

# The Boundary Committee: Deciding Where Deep Time Gets Divided

**Investigation question:** Given a record of which fossil groups occur in each of twelve rock layers, where should the major boundaries of a time scale be drawn, and what rule should a committee use to decide?

Data-driven decision

Groups of 4

1 session

Setup 5 · Activity 40 · Cleanup 5 min

MS-LS4-1 · practice

MS-ESS1-4 · practice

## Scientific purpose

Students act as the committee that divides a rock sequence into named spans. From a simulated table showing which of twelve fossil groups occur in each of twelve layers, they count groups per layer, compute the percent lost at every step, graph the result, and then apply a rule they set in advance to decide which drops are large enough to be boundaries. The lab makes the construction of the geologic time scale visible as a data-driven decision with stated criteria, and it has students find for themselves the pattern that boundaries follow the largest changes in the fossil record.

## Why this helps students with this chapter

Students meet the time scale as a finished chart and assume its lines were simply found. Giving them the raw pattern and the job of drawing the lines shows that boundaries follow the biggest changes in the fossil record, that 'big' needs a rule, and that reasonable committees can disagree while both being scientific. Computing percent lost rather than counting survivors also fixes a common error: a layer with fewer fossil groups is not automatically the site of an extinction.

## Standards connections

**MS-LS4-1** (practice, finding patterns of appearance and disappearance in a fossil sequence; no species or era names involved): A California Grade 8 performance expectation; here students practice its data-analysis half by tallying fossil groups layer by layer, computing losses, and describing the pattern of disappearances and new appearances through the sequence. Group names are invented, so no species or era names are learned or assessed.

**MS-ESS1-4** (practice, how boundaries on the time scale are chosen from strata evidence): A California Grade 8 performance expectation. Students build toward it by deciding, from evidence in a layered sequence, where a time scale's divisions should fall and defending the decision, which is the reasoning behind how the scale organizes Earth's history.

## Roles (rotate each session)

- **Data reader:** Reads the presence table layer by layer, naming which groups are present, which are new, and which have disappeared since the layer below.

- **Calculator:** Counts groups per layer, computes groups lost and percent lost ( $\text{lost} \div \text{groups in the layer below} \times 100$ ), and records them in the tally table.
- **Grapher:** Plots the number of groups against layer number as a line graph and marks every drop with its percent.
- **Committee chair:** Records the committee's rule before any calculating, runs the vote on each candidate boundary, and writes the decision table and the one-paragraph decision statement.

## Materials

| Item                                                            | Quantity | Per     | Note                                                          |
|-----------------------------------------------------------------|----------|---------|---------------------------------------------------------------|
| Printed fossil-presence table (from the recording sheet)        | 1        | group   |                                                               |
| Recording sheet with tally table, graph grid and decision table | 1        | student |                                                               |
| Calculator                                                      | 1        | group   |                                                               |
| Colored pencils (two colors) and a ruler                        | 1 set    | group   | One color for drops, one for new appearances on the graph.    |
| Sticky notes                                                    | 4        | group   | For voting on candidate boundaries before the final decision. |

**Estimated cost:** 1 to 2 per class (an estimate; Printing one table per group and one recording sheet per student; calculators, pencils and sticky notes are classroom stock.)

## Safety

- Paper and pencils only; no chemicals, heat or sharp tools beyond a ruler.
- No physical hazards. If groups move to present at the board, keep bags and chairs out of the walkway.

## Teacher preparation and setup

1. Print the presence table once per group, ideally in landscape so the twelve columns are readable; print recording sheets per student.
2. Draw a blank version of the graph on the board for the debrief so groups can overlay their lines.
3. Prepare three sample 'committee rules' to discuss if groups stall on setting one (for example: a boundary needs at least one-third of groups lost; a boundary needs at least two groups lost; a boundary needs the largest drops only).
4. Review the slide 20 task, which is a seven-layer warm-up version of this lab, so students know the percent-lost calculation.

