

Evidence Jigsaw: Twelve Clues to Earth's Past

Learning target: I can work with a team to decide what kind of information each piece of evidence gives (an age in years, an order, or what happened), place the evidence on a timeline of Earth's history, and defend which clues matter most.

Collaborative investigation

About 50 min

Jigsaw

MS-ESS1-4 · practice

MS-ESS2-3 · supports

MS-LS4-1 · supports

collaboration

discussion

data analysis

Standards connections

MS-ESS1-4 (practice): MS-ESS1-4 is a California Grade 8 performance expectation. Sorting real evidence into relative-order clues, absolute-age clues and event clues, then arranging it across Earth's 4.54-billion-year history, is the evidence-handling practice behind the PE's explanation; the time bins are given, so no period names are recalled.

MS-ESS2-3 (supports): Cards 5, 11 and 3 use the distribution of fossils and rocks across continents, marine fossils on a mountain range and glacial scratches as evidence of past plate motion and surface change, the Grade 7 data this PE names.

MS-LS4-1 (supports): MS-LS4-1 is a California Grade 8 performance expectation. Several cards describe fossils appearing or disappearing in order; students use the order, not species names.

Purpose: practice · **Time:** about 50 minutes · **Format:** jigsaw

Answers with reasoning

Twelve evidence cards (real findings, rounded values)

1 Card 1: Meteorite ages

Pieces of the iron meteorite that blasted out Meteor Crater in Arizona, and many stony meteorites, give mineral-clock ages of about 4.56 billion years.

Meteorites are fragments of asteroids, leftover pieces from the cloud that formed the sun and planets. No rock found on Earth is this old.

2 Card 2: Stromatolites

In Western Australia, rock about 3.5 billion years old contains layered, dome-shaped mounds. Their layers match the shape of living microbial mounds growing today in the shallow water of Shark Bay, Australia, where mats of microbes trap sediment. They are the oldest widely accepted fossils.

3 Card 3: Scratched bedrock and the Great Lakes

Across Canada and the northern United States, bare bedrock carries long parallel scratches and a polished surface, and boulders of Canadian rock types lie scattered as far south as Illinois. The basins of the Great Lakes were gouged out by moving ice sheets and filled with meltwater as the ice retreated, between about 14,000 and 10,000 years ago.

4 Card 4: Banded iron formations

Seafloor rocks between about 2.5 and 1.8 billion years old show thin rust-red layers rich in iron alternating with gray layers. Iron dissolved in seawater settles out only when it meets oxygen. Rocks like these mostly stop forming after about 1.8 billion years ago.

5 Card 5: Matching fossils on separate continents

Fossils of the same seed fern, *Glossopteris*, and of the same freshwater reptile, *Mesosaurus*, about 280 to 250 million years old, are found in South America, Africa, India, Antarctica and Australia, continents now separated by oceans these organisms could not cross. Rock belts in eastern North America also match belts in Scotland and Norway.

6 Card 6: Zircon grains

In the Jack Hills of Western Australia, a sandstone about 3 billion years old contains tiny zircon crystals with mineral-clock ages up to about 4.4 billion years. Zircon survives weathering and transport, so the grains outlived the original rock they formed in. They are the oldest known pieces of Earth.

7 Card 7: The iridium layer and a buried crater

At more than 100 sites worldwide, a thin clay layer is unusually rich in iridium, a metal rare in Earth's crust but common in asteroids. Below the clay, fossils include non-bird dinosaurs and many kinds of sea life; above it, those kinds are absent. Volcanic layers near the clay date to 66.0 million years, and a buried crater about 180 km wide under Chicxulub, Mexico, has the same age.

8 Card 8: The Siberian lava pile

In Siberia, stacked lava flows cover about 2 million square kilometers and reach several kilometers thick. Their mineral-clock ages cluster at about 252 million years, the same age as the level in rock strata worldwide where most kinds of sea fossils disappear in the most severe mass extinction known.

