

Three Sites, One History: When Did the Sea Creatures Vanish?

Investigation question: Three outcrops a few kilometers apart each show only part of the region's rock record. Can you stitch them into one sequence, find the levels where whole groups of fossils disappear, and explain how that sequence organizes the region's history?

Evidence-based mystery

Groups of 4

2 sessions

Setup 5 · Activity 75 · Cleanup 5 min

MS-ESS1-4 · assesses

MS-ESS2-2 · supports

Scientific purpose

Students receive the field logs of three fictional outcrops, each exposing a different slice of the same stack of layers, and must work out which layers are shared, build one composite column, locate two mass-extinction levels where fossils vanish, and use two dated layers to attach years to parts of the sequence. They then write a scientific explanation of how the composite sequence organizes the region's history, separating what was observed from what was inferred. The lab is the chapter's direct practice of constructing an explanation from rock-strata evidence.

Why this helps students with this chapter

Textbook figures hand students a finished composite sequence, so the reasoning that produced it stays invisible. Here students do that reasoning themselves: they must decide which layers are the same, discover that rock type alone is not enough, find that a thin ash bed is the best anchor, and notice that the fossils change most at exactly the levels geologists use as boundaries. Writing the explanation afterward makes them separate what the rocks show from what they concluded.

Standards connections

MS-ESS1-4 (assesses, the explanation built from strata and fossil evidence; no period names are required): A California Grade 8 performance expectation, placed here because the Grade 7 textbook teaches it. The written explanation in step 9 asks students to use evidence from rock strata (order, shared key beds, fossil disappearances, dated layers) to explain how the sequence organizes the region's history, which is the PE as written. In line with its assessment boundary, students never need to name periods or epochs.

MS-ESS2-2 (supports, reading environmental change from rock type): The sequence records a sea becoming a desert, then a river plain; students read these surface changes from rock type as background for the Grade 7 standard on surface change over time.

Roles (rotate each session)

- **Site reader:** Reads each site log aloud, layer by layer from the top, and makes sure every layer's rock type, thickness, fossils and notes are heard before any matching begins.

- **Matcher:** Proposes which layers at different sites are the same, states the evidence for each match, and records the match in the matching table.
- **Column drafter:** Draws the composite column to scale on graph paper (1 cm = 2 m of rock, with the two thin beds drawn as lines), labels every layer and marks the fossil disappearances.
- **Skeptic and reporter:** Challenges each match ('could that be a different gray limestone?'), checks the final order against all three logs, and presents the column to the class.

Materials

Item	Quantity	Per	Note
Site log cards: three cards per group (Site A, Site B, Site C) printed from the recording sheet table, with each layer on a separate strip	1 set (14 strips)	group	Cut each site's layers into separate strips and shuffle them within the site envelope so students must use the 'position in site' column to restore the order.
Envelopes labeled A, B, C	3	group	
Graph paper (1 cm squares)	2 sheets	group	
Colored pencils (at least five colors)	1 set	group	
Ruler	1	group	
Glue stick or tape	1	group	For fixing the final arrangement of strips before drawing.
Recording sheet	1	student	

Estimated cost: 3 to 5 per class (an estimate; Printing and cutting 14 strips per group on card stock (about \$2 for a class), envelopes and graph paper from stock; colored pencils and rulers are reused.)

Safety

- Paper, glue and colored pencils only; no chemicals or heat. Keep glue sticks capped between uses.
- If scissors are used to cut strips in class, cut away from fingers and pass them handle first.
- No physical hazards beyond ordinary classroom materials; the fictional sites are described, not visited.

Teacher preparation and setup

1. Print the site-log table from the recording sheet once per group on card stock, cut it into one strip per layer (14 strips), and sort the strips into the three site envelopes. Shuffle within each envelope.
2. Decide whether to tell students the sites are fictional at the start (recommended) or at the debrief; either way, say that the method is exactly what geologists do in the western United States.
3. Prepare a hidden 'answer column' on chart paper to reveal at the debrief: nine layers, bottom to top, with the two extinction levels and the two dated beds marked.
4. Review the key-bed idea from slide 6 so students know that an ash bed with a matching chemical fingerprint can be treated as the same layer.

Investigation design

Independent variable	Which site is examined (A, B or C) and the layer's position within that site
Dependent variable	The layer's position in the composite column and its age range in years
Controlled	Every group uses the same three site logs; Matching requires at least two lines of evidence; Columns drawn at the same scale (1 cm = 2 m); Only the dates printed on the logs may be used
Trials	One composite column per group; the class compares columns at the debrief, and differences in matching are resolved by returning to the evidence.
Comparison	Each group's composite order and extinction levels versus the hidden answer column; each group's age ranges versus the key.

