

The Evidence Jury: Twelve Clues, Two Eras, One Verdict

Learning target: I can work with a team to sort evidence for moving plates by type, date and strength, decide when the evidence became strong enough to accept, and defend that decision on my own.

Collaborative investigation

About 50 min

Jigsaw

MS-ESS2-3 · assesses

collaboration

discussion

data analysis

Standards connections

MS-ESS2-3 (assesses, interpreting fossil, rock, shape and seafloor evidence of past plate motion and judging its strength): Each card is a real data pattern of the kind the PE names (fossil and rock distributions, continental shapes, seafloor structures and ages). Students interpret what each pattern shows, rank how strongly it supports plate motion, and argue from the whole set; the individual section produces written evidence toward the PE.

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

Answers with reasoning

Twelve evidence cards (real findings; dates given)

1 Card 1: Mesosaurus (Fossils)

A reptile about 1 m long that lived in shallow coastal and inland waters about 280 million years ago. Its fossils occur in southern Brazil and Uruguay and in South Africa and Namibia, in rocks of the same age. It was not built for open ocean. Known to scientists before 1900; Wegener used it.

2 Card 2: Glossopteris (Fossils)

An extinct seed plant, a tree with tongue-shaped leaves, that lived 250 to 300 million years ago. Its leaves are found in South America, Africa, India, Australia and Antarctica. Its seeds were too large and heavy to blow across an ocean. The Antarctic leaves were collected by Scott's party in 1912 and described in 1914; Wegener used the plant's spread as evidence.

3 Card 3: Lystrosaurus (Fossils)

A pig-sized plant-eating reptile that lived on land about 250 million years ago and could not swim an ocean. Its bones are found in southern Africa, India, China and Russia, and, since a dig at Coalsack Bluff in December 1969, in Antarctica.

4 Card 4: Matching rock belts (Rocks)

Belts of old folded rock in eastern North America continue, with the same rock types, ages and order of layers, in northwest Africa and in Scotland and Norway. Placed side by side, the belts line up as one. Geologists had noticed this before 1912; Wegener used it.

5 Card 5: Ancient glacial scratches (Rocks)

Rocks about 300 million years old in South America, Africa, India, Australia and Antarctica carry the rubble and bedrock scratches left by ice sheets, although most of these places are warm today. When the lands are placed together, the scratch directions point outward from one center. Wegener used this evidence; a South African geologist strengthened it in the 1930s.

6 Card 6: Coal under Antarctic ice (Rocks)

Seams of coal, which forms only from thick layers of dead plants, occur in the Transantarctic Mountains, where no plant larger than a moss grows today. Coal was found there by a 1908 expedition and again by Scott's party in 1912. It shows that Antarctica's climate, or its position, has changed.

7 Card 7: The coastline fit (Shapes and ages)

The east coast of South America and the west coast of Africa look like two pieces of a torn page. A mapmaker noticed it in 1596; Wegener made it part of his 1912 argument. The fit is rough, because coastlines shift whenever sea level rises or falls.

8 Card 8: The continental shelf fit (Shapes and ages)

In 1965 a Cambridge team used a computer to fit the continents along the edge of the continental shelf, at a water depth of about 900 m, which is the true rim of each landmass. The shelf edges of South America and Africa fit with only small gaps and overlaps along more than 5,000 km.

9 Card 9: Young oceans, old continents (Shapes and ages)

Drilling in the 1970s and later showed that no seafloor in the open oceans is older than about 200 million years, while rocks on the continents reach about 4,000 million years. The oceans are far younger than the lands they separate, which means the ocean floor keeps being replaced.

10 Card 10: A ridge with a valley down its middle (Seafloor)

In 1952 Marie Tharp, plotting sonar depth readings by hand, found a deep valley running along the crest of the Mid-Atlantic Ridge. The 1957 map she made with Bruce Heezen showed the ridge winding down the middle of the Atlantic, halfway between the continents, following the bends of both coasts.

11 Card 11: Drill-core ages (Seafloor)

Between December 1968 and January 1969 the drill ship Glomar Challenger drilled 17 holes at 10 sites in a line across the South Atlantic ridge. The seafloor was youngest at the ridge crest and grew steadily older with distance on both sides, at about 2 cm per year on each side.

12 Card 12: Earthquake belts and trenches (Seafloor)

A worldwide network of seismographs set up in the early 1960s showed that most earthquakes fall in narrow belts: along mid-ocean ridges, and along deep trenches that ring the Pacific, where the earthquakes get deeper inland from the trench. The belts outline the edges of the plates.