9 Card 9: Deep-sea mud cores

Long cores of mud drilled from the ocean floor contain shells of tiny organisms whose chemistry records the temperature of the water they grew in. Reading down the core, the shells show about 50 swings between colder and warmer conditions during the last 2.6 million years, each swing lasting tens of thousands of years.

10 Card 10: Moon rock chemistry

The oldest rocks brought back by Apollo astronauts are about 4.4 to 4.5 billion years old. Their chemistry, including a fingerprint of oxygen types that differs from one body in the solar system to another, is nearly identical to rock from Earth's mantle and unlike meteorites from elsewhere.

11 Card 11: Sea fossils near the top of the world

The limestone near the summit of Mount Everest contains fossils of sea lilies and other sea animals roughly 470 million years old. Satellite positioning shows India still moving north into Eurasia at about 4 to 5 centimeters per year, and the collision that began lifting the Himalayas started about 50 million years ago.

12 Card 12: Human fossils in Africa

Fossil skulls and stone tools found at Jebel Irhoud in Morocco were dated to about 300,000 years by measuring how long burnt flint tools had been storing energy from natural radiation. They are the oldest known fossils of our own species. No human fossil of any kind is older than about 7 million years.

Part A: Expert round (one set per person)

1. Your expert set: _____. For each of your three cards, separate the observation from the claim it supports, then decide what kind of information it gives. A card can give more than one kind.

Answer: Set A: Card 1, observation: meteorite mineral-clock ages of about 4.56 billion years; claim: the solar system (and Earth) formed then; Y and W. Card 2, observation: layered 3.5-billion-year-old mounds shaped like living microbial mounds; claim: microbial life existed by 3.5 billion years ago; Y (through the rock's age) and W. Card 3, observation: scratched polished bedrock, far-traveled boulders, gouged basins filled 14,000 to 10,000 years ago; claim: ice sheets covered the region and shaped it; W, with Y for the filling dates. Set B: Card 4, observation: iron-rich layers in 2.5- to 1.8-billion-year-old seafloor rock that mostly stop after 1.8 billion years; claim: oxygen was reacting with iron in the oceans and the iron ran low; W and Y. Card 5, observation: identical fossils of land and freshwater organisms on five continents; claim: the continents were joined (Pangaea) about 280 to 250 million years ago; W and O (and Y via the fossil ages). Card 6, observation: 4.4-billion-year zircon grains in 3-billion-year sandstone; claim: solid crust existed by 4.4 billion years ago; Y and O (grain older than rock). Set C: Card 7, observation: worldwide iridium clay, fossils vanishing above it, 66.0-million-year volcanic dates, a crater of the same age; claim: an asteroid impact 66 million years ago caused a mass extinction; Y, O and W. Card 8, observation: a huge lava pile dated 252 million years matching the level where most sea fossils vanish; claim: giant eruptions coincided with (and likely drove) the worst mass extinction; Y, O and W. Card 9, observation: about 50 cold-warm swings in deep-sea shells over 2.6 million years; claim: repeated glacial and interglacial periods; W and O (with Y for the span). Set D: Card 10, observation: oldest moon rocks 4.4 to 4.5 billion years with chemistry matching Earth's mantle; claim: the moon formed from Earth material soon after Earth formed; Y and W. Card 11, observation: 470-million-year sea fossils near Everest's summit, India moving north 4 to 5 cm per year, collision from 50 million years ago; claim: seafloor rock was lifted by a continental collision that is still going on; W, O and Y. Card 12, observation: 300,000-year-old skulls and tools; claim: our species existed by then; Y and W.

Why: Grade the expert round on separating observation from claim and on reasonable Y/O/W choices; the letters have some flexibility and the discussion is the point.

Also acceptable: Accept O for any card that uses 'above/below' or 'oldest'; accept Y for cards whose rock age was measured even if the event itself was not dated directly.