Student procedure

1. Open envelope A. Use the 'position at this site' column to put Site A's strips in order, top (youngest) to bottom (oldest). Repeat for Sites B and C. Each site is a separate stack of its own; do not mix sites yet.
2. Read each stack aloud. For every layer, note the rock type, thickness, fossils and any note about dating or a chemical fingerprint. Write in the first recording-sheet box which site shows the youngest rock and which shows the oldest, with your reason.
3. Find layers that appear at two sites. For each proposed match, write the evidence in the matching table: rock type, fossils, thickness and any fingerprint or date. A match needs at least two lines of evidence; rock type alone is not enough.
4. Slide the three stacks sideways so that matched layers sit level with one another. Check: does every layer above a match stay above it at both sites, and every layer below stay below? If not, the match is wrong.
5. Once the stacks line up, read off the complete order from the oldest layer at the bottom of Site C to the youngest at the top of Site A. Write the nine layers in order on the recording sheet.
6. Draw the composite column on graph paper at 1 cm = 2 m of rock, oldest at the bottom. Draw the two beds thinner than 10 cm as single lines and label them. Color each layer by rock type and sketch a symbol for each fossil type in the layers where it occurs.
7. Mark with an arrow every level above which a fossil type never appears again. Decide which of these levels are large enough to call a mass extinction (several types vanish together) and label them.
8. Write the two laboratory dates beside their layers. Then write an age range (older than, younger than, or between) beside every other layer, using only those two dates and the date of the basement rock.
9. Session 2: write your explanation (q9 on the analysis sheet) of how the composite sequence organizes the region's history. Mark each sentence E (something the logs record) or X (something you concluded). Present the column to another group and have their skeptic challenge one match.

Expected observations

- Composite order, oldest to youngest: speckled granite (1,100 Ma), black shale, gray limestone, brown sandy limestone, white ash Z-7 (252 Ma), red sandstone, gray mudstone, gray clay with glassy beads (66 Ma), yellow mudstone. Total about 36 m plus the granite.

- Matches: B3 = C1 (ash, fingerprint Z-7, same thickness, same position above the sandy limestone); B4 = C2 (sandy limestone, same fossils, same thickness); B5 = C3 (gray limestone, same fossils, same thickness); A3 = B1 (gray mudstone with dinosaur bones and conifer wood); A4 = B2 (red sandstone with footprints).
- Trilobites, crinoids and brachiopods last appear in the sandy limestone directly below the 252 Ma ash; dinosaur bones last appear in the gray mudstone directly below the 66 Ma clay. Most groups find both levels once the column is drawn.

Likely difficulties

- Groups try to combine all 14 strips into one stack immediately and double-count the shared layers; insist on three separate stacks first, then sliding them level.
- Some groups match Site B's gray limestone with Site A's gray mudstone because both are gray; the skeptic role and q3 exist for this.
- Students write a single age for the red sandstone instead of a range; remind them that only the two thin beds and the granite carry measured dates.
- The worn granite surface is overlooked; prompt with 'what happens to a rock surface that sits exposed for a long time before anything is deposited on it?'
- The 1 cm = 2 m scale makes the two thin beds invisible; students should draw them as lines and label them, not try to scale them.

Structured debrief

1. Reveal the answer column and have groups compare. Ask which match caused the most argument; typically the two limestones at Site B and Site C, because they are the same at both sites but students worry they are different gray limestones until they see both sit under the same sandy limestone and ash.
2. Ask each group which single layer did the most work. The ash with fingerprint Z-7 anchors B to C and carries a date; the glassy-bead clay carries the other date. Point out that two thin beds that took days to form pin down a 36-meter stack.
3. Walk the extinction levels together: sea-floor animals vanish just below the 252 Ma ash and never return above it; dinosaur bones stop below the 66 Ma clay. Explain that these are the same two levels geologists use for the end of the Paleozoic and Mesozoic eras, without requiring students to remember those names.
4. Collect three or four q9 paragraphs and have the class sort the sentences into E and X. The goal is to see that 'trilobites stop below the ash' is an observation while 'a mass extinction happened about 252 million years ago' is a conclusion from several observations together.

Recording sheet: what students fill in

Lab 2 recording sheet: Three sites, one history

The three sites below are fictional and simplified for this investigation, but the method is the one geologists use. Thickness is given in meters (m) or centimeters (cm). 'Lab date' means an age measured in years from the layer's own minerals; Ma means million years ago.

