

The Torn Map: Which Fit Do the Fossils Allow?

Investigation question: Five torn card shapes fit together by shape in more than one way. Which arrangement do the fossil, rock-belt and ice-scratch clues allow, and which clue decides it?

Evidence-based mystery

Groups of 4

1 session

Setup 5 · Activity 40 · Cleanup 5 min

MS-ESS2-3 · assesses

Scientific purpose

Students receive five card 'landmasses' whose tabs and notches allow two different fits. Using only the evidence marked along the card edges (fossil dots, a rock-belt stripe and glacier-scratch arrows), they score each candidate arrangement with fixed rules, decide which one the evidence allows, and rank the clues by how much each one helped. The lab reproduces Wegener's reasoning without giving students a map to remember: the cards are deliberately not shaped like real continents, so the fit has to be earned from the evidence.

Why this helps students with this chapter

Students who are told 'the continents fit together' usually accept it without noticing that a shape fit alone proves little. Here the shape fit is genuinely ambiguous, so students feel the problem Wegener faced and discover for themselves that a clue found everywhere (Glossopteris) cannot decide anything, while a clue found in only two places (Mesosaurus) and a direction clue (ice scratches) can. That is the core reasoning of MS-ESS2-3: it is the pattern of distribution, not the presence of a fossil, that counts as evidence.

Standards connections

MS-ESS2-3 (assesses, interpreting the distribution of fossils and rock types, together with the shapes of landmasses, as evidence of past plate motion): Students analyze where fossil and rock markings fall along landmass edges, test whether they continue across a join, and argue from that pattern that the pieces were once connected and have since moved apart. This is the fossil-and-rock half of the PE; seafloor structures are handled in Labs 2 and 3.

Roles (rotate each session)

- **Fitter:** Tries every tab-and-notch combination and lays out each arrangement that works by shape. Sketches each one on the recording sheet before any evidence is checked.
- **Scorer:** Reads the markings on both sides of each join, applies the scoring rules out loud, and records matches, mismatches and conflicts.
- **Checker:** Re-scores every join independently without looking at the Scorer's numbers; the two must agree before a total is written.
- **Reporter:** Writes the group's decision and the evidence ranking, and presents the deciding clue to the class in one minute.

Materials

Item	Quantity	Per	Note
Card-stock landmass set (five cards, A to E, cut and marked by the teacher from the template in the prep notes)	1 set	group	Cards from a sheet of 65 lb card stock; put each set in a labeled envelope.
Colored dot stickers, about 1 cm: green, red and blue	about 20 dots in total per set	group	Used during prep; students do not add stickers.
Brown and black markers	1 each	class	For the rock-belt stripes and ice-scratch arrows during prep.
Ruler marked in centimeters	1	group	
Sealed 'reveal' envelope naming which real landmass each card stands for	1	group	
Recording sheet	1	student	
Globe or wall map of the world	1	class	Used only after the reveal.

Estimated cost: 8 to 12 per class, reusable (an estimate; Estimate. One pack of card stock (about \$5) makes 10 sets; one pack each of green, red and blue dot stickers (about \$2 each) covers 10 sets; markers, rulers and envelopes are classroom stock. The sets can be reused for years if kept in envelopes.)

Safety

- Card cutting with scissors or a craft knife is done by the teacher during prep, not by students. If students help cut, use blunt-tipped scissors and cut away from fingers.
- Sticker backings and card scraps are a slip hazard on hard floors; collect them as you go.
- No chemicals, heat or glass; the only materials students handle are card, paper and a ruler.