- Observation and claim separated for all three cards
- A defensible Y/O/W choice for each

Part B: Home group task

1. Lay a strip of masking tape along the desk or floor and mark five bins on it: Bin 1, 4.54 to 4.0 billion years ago; Bin 2, 4.0 to 2.5 billion years ago; Bin 3, 2.5 billion to 539 million years ago; Bin 4, 539 to 66 million years ago; Bin 5, 66 million years ago to today.
2. Each expert places their three cards in the bin of the event the card is evidence for (not the bin where the evidence was found; a 3-billion-year-old sandstone holding 4.4-billion-year-old grains goes in Bin 1).
3. Mark each card with a small sticky note: Y for an age in years, O for order only, W for 'what happened'. Some cards get two notes.
4. Complete the group record table.
5. As a group, choose the three cards that are the strongest evidence that Earth's history is organized by events recorded in rocks and fossils. Agree on one sentence for each choice.
6. Prepare a one-minute defense of your three choices. Every member must be able to give it.

Group record (fill in)

Card	Event it supports	Y / O / W	Bin (1-5)
1			
2			
3			
4			
5			
6			
7			
8			
9			
10			
11			
12			

2. Group answer: Which three cards did you choose as the strongest evidence that Earth's history is organized by events recorded in rocks and fossils? Write one sentence of justification for each.

Answer: Group-specific. Strong choices with reasons: Card 7 (a worldwide layer in the strata marks a sudden change in fossils and carries a date, the model of an event-based boundary); Card 8 (a dated event matching a fossil disappearance at one level worldwide); Card 4 (a change in the kind of rock forming records a change in Earth's chemistry over time); Card 2 or 6 (the oldest evidence of life or crust sets the earliest events). Weaker as 'organized by events': Card 1 alone (an age, not an event in strata), Card 12 (a date for one species).

Why: The choice matters less than whether each justification connects the card to a change recorded in rock or fossils.

Also acceptable: Any three cards with event-based justifications earn full credit.

- Three cards named
- Each justification links the card to a change recorded in rocks or fossils

3. Group answer: Write the strongest challenge the neighboring group made to your choices or your bin placements, and how you answered it.

Answer: Common challenges and good replies: 'Card 6 should be in Bin 2 because the sandstone is 3 billion years old' (reply: the card is evidence that crust existed at 4.4 billion years; the event supported goes in Bin 1). 'Card 11 belongs in Bin 4 because the fossils are 470 million years old' (reply: the fossils date the seafloor, but the event the card supports, the collision lifting them, began 50 million years ago, Bin 5; a group may reasonably place a second marker in Bin 4). 'Card 9 is not evidence of an ice age, only of temperature swings' (reply: repeated swings of tens of thousands of years with ice-sheet growth and retreat are what glacial and interglacial periods are). 'Card 1 should not count as strongest because it is not from strata' (reply: fair, which is why the group chose cards that show events in strata).

Why: Look for a specific challenge and a reply that uses the card's own words.

Also acceptable: Any reasonable challenge with an evidence-based reply earns credit.

- A real challenge recorded
- Reply uses evidence from the cards

Part C: Individual accountability (complete alone)

4. Which cards give an age in years? What do all of those cards have in common about the kind of material that was dated?

Answer: Cards with an age in years: 1 (meteorites), 2 (the rock holding the stromatolites), 6 (zircons), 7 (volcanic layers near the clay and the crater), 8 (the lava pile), 10 (moon rocks), 12 (burnt flint tools), and the sandstone in 6 and the seafloor rock in 4 also carry measured ages. What they have in common: the dated material formed by cooling or heating, mostly volcanic or once-molten rock and minerals (meteorites, lava, ash, moon rock, zircon), or, for Card 12, material whose clock was reset by heating. Ordinary sediment and fossils are not dated directly; their ages come from the dated layers around them.

Why: This generalizes the lesson's point that absolute dating works on a limited set of materials.