Site logs (print on card stock and cut into one strip per layer)*Simulated teaching dataset: the numbers are invented to be realistic, not measured.*

Site	Position at this site (1 = top)	Rock type and color	Thickness	Fossils	Notes
A: Dry Wash cliff	1	yellow mudstone	5 m	mammal teeth, broad leaves	top of cliff
A: Dry Wash cliff	2	gray clay with tiny glassy beads	1 cm	none	lab date 66 Ma
A: Dry Wash cliff	3	gray mudstone	8 m	dinosaur bones, conifer wood	
A: Dry Wash cliff	4	red sandstone with cross-bedding	10 m	reptile footprints	base of cliff; lower layers buried
B: Highway road cut	1	gray mudstone	8 m	dinosaur bones, conifer wood	top of road cut
B: Highway road cut	2	red sandstone with cross-bedding	10 m	reptile footprints	
B: Highway road cut	3	white volcanic ash	2 cm	none	chemical fingerprint Z-7; lab date 252 Ma
B: Highway road cut	4	brown sandy limestone	3 m	crinoids, brachiopods, trilobites	
B: Highway road cut	5	gray limestone	6 m	crinoids, brachiopods, trilobites	base of road cut; lower layers buried
C: Quarry	1	white volcanic ash	2 cm	none	chemical fingerprint Z-7; top of quarry wall
C: Quarry	2	brown sandy limestone	3 m	crinoids, brachiopods, trilobites	
C: Quarry	3	gray limestone	6 m	crinoids, brachiopods, trilobites	
C: Quarry	4	black shale	4 m	trilobites, brachiopods	rests on a worn, uneven granite surface
C: Quarry	5	speckled granite	more than 20 m	none	lab date 1,100 Ma; quarry floor

Matching table: layers that are the same at two sites

Layer at first site (site and position)	Same layer at second site (site and position)	Evidence 1	Evidence 2	Confidence (high / medium / low)

The composite sequence, with age ranges

Order (1 = oldest)	Layer (rock type)	Fossils	Age in years: measured, or range from the dated layers	Fossil types that never appear above this layer
1				
2				
3				
4				
5				
6				
7				
8				
9				

 Draw the composite column to scale (1 cm = 2 m), oldest layer at the bottom. Draw the two thin beds as labeled lines. Color by rock type, add a symbol for each fossil type, write the two lab dates and the granite date beside their layers, and mark every mass-extinction level with an arrow and a label.

Answer: A column with nine layers, oldest at the bottom: granite (drawn at the base, labeled 1,100 Ma), black shale 2 cm tall, gray limestone 3 cm, sandy limestone 1.5 cm, ash as a labeled line (252 Ma), red sandstone 5 cm, gray mudstone 4 cm, clay as a labeled line (66 Ma), yellow mudstone 2.5 cm. Fossil symbols in the correct layers; arrows at the top of the sandy limestone (sea-floor animals vanish) and at the top of the gray mudstone (dinosaurs vanish), each labeled as a mass-extinction level.

Why: At 1 cm = 2 m the column is about 18 cm tall plus the granite; the two thin beds must be drawn as lines, which the key accepts.

- Correct order of all nine layers, oldest at bottom
- Scale approximately right for the thick layers; thin beds drawn as labeled lines
- Fossil symbols placed in the correct layers
- Both extinction levels marked and both dates written beside the correct beds

1. Which site exposes the youngest rock and which exposes the oldest? Give the evidence from the logs.

Answer: Site A exposes the youngest rock: its top layer (yellow mudstone with mammal teeth) lies above the 66 Ma clay, so it is younger than 66 million years. Site C exposes the oldest: the speckled granite at the quarry floor has a lab date of 1,100 Ma, and the black shale resting on it appears nowhere else.

Why: Students must use the dated layers, not guesses about fossils, since mammals, dinosaurs and trilobites are not formally ordered for them.

- Names A as youngest with the 66 Ma clay or the mammal layer above it
- Names C as oldest with the 1,100 Ma granite or the shale beneath everything else

2. Which match did your group make first, and why was it the easiest one to trust?

Answer: Most groups match the white ash first (B3 with C1): same rock, same thickness, the same chemical fingerprint Z-7, and the same layer (brown sandy limestone with the same fossils) directly beneath it at both sites. The fingerprint makes it the most trustworthy match.

Why: Any first match is acceptable if the reason is sound; the ash is the expected answer and sets up q8.

Also acceptable: Accept the red sandstone (A4 = B2) with footprints and cross-bedding as a first match, or the dinosaur-bone mudstone (A3 = B1), with evidence stated.

Analysis questions: answer key

3. Site B has a 'gray limestone' and Site A has a 'gray mudstone'. Why would matching those two be a mistake? What rule for matching does this show?