Teacher preparation and setup

1. Cut five cards per set from card stock using these shapes. Every tab is a bump 1 cm deep and every notch is a cut-out 1 cm deep. Card A: 8 cm wide by 12 cm tall, with a 3 cm wide tab on its right edge centered 6 cm from the top and another 3 cm wide tab on its left edge centered 6 cm from the top. Card B: 10 cm wide by 12 cm tall, with a 3 cm wide notch on its left edge centered 6 cm from the top, a 2 cm wide tab on its right edge centered 4 cm from the top, and a 4 cm wide notch on its bottom edge centered 5 cm from the left corner. Card C: 6 cm wide by 7 cm tall, with a 2 cm wide notch on its left edge centered 4 cm from the top. Card D: 14 cm wide by 8 cm tall, with a 4 cm wide tab on its top edge centered 5 cm from the left corner and a 3 cm wide notch on its right edge centered 3 cm from the top. Card E: 8 cm wide by 7 cm tall, with a 3 cm wide tab on its left edge centered 3 cm from the top and another 3 cm wide tab on its right edge centered 3 cm from the top. Write the letter in the middle of each card and the word TOP along each card's top edge.
2. Why the shapes are built this way: with every TOP label facing up, a tab on a card's right edge can only enter a notch on a neighbor's left edge, and a left-edge tab can only enter a right-edge notch. A and E

each carry a 3 cm tab on both side edges, and B's left notch and D's right notch are both 3 cm wide, so by shape alone either A or E can sit at B's left edge (using its right tab) and the other at D's right edge (using its left tab). That gives exactly two complete shape-fits; cards may sit higher or lower than a neighbor, but a tab must sit fully inside the notch. The evidence must decide. C fits only B's right edge and D fits only under B.

3. Add the evidence markings within 1 cm of the edges, measuring along the edge from the card's top corner for vertical edges and from the left corner for horizontal edges. Card A, right edge: brown stripe at 3 cm, green dot at 5 cm, black arrow pointing LEFT (into the card) at 7 cm, red dot at 9 cm. Card B, left edge: brown stripe at 3 cm, green dot at 5 cm, black arrow pointing LEFT (out of the card) at 7 cm, red dot at 9 cm. Card B, right edge: green dot at 2 cm, blue dot at 5 cm. Card C, left edge: green dot at 2 cm, blue dot at 5 cm. Card B, bottom edge: green dot at 2 cm, blue dot at 7 cm, black arrow pointing UP (into the card) at 9 cm. Card D, top edge: green dot at 2 cm, blue dot at 7 cm, black arrow pointing UP (out of the card) at 9 cm. Card D, right edge: green dot at 1 cm, black arrow pointing RIGHT (out of the card) at 5 cm. Card E, left edge: green dot at 1 cm, black arrow pointing RIGHT (into the card) at 5 cm. The two outer edges also carry markings, because real continents have evidence on every coast: Card A, left edge: green dot at 4 cm, black arrow pointing LEFT (out of the card) at 7 cm. Card E, right edge: green dot at 2 cm, black arrow pointing RIGHT (out of the card) at 5 cm. Draw each brown stripe as a 1 cm long bar touching the edge, and each arrow about 1.5 cm long.
4. Prepare one reveal slip per group that reads: 'A stands for South America. B stands for Africa. C stands for India. D stands for Antarctica. E stands for Australia. The cards are simplified stand-ins, not real outlines.' Seal it in an envelope marked DO NOT OPEN UNTIL STEP 8.
5. Do one full run yourself with the scoring rules on the recording sheet. The correct fit (A against B's left edge, C against B's right edge, D under B, E against D's right edge) should score 11 with no mismatches or conflicts; the decoy fit (E's right tab in B's left notch, A's left tab in D's right notch) should score 1: its E-to-B join has one match, two mismatches and one head-on arrow conflict, and its A-to-D join has one match and one head-on arrow conflict, while the unchanged C and D joins add 5.
6. Print the recording sheet and have a globe or world map ready but covered until the reveal.

Investigation design

Independent variable	The candidate arrangement being tested (which card sits against B's left edge and which sits against D's right edge)
Dependent variable	The evidence score for the arrangement: matches minus mismatches minus two times conflicts, summed over all four joins
Controlled	The same five cards with the same markings for every arrangement; The same scoring rules and the same 1 cm position tolerance; Tops of cards aligned the same way for every fit; Each join scored by two students independently and reconciled
Trials	Two candidate arrangements per group, each scored twice (Scorer and Checker). The class pools the scores to see that every group reaches the same winner.
Comparison	Arrangement 1 versus arrangement 2 on total score, and each kind of clue on whether it could tell the arrangements apart.

