: Examples of testable questions: Do the oldest Earth rocks show signs of being melted or squeezed after they formed? Are there very old rocks deep under the continents that drilling could reach? Do moon rocks show signs of melting after 4.5 billion years ago? Are the 4.4-billion-year-old zircon grains found anywhere else on Earth? Are the oldest rocks on every continent about the same age?

Why: A good question names an observation or measurement. 'Why is the moon old?' is not testable as written; 'Do moon rocks show re-melting?' is.

Also acceptable: Accept questions about how the mineral clock works as long as they are framed as checks ('Does the clock give the same age on two different minerals from one rock?').

- Two questions
- Each names something that could be observed, measured or searched for

Teacher notes

All ages are real, current reference values: meteorites about 4.56 billion years (the Canyon Diablo meteorite, Patterson's 1956 lead-isotope work); oldest Apollo samples 4.4 to 4.5 billion years; Jack Hills zircons about 4.4 billion years in a sandstone roughly 3 billion years old; Acasta Gneiss about 4.0 billion years; Pilbara stromatolites about 3.5 billion years; Earth 4.54 billion years (U.S. Geological Survey). The textbook rounds Earth's age to 4.6 billion years, which is really the age of the solar system; use 'about 4.5 to 4.6 billion' with students and keep 4.54 as the reference value. Do not teach the mechanics of radiometric dating here; the callout's 'clock that resets on melting' is enough for this grade and is accurate. Collect the q4 explanations and keep them; W7 and the synthesis slide ask students to revise them. The staircase in the bar chart is the hook: the missing 500 million years of Earth rock is the strongest everyday evidence that Earth's surface is constantly remade.

Scaffold offered to students: Sentence frames for the first explanation

If q4 feels hard, start with one of these: 'The oldest Earth rocks are gone because ___, which could not happen on the moon because ___.' Or: 'The moon and the meteorites kept their old rocks because nothing ___ them, but on Earth ___ keeps changing the surface.' You may also draw a quick sketch of what Earth's surface does over millions of years and label it instead of writing a full paragraph.

Extension: Why the moon is a better time capsule

The moon has no oceans, no rain, almost no air and no moving plates, and its surface is covered with craters that are billions of years old. Earth has only about 200 confirmed impact craters, most of them young. Predict which body has more very old rock exposed at its surface today and explain why, then suggest what that means for a scientist who wants to study the first 500 million years of the solar system. Write a short paragraph with at least two reasons.