Also acceptable: Accept 'volcanic rock and minerals' as the common feature; Card 12's heating-based method is an acceptable exception to note.

- Lists most of the Y cards
- Identifies once-molten or heated material as the common feature

5. Cards 7 and 8 each pair a dated volcanic or impact clue with a level in the strata where fossils disappear. Explain why the pairing matters: what would each card prove on its own, and what does the pair prove together?

Answer: On its own, the dated lava pile (Card 8) proves only that huge eruptions happened 252 million years ago; the fossil level on its own proves only that many kinds of sea life disappeared at one point in the order of layers, without saying when or why. Together, they show the disappearance happened at the same time as the eruptions, which makes the eruptions a likely cause and gives the extinction an age in years. The same logic links the iridium clay and crater (Card 7) to the 66-million-year extinction. A date plus a change in the strata is how the time scale gets both its boundaries and its numbers.

Why: This is the chapter's 'bookmark plus event' idea applied to real cases, and it includes the caution that coincidence in time supports, but does not by itself prove, cause.

Also acceptable: A student who adds that 'same time' does not automatically mean 'cause' is reasoning well.

- States what the dated clue proves alone
- States what the fossil level proves alone
- Explains that the pair gives timing and a likely cause

6. Choose one card that was not in your expert set. Explain its observation, the claim it supports, and one alternative explanation a skeptic might offer, then say what further evidence would decide between them.

Answer: Model answer for Card 5: observation: the same seed fern and freshwater reptile fossils on five continents now separated by oceans; claim: the continents were joined into Pangaea when those organisms lived, about 280 to 250 million years ago. Skeptic's alternative: the seeds or animals crossed the oceans (rafting on logs, or across land bridges that later sank). Deciding evidence: the reptile lived in fresh water and could not survive the open ocean; the matching rock belts and mountain structures across the Atlantic (also on the card) would not be explained by travel; and the fit of the continental edges plus the age pattern of the seafloor, which is youngest at the mid-ocean ridge and older toward the continents, shows the ocean opened after those fossils formed. Other cards: for Card 3, a skeptic might say rivers scratched the rock (reply: the scratches are parallel over huge areas and the boulders came from hundreds of kilometers north, which flowing water does not do); for Card 2, a skeptic might say the mounds formed without life (reply: compare the fine layering with living Shark Bay mounds and look for microscopic fossils and chemical traces of life in the layers).

Why: Full credit requires all four parts: observation, claim, a genuine alternative, and a test. The alternative should be one a reasonable person might offer, not a strawman.

Also acceptable: Any card is acceptable; grade the structure of the argument.

- Observation and claim stated correctly for the chosen card
- A plausible alternative explanation
- Further evidence that would decide between them

7. Bins 1 to 3 cover about 88 percent of Earth's history but hold fewer cards than Bins 4 and 5. Explain why there is less evidence from early Earth, using at least one card as an example.

Answer: Early rock is scarce because Earth's surface has been recycled: old crust has been pushed back into the mantle by plate motion, melted, squeezed and worn away, so almost nothing survives from the first 500 million years and little from the next billion. Card 6 shows this directly: the 4.4-billion-year zircon grains are the only pieces left of their original rock, which was destroyed, and they survived only because zircon is tough. Card 1 and Card 10 show the other side: the asteroids and the moon were not recycled, so their old rock survived. Early life was also microscopic and soft (Card 2), which fossilizes poorly, so the early fossil record is thin as well.

Why: Connects the jigsaw to the phenomenon in W1 and to the reason the time scale's early eons have few divisions.

Also acceptable: Accept an answer built on Cards 1 and 10 (space rocks survived because they were never recycled) as the example.