Student procedure

1. Lay the five cards on the desk with every TOP label facing up and the same way. Do not open the reveal envelope. Read the scoring rules on the recording sheet together before you touch the cards.
2. Shape round (Fitter leads): find every way the cards can be joined so that each tab sits fully inside a notch of the same width and the two edges lie flush. Never rotate or flip a card; every TOP label stays up. A card may sit higher or lower than its neighbor. Each time you find a complete arrangement that uses all five cards, sketch it in the 'Arrangements found by shape' table. Stop when you are sure you have them all. There are more than one.
3. Before scoring, predict: write which arrangement your group thinks is right and why, in one sentence, in the prediction box.
4. Evidence round, arrangement 1 (Scorer leads, Checker scores independently): for each join, compare the markings on the two touching edges. A MATCH is the same symbol on both sides within 1 cm of the same position along the join, and for arrows, pointing the same way. A MISMATCH is a symbol on one side with nothing of the same kind opposite it within 1 cm. A CONFLICT is a pair of arrows pointing toward each other. Record counts for each join in the scoring table.
5. Repeat the evidence round for arrangement 2. Scorer and Checker compare numbers; if they disagree on any join, re-examine that join together until they agree.
6. Compute each arrangement's score: matches minus mismatches minus two times conflicts. Write the totals and circle the winning arrangement.
7. Evidence ranking: for each kind of marking (green dot, red dot, blue dot, brown stripe, arrow), decide whether it helped tell the two arrangements apart, and write a one-line reason. Then draw the winning arrangement on the recording sheet and draw each clue as a continuous line or dot pair running across the join.
8. Open the reveal envelope. Read which real landmass each card stands for. Look at the globe and compare the positions of those five landmasses today with the arrangement on your desk. Write the one biggest difference you notice.
9. Answer the analysis questions individually, then compare within the group. The Reporter prepares a one-minute summary naming the deciding clue.

Expected observations

- Groups find exactly two complete shape-fits: A on B's left with E on D's right, and E on B's left with A on D's right (E and A sit a little lower and higher than their neighbors in the decoy). A few groups try C or D in other places, or try to flip a card, and find the tabs do not fit.
- The correct arrangement scores $4 + 2 + 3 + 2 = 11$ with no mismatches or conflicts. The decoy scores 1: its E-to-B join has one match, two mismatches and one head-on arrow conflict (score -3), its A-to-D join has one match and one head-on arrow conflict (score -1), and the unchanged C and D joins add 5.
- The evidence ranking comes out the same for every group: green does not help, red and brown help most, arrows help and also produce the only conflicts, blue helps only to confirm joins that shape already fixed.

Likely difficulties

- Students rotate or flip a card to force a tab into a notch; the TOP labels and the rule 'tab fully inside the notch, edges flush, TOP always up' fix this. In the decoy the short card E sits 3 cm lower than B and A sits 3 cm higher than D, which is allowed.
- Students count a symbol as a match if it is anywhere on the opposite edge; insist on the 1 cm position rule and have the Checker use the ruler.
- Students argue the decoy is 'close enough' because it has 7 matches. Point to the mismatches and the conflict: a good fit is not one with many matches but one with no contradictions.
- Groups that recognize the real continents early (rare, since the cards are not shaped like them) should be asked to score anyway; the point is the evidence, not the answer.

Structured debrief

1. Pool every group's totals on the board. Every group should have the same winner with a score of 11 against 1. Ask why groups that predicted differently in step 3 still ended at the same answer: the rules did the deciding, not the prediction.
2. Run down the evidence ranking together. Green (Glossopteris) appears on all five cards, so it supports 'joined' but cannot say 'joined how.' Red (Mesosaurus) is on only A and B, so it pins one join. The arrows add direction, which is why the decoy fails with a conflict. Connect to Wegener: he needed many kinds of evidence because each kind answers a different question.
3. After the reveal, hold the globe next to a finished arrangement. The group that found the biggest difference usually names the ocean between South America and Africa, or India far to the north. Ask what has to be true if this arrangement was ever real: the pieces moved thousands of kilometers. Then ask what the cards cannot tell you: how, how fast, or what pushed them. That is the gap the rest of the lesson fills.
4. Close on q7: this evidence shows connection, not motion. Scientists in 1926 accepted the connection but not the motion because no one could say what moved the continents. The seafloor evidence (Labs 2 and 3) is what answered that.