Part A: Expert round (one family per person)

1. Your family: _____. For each of your three cards, write one sentence that says what the card shows about the continents or the seafloor, and give it a strength score: 3 = very hard to explain without moving plates; 2 = supports moving plates but another explanation is possible; 1 = consistent with moving plates but weak on its own.

Answer: Expected summaries and scores. Fossils: Card 1 shows the same shallow-water reptile on two coasts now 3,000 km apart (2 or 3; a land bridge was the 1915 rival); Card 2 shows one heavy-seeded plant on five southern continents, including polar Antarctica (2 or 3); Card 3 shows a land animal on several continents including Antarctica (3). Rocks: Card 4, belts line up as one when the continents are joined (2); Card 5, glacial scratches point outward from one center only when the lands are reassembled (3); Card 6, coal under ice shows a changed climate or position, not which (1 or 2). Shapes and ages: Card 7, rough coastline fit (1 or 2; could be coincidence); Card 8, shelf edges fit along 5,000 km (3); Card 9, oceans are far younger than continents, so seafloor is replaced (2 or 3). Seafloor: Card 10, a ridge with a crest valley midway between the coasts, following their bends (2 or 3); Card 11, ages increase symmetrically from the ridge (3); Card 12, earthquake belts outline plates and deepen inland from trenches (3).

Why: Scores are a judgment, and the reason matters more than the number. Accept a score that differs by one from the expected value when the student names a sensible other explanation or its absence.

Also acceptable: Any defensible score with a stated reason.

- One accurate sentence per card
- A score for each with a reason that uses the other-explanation test

Part B: Home group task

1. Each expert teaches their three cards in under two minutes each: what it shows, its strength score, and the reason for the score.
2. Sort all twelve cards into two piles by date: 'Available to Wegener by 1915' and 'Found after 1945'. Use the dates on the cards.
3. Fill in the jury table: for each card, its family, its pile, its agreed strength score, and the one other explanation (if any) that could account for it without moving plates.
4. Add up the strength scores in each pile. Then decide, as a group: if you had been a geologist in 1926, with only the first pile, would you have accepted that the continents move? And in 1970, with both piles?
5. Agree on the one card you would show a doubter first, and why. Every member must be able to give the verdict and defend the chosen card.

Jury table (fill in)

Card	Family	By 1915 or after 1945?	Strength (1-3)	Another explanation without moving plates?
1				
2				
3				
4				

Card	Family	By 1915 or after 1945?	Strength (1-3)	Another explanation without moving plates?
5				
6				
7				
8				
9				
10				
11				
12				

2. Group answer: Which cards went in the 'by 1915' pile and which in the 'after 1945' pile? What was the total strength score of each pile?

Answer: By 1915: cards 1, 2, 4, 5, 6, 7 (the fossils and rocks Wegener used, the coastline fit; Antarctic coal and *Glossopteris* were collected in 1908-1912 and described by 1914). After 1945: cards 3 (1969), 8 (1965), 9 (1970s), 10 (1952-57), 11 (1968-69), 12 (early 1960s). Typical totals with the expected scores: about 12 to 14 for the 1915 pile and about 16 to 18 for the after-1945 pile.

Why: The sort is fixed by the dates on the cards; totals vary with scoring and should be checked for consistency with the group's jury table, not against a single number.

Also acceptable: A group that puts Card 6 after 1945 because the coal's meaning was not clear until later should be corrected on the date but credited for the reasoning.

- Correct six-and-six sort
- Totals that match the group's own table

3. Group verdict: Would your group have accepted moving continents in 1926? In 1970? Give the main reason for each answer, and name the card you would show a doubter first.

Answer: Either verdict for 1926 is defensible if reasoned: 'no', because the 1915 pile could be explained by sunken land bridges and a warmer Earth, and no mechanism existed; or 'yes', because the glacial scratches (Card 5) and the fossils together were very hard to explain otherwise. For 1970 the verdict should be 'yes': the seafloor cards supply a mechanism (new floor made at the ridge, destroyed at trenches) and a tested prediction (Card 11), and Cards 8, 9 and 12 agree. The first card for a doubter is usually Card 11 (a prediction that came true) or Card 8 (a fit too good for coincidence).

Why: The 1926 verdict is a genuine historical judgment; the 1970 verdict is not. Look for the mechanism-and-prediction reasoning in the 1970 answer.