- Explains recycling or destruction of old rock
- Uses at least one card as an example
- Optionally notes that early life was microscopic

Scoring rubric

Criterion	4 • Exemplary	3 • Proficient	2 • Developing	1 • Beginning
Expert analysis (q1)	All three cards have the observation cleanly separated from the claim, with defensible Y/O/W choices and a reason for each.	Three cards analyzed; one observation and claim are blended or one letter choice is unexplained.	Cards summarized rather than analyzed; claims copied from the card without identifying the observation.	Expert section mostly blank or inaccurate.
Timeline placement and record	All twelve cards placed in the bin of the event they support, record table complete and consistent with the placements, letters marked.	Ten or eleven cards placed correctly; record table complete.	Several cards placed by where the evidence was found rather than the event supported; record partly complete.	Cards placed without reference to dates or events; record incomplete.
Choice and defense of the strongest clues	Three cards chosen with justifications that link each to a change recorded in rocks or fossils; every member can give the defense and answers a challenge with card evidence.	Three cards with reasonable justifications; defense given by one or two members, or the challenge answered without card evidence.	Cards chosen for being 'interesting' or 'old' without linking to recorded change; defense restates the choice without reasons.	No choice made, or justifications unrelated to the cards.
Individual accountability (Part C)	All four Part C answers accurate, use the cards as evidence, and show the student understands cards outside their expert set.	Three of four accurate with evidence; one thin or partly incorrect.	Two accurate; others restate the group's result without reasoning.	Part C mostly blank or inaccurate.

Teacher notes

All twelve cards describe real findings with current rounded values: Canyon Diablo and other meteorites about 4.56 billion years; Pilbara stromatolites about 3.5 billion years compared with living Shark Bay mounds; glacial striations, erratics and the Great Lakes basins filled by meltwater roughly 14,000 to 10,000 years ago; banded iron formations mostly 2.5 to 1.8 billion years; Glossopteris and Mesosaurus distributions (classic Pangaea evidence); Jack Hills zircons up to about 4.4 billion years in sandstone about 3 billion years old; the iridium layer, 66.0-million-year dates and the roughly 180-km Chicxulub crater; the Siberian Traps at about 252 million years coinciding with the end-Permian extinction; about 50 glacial-interglacial cycles in the last 2.6 million years from deep-sea records; Apollo samples 4.4 to 4.5 billion years with Earth-like oxygen-isotope chemistry; Ordovician marine limestone with crinoids near Everest's summit, India converging at about 4 to 5 cm per year, collision from about 50 million years ago; Jebel Irhoud Homo sapiens fossils at about 300,000 years dated by thermoluminescence of burnt flint. Expected bins: Cards 1, 6, 10 in Bin 1; Card 2 in Bin 2; Card 4 in Bin 3; Cards 5 and 8 in Bin 4; Cards 3, 7, 9, 11, 12 in Bin 5 (Card 11 may carry a second marker in Bin 4 for the fossils' age; Card 7 sits at the Bin 4/5 boundary). Cards 7 and 8 describe timing that coincides with extinctions; the causal link is well supported for the asteroid and widely accepted for the Siberian eruptions, but tell students that 'same time' is evidence for cause, not proof. Species names on the cards are context only and are not assessed.

Scaffold offered to students: Observation versus claim

The observation is what you could photograph or measure: 'scratches on bedrock,' 'a 4.56-billion-year mineral-clock age.' The claim is what it is evidence for: 'ice sheets moved over this rock,' 'the solar system formed 4.56 billion years ago.' If you cannot photograph it, it is probably the claim. For the Y/O/W note: Y only if the card gives a number of years from a mineral clock or similar measurement; O if the card uses position in strata (above/below) or 'oldest'; W if the card tells what event or condition happened.

Extension: The thirteenth card

Write a thirteenth evidence card for an event the deck does not cover well: the formation of the moon. Research the giant impact hypothesis and write the card in the same format (what was observed, with real values), then explain which bin it goes in, which letters it earns (Y, O, W), and whether Card 10 already supports the same claim. Finish with one sentence on why two independent kinds of evidence for one event are worth more than one kind.