Recording sheet: what students fill in

Lab 1 recording sheet: The torn map

Scoring rules — Compare the two edges that touch at each join. **Match** (+1): the same symbol on both sides within 1 cm of the same position; arrows must point the same way. **Mismatch** (−1): a symbol on one side with nothing of the same kind within 1 cm opposite it. **Conflict** (−2): two arrows pointing toward each other. Score = matches − mismatches − 2 × conflicts.

green dot

Fossil of Glossopteris, an extinct seed plant with tongue-shaped leaves.

red dot

Fossil of Mesosaurus, a small reptile that lived in shallow water and could not cross an ocean.

blue dot

Fossil of Lystrosaurus, a pig-sized land animal.

brown stripe

A belt of old mountain rock with a particular type and age of rock layers.

black arrow

Scratches left by an ancient glacier; the arrow points the way the ice was flowing.

Arrangements found by shape (write which card touches which edge)

Arrangement	Card on B's left edge	Card on B's right edge	Card under B	Card on D's right edge
1				
2				
3 (if any)				

Prediction before scoring: which arrangement do you think is right, and why?

Evidence score for each join

Arrangement and join	Matches (+1 each)	Mismatches (–1 each)	Conflicts (–2 each)	Join score
Arr. 1: card on B's left				
Arr. 1: B's right with C				
Arr. 1: B's bottom with D				
Arr. 1: card on D's right				
Arrangement 1 TOTAL				
Arr. 2: card on B's left				
Arr. 2: B's right with C				
Arr. 2: B's bottom with D				
Arr. 2: card on D's right				
Arrangement 2 TOTAL				

Evidence ranking: could this clue tell the two arrangements apart?

Clue	How many cards carry it?	Helped decide? (yes/no)	Why
Green dot (Glossopteris)			
Red dot (Mesosaurus)			
Blue dot (Lystrosaurus)			
Brown stripe (rock belt)			
Black arrow (ice scratches)			

-  Draw the winning arrangement with all five cards labeled. Draw each clue as a line or pair of dots that runs across the join it belongs to, and draw the ice arrows so the flow direction is continuous.

Answer: Five labeled cards in the winning arrangement: A on B's left, C on B's right, D under B, E on D's right. The brown stripe, green, red and blue dots are drawn as continuous lines or paired dots crossing their joins, and the arrows show ice flowing from D upward into B, from D rightward into E, and leftward from B into A.

Why: The drawing checks that students can turn point evidence into continuous features and show the ice flow as one consistent pattern radiating from D.

- All five cards placed and labeled correctly
- Each clue drawn continuous across its join
- Arrow directions consistent across joins

1. Which arrangement won, by how many points, and which single clue did the most to separate the two arrangements?

Answer: Arrangement 1 (A on B's left, C on B's right, D under B, E on D's right) won, 11 to 1, a margin of 10 points. The deciding clues are the red dot (Mesosaurus), which only A and B carry, and the ice arrows, which collide head-on at both changed joins in the decoy.

Why: The decoy's E-to-B join loses the brown stripe and red dot as mismatches and gets an arrow conflict; its A-to-D join gets a second arrow conflict. Accept either red dot or arrows as 'the' deciding clue if the reason is given.

- Names the winning arrangement and the margin
- Names a clue that appears on only some cards or the arrow conflict as the deciding factor

2. After the reveal: name the biggest difference between the arrangement on your desk and where those five landmasses are on the globe today.

Answer: Today the five landmasses are separated by oceans thousands of kilometers wide; the most common answer is the Atlantic Ocean between South America and Africa, or that India now sits far to the north against Asia rather than beside Africa and Antarctica.