Answer: Mudstone and limestone are different rock types, the limestone holds sea-floor fossils (crinoids, trilobites) while the mudstone holds dinosaur bones and conifer wood, and their thicknesses differ (6 m versus 8 m). Gray is a color many rocks share. The rule: a match needs at least two independent lines of evidence (rock type, fossils, thickness, fingerprint, position in the sequence), and color alone is never enough.

Why: The decoy tests whether students match on surface appearance. Both fossils and rock type must be checked.

- Gives at least two differences between the layers
- States a matching rule that requires more than one line of evidence

4. At what level do the trilobites and crinoids disappear for good, and at what level do the dinosaur bones? For each, say which dated layer sits closest and what that tells you about when the disappearance happened.

Answer: Trilobites, crinoids and brachiopods last appear in the brown sandy limestone, directly below the white ash dated 252 Ma; they never appear in the red sandstone or any layer above. So their disappearance happened at or just before about 252 million years ago. Dinosaur bones last appear in the gray mudstone directly below the gray clay dated 66 Ma, and never above it, so the dinosaurs disappeared at or just before about 66 million years ago.

Why: The dated beds sit immediately above the last appearances, which is why the dates can be attached to the disappearances. Students should say 'at or just before', not 'exactly at'.

- Locates the sea-floor fossils' last appearance below the 252 Ma ash
- Locates the dinosaurs' last appearance below the 66 Ma clay
- States that the dated bed gives an approximate time for each disappearance

5. Give the age range of the red sandstone and explain how you got it. Could the sandstone be 100 million years old? 300 million? 10 million?

Answer: Between 252 and 66 million years old. The sandstone lies above the ash dated 252 Ma (so it is younger than 252 Ma) and below the mudstone that lies under the clay dated 66 Ma (so it is older than 66 Ma). It could be 100 million years old (inside the range). It could not be 300 million (older than the ash beneath it) or 10 million (younger than the clay above it).

Why: Bracketing by dated beds is the core skill. The range is wide because nothing between the two beds is dated.

Also acceptable: Accept 'younger than 252 Ma and older than 66 Ma' in words, with the reasoning.

6. The red sandstone is 10 m thick and the volcanic ash is 2 cm thick. Which took longer to form, and how do you know? What does this say about using thickness to measure time?

Answer: Not knowable from thickness alone, but almost certainly the sandstone. A volcanic ash bed settles in hours to days after an eruption; sand dunes pile up over thousands to millions of years. Thickness measures how much material arrived, not how long it took; rates differ enormously between a single ashfall and slow dune migration, and some intervals leave no layer at all. So thickness cannot be used as a clock without knowing the rate.

Why: Students need the idea that deposition rates vary by orders of magnitude.

- Says the ash formed quickly and the sandstone slowly, with a reason
- States that thickness is not a measure of time without a known rate

7. The black shale rests on a worn, uneven surface of 1,100-million-year-old granite. Does the composite column record every year from 1,100 Ma to today? Explain what the worn surface tells you.

Answer: No. The worn, uneven granite surface shows that the granite was exposed and eroded for a long time before the black shale was laid down on top of it; the layers that may once have covered it were removed, and no layer records that interval. So the column has a gap of unknown length between 1,100 Ma and the shale. Rock records are incomplete: time passes without deposition, and erosion removes layers that did form.

Why: This is an unconformity. Students do not need the term; they need the idea of missing time read from the worn surface.

- Answers no and names the worn surface as the evidence
- Explains that erosion or no deposition means missing time
- Does not claim the gap's length can be read from the column

8. A classmate says, 'Site B and Site C both have an ash bed, so of course they are the same layer.' What evidence makes the ash match stronger than 'both are ash'? What would weaken it?

Answer: Stronger: both ash beds have the same chemical fingerprint Z-7, which ties them to one eruption; both are 2 cm thick; and both sit directly on the same brown sandy limestone with the same fossils and under a layer with no sea-floor fossils. Weaker: a different fingerprint, a different layer beneath one of them, or sea-floor fossils continuing above one ash but not the other would all suggest two different eruptions.

Why: Multiple independent lines of evidence make a correlation; students should name the fingerprint and the position.

- Names the fingerprint and at least one positional or fossil line of evidence
- Names something that would weaken the match

9. Write a scientific explanation (one paragraph) of how your composite sequence organizes this region's history, from oldest to youngest. Use evidence from the order of layers, the matched key bed, the fossil disappearances and the dated layers. Label each sentence E (observed in the logs) or X (your conclusion).