## Investigation design

**Independent variable** Layer number (1 = oldest, 12 = youngest)

|                           |                                                                                                                                                                                                |
|---------------------------|------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| <b>Dependent variable</b> | Number of fossil groups present, groups lost since the layer below, and percent lost                                                                                                           |
| <b>Controlled</b>         | Every group uses the same presence table; Percent lost is always computed against the layer below; The committee rule is fixed before calculating; Counts are checked by a second group member |
| <b>Trials</b>             | One analysis per committee; the class compares decisions across committees, which usually differ only on the 20 percent step.                                                                  |
| <b>Comparison</b>         | Each committee's boundaries against the others' and against its own by-eye prediction from q1.                                                                                                 |

## Student procedure

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1. Before any counting, look at the presence table and record in q1 where your group thinks the biggest change in the fossil record happens, by eye alone.
2. As a committee, set a rule for what counts as a boundary-sized loss, and have the chair write it in q2 before calculating. A rule must be a number (a percent or a count of groups lost) that can be checked.
3. For each layer from 1 to 12, the data reader names the groups present. The calculator counts them and records the number in the tally table.
4. For each layer from 2 to 12, list the groups present in the layer below that are absent in this layer (lost) and the groups present in this layer that were absent in the layer below (new). Record both counts.
5. Compute percent lost for each layer:  $\text{groups lost} \div \text{number of groups in the layer below} \times 100$ , rounded to a whole number. Check that layers with no losses read 0 percent.
6. Plot number of groups (vertical) against layer number (horizontal) as a line graph. Label every drop with its percent lost and mark every layer with new appearances in the second color.
7. List every step with a loss as a candidate boundary in the decision table. Apply your rule to each candidate and record whether it passes. Vote with sticky notes if the committee disagrees, and record the vote.
8. Rank the passing boundaries from largest to smallest loss. Write a decision statement (three to five sentences) saying where the boundaries go, what rule was used, and what the committee was unsure about.
9. Answer the analysis questions individually, then compare with your committee and with a neighboring committee that may have used a different rule.

## Expected observations

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- Groups per layer: 3, 5, 6, 7, 8, 4, 5, 5, 6, 5, 5, 5. Losses: layer 6 loses G1, G2, G3, G5 (4 of 8, 50 percent); layer 8 loses G6 (1 of 5, 20 percent); layer 10 loses G8 and G9 (2 of 6, 33 percent). All other steps lose nothing.
- New appearances: layer 2 (G3, G5), 3 (G6), 4 (G7), 5 (G8), 7 (G9), 8 (G10), 9 (G11), 10 (G12). New groups appear in the layers right after each large loss.
- Most committees draw boundaries at 5-6 and 9-10; the 7-8 step divides committees depending on the rule they set.