Why: Any correctly observed difference earns credit; the purpose is to make students state that the pieces must have moved very far.

Also acceptable: Antarctica is now at the South Pole; Australia is far to the east; the pieces are no longer touching at all.

Analysis questions: answer key

3. Green dots appear on every join in both arrangements. Explain why a clue that is found everywhere cannot help you choose between arrangements, even though it is real evidence that the lands were once connected.

Answer: A clue is useful for choosing between arrangements only when it is present in some places and absent in others, because then one arrangement lines it up and the other does not. Green dots are on every join edge, so every arrangement scores the same on them: they match in the decoy exactly as often as in the correct fit. They still show the lands were connected (the plant could not have spread across an ocean), but they carry no information about which edge touched which.

Why: This is the heart of 'distribution as evidence.' The presence of a fossil shows connection; the pattern of where it is and is not shows the arrangement.

- States that a clue present everywhere scores the same in every arrangement
- Distinguishes 'shows connection' from 'shows which arrangement'

4. The red dot (Mesosaurus) appears on only two cards. Why does a small shallow-water reptile found on exactly two landmasses make such a strong clue? What would weaken it?

Answer: Because Mesosaurus could not cross an open ocean, its fossils on two landmasses mean those two were connected, and because it appears on only those two, it pins exactly that join and rules out any arrangement that separates A from B. It would be weakened if Mesosaurus fossils were found on other landmasses too (then it would be like the green dot), if the animal turned out to be a strong ocean swimmer, or if the fossils on the two cards were of very different ages.

Why: Students should connect the animal's biology (shallow-water, small) with the geography (only two places) to explain the strength of the clue.

- Explains that the animal could not cross an ocean
- Explains that being found in only two places pins one join
- Gives at least one condition that would weaken the clue

5. In the decoy arrangement, two ice-scratch arrows point toward each other across a join. Explain why that is a conflict and not just a mismatch. What does it mean physically for the ice?

Answer: A mismatch means one side has a clue the other lacks; that could happen if the evidence on one side was eroded or never found. A conflict is two clues that cannot both be true at once: ice cannot flow from E into B and from B into E across the same line at the same time. The arrows record which way a single ice sheet moved, so a correct join must show the flow continuing in one direction across it.

Why: Conflicts are weighted -2 because a contradiction is stronger evidence against an arrangement than a missing clue.

- States that the two arrows cannot both be true
- Explains the physical meaning: one ice sheet flows one way across a join

6. Suppose a sixth card, F, had a 3 cm tab that also fit B's left notch, but F carried no markings at all along that edge. Would F be ruled in or ruled out, and by what rule? Explain.

Answer: F would be ruled out by the mismatch rule. B's left edge carries four markings (stripe, green, arrow, red); F would offer nothing opposite any of them, so the join would score $0 - 4 = -4$ even with no conflict. Shape fit alone is not enough; an edge that matches by shape but carries no continuing evidence fails the test.

Why: This checks that students apply the rules rather than the shape, and reinforces that absence of expected evidence counts against a fit.

Also acceptable: Accept 'ruled out, score -4' or 'ruled out because every clue on B would be a mismatch.'

7. Wegener had this kind of evidence in 1912, and many scientists still did not accept that the continents had moved. Using what you did today, explain what this evidence can show and what it cannot show.

Answer: This evidence can show that the landmasses were once joined in a particular arrangement, because fossils of animals that could not cross oceans, rock belts and ice-flow directions all continue across the joins only in that arrangement. It cannot show how the pieces moved, how fast, when, or what force moved them. In 1912 the cards (the land evidence) were all anyone had; the ocean floor between the pieces was unmapped, and no known force could move a continent. Scientists could accept 'once connected' and still doubt 'drifted,' which is what many did until seafloor evidence in the 1950s and 1960s supplied the missing part.

Why: Full credit requires both halves: what the evidence establishes and what it leaves open, tied to the historical hesitation.