Answer: Model paragraph: (E) At the quarry, 1,100-million-year-old granite with a worn surface lies under black shale with trilobites. (X) So the region's oldest recorded history is a long-eroded basement followed, after a gap, by a muddy sea. (E) Limestones with crinoids, brachiopods and trilobites follow at Sites B and C, topped by a 2 cm ash with fingerprint Z-7 dated 252 Ma at both sites. (X) The ash is one layer, so Sites B and C are the same sequence, and the sea lasted until about 252 million years ago. (E) Above the ash at Sites A and B is red sandstone with footprints, then mudstone with dinosaur bones; no sea-floor fossils appear in either. (X) The sea-floor animals disappeared around the time of the ash, and the region became a desert and then a river plain where dinosaurs lived, sometime between 252 and 66 million years ago. (E) A 1 cm clay with glassy beads dated 66 Ma lies above the dinosaur layer, and above it only mammal teeth and leaves occur. (X) The dinosaurs disappeared at about 66 million years ago, and mammals occupied the land afterward. (X) The sequence organizes the region's history into three chapters separated by the two levels where fossils change most, with dates attached by the two thin beds.

Why: Full credit requires oldest-to-youngest order, the key bed used to join sites, both fossil disappearances, both dates, and correct E/X labels on most sentences.

- Runs from oldest to youngest
- Uses the Z-7 ash to join Sites B and C
- Identifies both fossil-disappearance levels and attaches the nearby dates
- Labels observations E and conclusions X correctly on at least most sentences
- States how the sequence organizes the history into spans

10. How is this activity like what geologists did to build the geologic time scale, and how is it different? Give one likeness and two differences.

Answer: Alike: geologists also matched layers across many places using key beds and fossils, found the levels where fossils changed most, and drew their boundaries there, attaching years later from dated volcanic layers. Different (any two): real geologists combined hundreds of sites across continents, not three; real layers have faults, folds, gaps and fossils that are rare or hard to identify; real dates come with uncertainty and the boundaries get revised; and the time scale covers 4.54 billion years while this column covers one region and a limited span.

Why: Connects the activity to the construction of the time scale and to its revisable nature.

- Gives one accurate likeness about matching or boundaries at fossil changes
- Gives two accurate differences

Individual evidence of learning

Each student submits their own recording sheet (q1, q2, the matching table, the composite sequence table, the drawn column) and written answers to q3 through q10. The q9 explanation paragraph with its E/X labels is the primary evidence toward the standard; the composite table and q4 show whether the student located the extinction levels and used the dated beds correctly.

Assessment criteria

Criterion	Proficient looks like
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Correlation	All five matches correct, each supported by two lines of evidence, and the composite order of nine layers correct.
Reading change in the record	Both fossil-disappearance levels located, each tied to the nearest dated layer, and the red sandstone given the range 252 to 66 Ma.
Explanation from evidence	The q9 paragraph moves from oldest to youngest, cites the key bed, the fossil changes and the dates, and labels observations and conclusions correctly.
Reasoning about limits	Explains that thickness is not time (q6) and that the worn granite surface means missing time (q7).

Accessibility adaptations

- Provide the site strips in large print with a colored stripe per rock type and a tactile sticker per fossil type for students with low vision; let a partner slide the stacks while the student calls the matches.
- Give a partly completed composite table (rows 1, 5 and 9 filled) and a column frame with the scale already marked for students who need more support.
- Allow the q9 explanation to be dictated or recorded, and provide the sentence frame 'The ___ stop below the ___, which shows ___ because ___.'
- Offer a bilingual word strip for limestone, mudstone, sandstone, shale, ash, fossil, older and younger, and pair the site-reader role with a student comfortable reading aloud.

Low-cost alternative

Skip the card strips and have groups work directly from the printed site-log table, sketching the three stacks on scrap paper and drawing the composite column on plain paper with a ruler. The reasoning is identical.

Model limitations

The sites are fictional and simplified: real outcrops have gaps, faults, layers that change thickness sideways and fossils that are rare or hard to identify. Real ash beds are matched by careful chemical analysis, not a printed code, and real dates carry uncertainty. The two extinction levels are placed to mirror the end-Permian and end-Cretaceous events, with one small invented difference: the sea-floor animals here vanish directly below the ash, while in real sequences the last appearances are often spread over a thicker interval. The activity has not been physically tested by the authors.

Teacher notes

Check the composite table against the expected Observations order first; a wrong order usually traces to the limestone-mudstone decoy or to double-counting the shared red sandstone. For q9, grade the E/X labeling generously on borderline sentences (a statement combining an observation and a conclusion can be either) but not on sentences that present a conclusion as an observation. Keep the hidden answer column up for the next class's slide 20 task.