Also acceptable: Accept Card 12 or Card 5 as the first card if the reason is sound.

- A verdict for each date with a reason
- The 1970 reason mentions the seafloor evidence
- A first card named with a reason

4. Group answer: Write the strongest challenge the neighboring group made to your verdict or your first-card choice, and how you answered it.

Answer: Common challenges and strong replies: 'Fossils could have crossed on a land bridge' (a bridge of continental rock would still be there; the seafloor between the continents is young volcanic rock, Cards 9 and 11). 'The shapes could be a coincidence' (a rough coastline match could be, but a 5,000 km shelf-edge fit with small gaps, Card 8, is not). 'How do we know the plates still move?' (satellite measurements today give the same rates as the drill cores, and the earthquake belts are active now, Card 12). 'Maybe the whole Earth was warm' (the glacial scratches, Card 5, show ice sheets at the same time on lands that lie near the equator today, which a warm Earth cannot explain unless those lands were then joined near the pole).

Why: Credit the record of a real challenge and a reply that uses specific cards.

Also acceptable: Any reasonable challenge and evidence-based reply.

- A specific challenge recorded
- A reply that cites at least one card

Part C: Individual accountability (complete alone)

5. Choose one card from a family that was **not** yours. Explain in your own words what it shows and why it supports the idea that plates have moved.

Answer: Any card from another family, accurately explained. Example for Card 5: ice sheets left scratches in India, Africa, Australia and South America at the same time about 300 million years ago; today those places are far apart and mostly warm, but when the continents are placed together near the South Pole the scratches all point outward from one center, which is what one large ice sheet on one joined landmass would leave. That is hard to explain if the continents had always been where they are.

Why: This checks that the expert teaching worked. The explanation must be in the student's words and must connect the pattern to motion.

Also acceptable: Any card correctly explained.

- Card from a different family
- What the card shows, accurately
- Why it supports plate motion

6. Card 1 (Mesosaurus) and Card 11 (drill-core ages) both support moving plates. Explain why most juries give Card 11 a higher strength score. Use the phrase 'another explanation' in your answer.

Answer: Card 1 allows another explanation: in 1915 scientists could say a land bridge once joined the continents and later sank, so the reptile walked or swam along it. Card 11 allows no other explanation: ages that start at zero at the ridge and rise evenly on both sides mean the seafloor was built strip by strip at the ridge while the sides moved apart; a floor that had always been there would be the same age everywhere. Card 11 was also a prediction tested after it was made, which Card 1 was not.

Why: The other-explanation test is the heart of judging evidence strength. The prediction point is a bonus.

Also acceptable: Accept 'Card 11 was a test that could have failed' as the main reason.

- Names a rival explanation for Card 1
- Explains why Card 11 has none
- Uses the phrase 'another explanation'

7. Card 6 (coal) and Card 2 (Glossopteris in Antarctica) could each be explained by 'the whole Earth was warmer back then' instead of by moving plates. Which **other** card shows that a warmer Earth cannot be the whole explanation, and how?

Answer: Card 5 (glacial scratches). A warmer Earth could explain forests and coal in Antarctica, but it cannot explain ice sheets in India, Africa, Australia and South America at about the same time, since those lands are near the equator now. The only arrangement that gives all the southern lands ice at once is a joined landmass near the South Pole, which means the lands have moved. Card 3 (a land animal in Antarctica) also works: a warm Earth does not put a pig-sized animal across an ocean.

Why: A milder climate is part of the real story (the Antarctic forests grew near the pole when it had no ice sheet), so the point is that climate alone cannot explain the shared fossils or the single glacial center. This is the same logic as the Worksheet 1 extension: a warm Earth explains some clues but not all of them together.

Also acceptable: Accept Card 3 with the correct reasoning.

- Names Card 5 (or Card 3 with the ocean-crossing reason)
- Explains why a warm Earth fails for that card

8. Write a paragraph for a doubter who says, 'Scientists changed their minds about drift once, so they might change them again.' Use at least three cards from at least two families to explain why plate tectonics is now a theory, and explain what, in science, would be needed to overturn it.