- States that the evidence shows the lands were connected in a specific arrangement
- States that it does not show mechanism, rate or timing
- Links the gap to why scientists hesitated

8. Real continental edges are not tabs and notches, and real fossils are found in areas, not along edges. Name two ways the card model is unlike the real evidence, and say whether each difference makes the real case stronger or weaker than the model.

Answer: Any two of: real edges are irregular shelf outlines, not tabs and notches, which makes a real shape fit less exact but also harder to fake (stronger, because a close irregular fit is unlikely by chance). Real fossils cover areas inside continents, not points on edges, so matching them means showing whole regions line up (stronger, because an area match carries more detail than a dot). Real rock belts are matched by rock type, age and the order of layers, not by a color (stronger). The cards give no ages, while real evidence from different eras must be matched to the same time (weaker if ages disagree, stronger when they agree). The cards have no ocean floor between them, while the real pieces are separated by seafloor that carries its own evidence (stronger, see Labs 2 and 3).

Why: Accept any two accurate differences with a defended judgment either way; the quality of the reasoning matters more than the direction.

- Names two specific, accurate differences
- Judges the effect of each on the real argument with a reason

Individual evidence of learning

Each student submits their own recording sheet with both scoring tables completed, the evidence ranking, the drawing of the winning arrangement with continuous clue lines, and written answers to q1 through q8. The scoring table and q3, q4 and q7 are the primary evidence toward MS-ESS2-3.

Assessment criteria

Criterion	Proficient looks like
Shape round and scoring	Both shape-fits found and sketched; every join scored with the rules; totals of 11 and 1 (or within one point with a stated reason); Scorer and Checker reconciled.
Evidence reasoning	Explains that a clue found on every card cannot discriminate, that a clue found on only two cards pins a join, and that arrows add direction; names Mesosaurus or the arrows as the deciding clue with a reason.
Limits of the evidence	States in q7 that fossil and rock matches show the lands were connected but not how or why they moved, and names the missing mechanism as the reason scientists hesitated.
Model critique	Names two specific differences between the cards and real continents in q8 and judges the effect of each on the strength of the real argument.

Accessibility adaptations

- Make a large-format set (double all dimensions) on poster board for students with low vision or limited fine-motor control, and use raised puffy stickers so the dots can be found by touch.
- Provide a scoring table with the first join already worked as a model, and allow the Scorer and Checker roles to be shared by one student working with a partner who reads the markings aloud.
- Accept the evidence ranking and q7 as a recorded spoken explanation, and provide a picture-glossary card for Glossopteris, Mesosaurus, Lystrosaurus, rock belt and glacier in the student's home language.
- Let students who need movement build the arrangement on the floor with the large set and walk the ice-arrow directions.

Low-cost alternative

Cut the cards from cereal-box cardboard and draw the dots with colored markers instead of stickers. If no colored markers are available, use the letters G, M, L, R and an arrow in pencil; the scoring works the same way.

Model limitations

The cards are simple polygons, not real continental outlines, and real continental edges are best matched at the submerged edge of the continental shelf, not the coast. Real fossils and rock belts occupy areas across a continent, not points along an edge, and a real match is judged by rock type, age and layer order, not by a colored dot; the 1 cm tolerance and the scoring formula are invented for the activity. The cards also say nothing about when the pieces separated, how fast they moved, or what moved them, which is exactly the gap that stopped scientists in the 1920s. This activity has not been physically tested by the authors; the dimensions and scores were checked on paper only, so run one set yourself before class.

Teacher notes

Scores assume the markings were placed exactly as in the prep list, where every pair that should match sits at the same position along its join; a group that reports a different total has usually misplaced a sticker or misread a position, so check that join with the ruler. The historical analogs are deliberately simplified:

Glossopteris is found on all five southern landmasses, Mesosaurus in Brazil and southern Africa, Lystrosaurus in Antarctica, southern Africa and India (and also in Asia, which the cards omit), the rock-belt match stands in for several real belts, and the glacial scratches represent the Permo-Carboniferous ice sheet that covered southern Pangaea about 300 million years ago. Do not present the cards as real outlines or the scoring numbers as real data.