Answer: Model paragraph: Scientists did not change their minds about the evidence; they set drift aside because it had no mechanism and no tested prediction. Plate tectonics has both. Marie Tharp's ridge with its crest valley (Card 10) showed where new seafloor could form; the Glomar Challenger's cores (Card 11) tested the prediction that ages rise away from the ridge, and it came true on both sides; the earthquake belts (Card 12) outline the plates and show them moving now. These agree with the older evidence from a different direction entirely: the shelf edges fit along 5,000 km (Card 8), and one ice sheet's scratches point outward from one center (Card 5). When independent measurements by different people all point to the same moving plates, the explanation is a theory. To overturn it, someone would need new evidence that the theory cannot explain and a better explanation that accounts for everything these cards show, including the satellite rates measured today. Finding a detail to refine, such as which force moves plates most, is not the same as overturning the theory.

Why: Full credit needs at least three cards from two families, the mechanism-and-prediction point, the independence point, and a correct statement of what overturning would require.

Also acceptable: A student who notes that theories are refined (the driving-force debate) without being overturned is giving a strong answer.

- Distinguishes 'no mechanism' from 'wrong evidence' in the history
- At least three cards from at least two families
- Explains that independent lines agreeing make a theory
- States what would be needed to overturn it

Scoring rubric

Criterion	4 • Exemplary	3 • Proficient	2 • Developing	1 • Beginning
Expert teaching (Part A)	All three cards summarized accurately with scores and reasons that use the other-explanation test; the expert could teach them without reading the card.	Three accurate summaries; one score lacks a reason.	Summaries are partly copied from the cards or one card is misread; scores given without reasons.	Cards not summarized, or summaries inaccurate.

Jury table and sort (Part B)	All twelve cards sorted correctly by date; strength scores consistent with the reasons in the last column; totals correct.	One card misdated or one score inconsistent with its reason.	Two or more cards misdated, or several scores given with no other-explanation entry.	Table largely incomplete.
Verdict and defense (Part B)	Reasoned verdicts for both 1926 and 1970 that use the mechanism-and-prediction idea; a first card chosen with a reason; the neighboring group's challenge recorded and answered with specific cards; every member can give the defense.	Verdicts and first card reasoned; the challenge is answered without naming cards, or only some members can defend.	Verdicts stated without reasons, or the 1970 verdict ignores the seafloor evidence.	No verdict or no defense.
Individual accountability (Part C)	All four answers accurate, in the student's own words, citing specific cards; q8 meets all its criteria.	Three of four accurate with card evidence; one thin.	Two accurate; the rest restate the group's result without reasoning.	Part C mostly blank or inaccurate.

Teacher notes

Print and cut the twelve cards; hand each home group a shuffled deck so the date sort is genuine. Each expert family contains cards of different strength on purpose. All findings and dates are real: Mesosaurus (Early Permian, Paraná and Karoo basins); Glossopteris collected near the Beardmore Glacier in February 1912 and described by A. C. Seward in 1914; Lystrosaurus at Coalsack Bluff in December 1969; the Appalachian-Caledonian-Anti-Atlas belts; Permo-Carboniferous glacial deposits, extended by Alexander du Toit in 1937; Antarctic coal found by Shackleton's 1908 party and Scott's 1912 party; Ortelius 1596; Bullard, Everett and Smith's 1965 fit at 500 fathoms (about 900 m); oldest open-ocean seafloor about 180 million years, oldest continental rock about 4,000 million years; Tharp's rift valley (1952) and the 1957 Heezen-Tharp map; Glomar Challenger Leg 3 (December 1968 to January 1969, 17 holes at 10 sites); the World-Wide Standardized Seismograph Network (1961 onward). Magnetic stripes are omitted because the MS-ESS2-3 assessment boundary excludes paleomagnetic anomalies. If a group argues that the 1926 verdict should have been 'yes', praise the reasoning and point out that a minority of geologists, especially in South Africa, did accept drift at the time.

Scaffold offered to students: The 'another explanation' test

To score a card, ask: could this pattern exist if the continents and seafloor had never moved? If you can think of a reasonable other story (a land bridge that sank, a warmer planet everywhere, a coincidence of shapes), the card is a 2. If the only story that fits is moving plates, it is a 3. If the card would look the same either way, it is a 1. Write the other story in the last column of the jury table; if the column is empty, the score should be 3.

Extension: Order the after-1945 pile

Put the six after-1945 cards in date order and write a short timeline that shows how each discovery made the next one possible: how the ridge map led to the spreading idea, how the spreading idea led to a prediction, how the drill ship tested it, and how the earthquake belts and the age limit on seafloor completed the picture. Then explain which single discovery, if it had come out the other way, would have ended the idea of seafloor spreading.