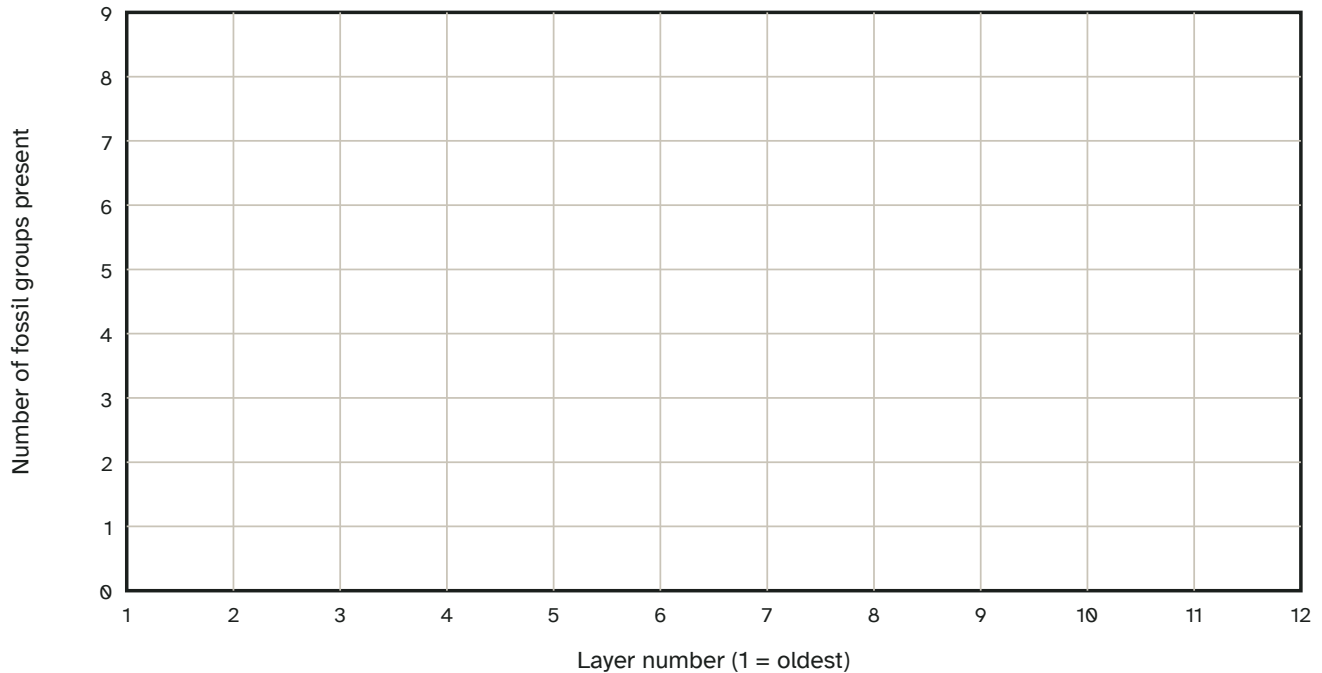


| Fossil group             | L1 | L2 | L3 | L4 | L5 | L6 | L7 | L8 | L9 | L10 | L11 | L12 |
|--------------------------|----|----|----|----|----|----|----|----|----|-----|-----|-----|
| G5 Branching corals      |    | X  | X  | X  | X  |    |    |    |    |     |     |     |
| G6 Armored fish          |    |    | X  | X  | X  | X  | X  |    |    |     |     |     |
| G7 Seed ferns            |    |    |    | X  | X  | X  | X  | X  | X  | X   | X   | X   |
| G8 Track-making reptiles |    |    |    |    | X  | X  | X  | X  | X  |     |     |     |
| G9 Coiled swimmers       |    |    |    |    |    |    | X  | X  | X  |     |     |     |
| G10 Small furry mammals  |    |    |    |    |    |    |    | X  | X  | X   | X   | X   |
| G11 Flowering plants     |    |    |    |    |    |    |    |    | X  | X   | X   | X   |
| G12 Feathered flyers     |    |    |    |    |    |    |    |    |    | X   | X   | X   |

**Tally table**

| Layer | Number of groups present | Groups lost since the layer below (names) | Number lost | Percent lost | New groups (names) |
|-------|--------------------------|-------------------------------------------|-------------|--------------|--------------------|
| 1     |                          | -                                         | -           | -            | -                  |
| 2     |                          |                                           |             |              |                    |
| 3     |                          |                                           |             |              |                    |
| 4     |                          |                                           |             |              |                    |
| 5     |                          |                                           |             |              |                    |
| 6     |                          |                                           |             |              |                    |
| 7     |                          |                                           |             |              |                    |
| 8     |                          |                                           |             |              |                    |
| 9     |                          |                                           |             |              |                    |
| 10    |                          |                                           |             |              |                    |
| 11    |                          |                                           |             |              |                    |
| 12    |                          |                                           |             |              |                    |

## Number of fossil groups present in each layer



### Decision table

| Candidate boundary<br>(between layers) | Groups<br>lost | Percent<br>lost | Passes our<br>rule? (yes/no) | Vote<br>(for/against) | Rank among passing<br>boundaries |
|----------------------------------------|----------------|-----------------|------------------------------|-----------------------|----------------------------------|
|                                        |                |                 |                              |                       |                                  |
|                                        |                |                 |                              |                       |                                  |
|                                        |                |                 |                              |                       |                                  |

- Before counting: looking at the table by eye, between which two layers does the biggest change seem to happen? Why do you think so?

**Answer:** Most students pick between layers 5 and 6, because four rows of X's end at layer 5 at once. Some pick 9 to 10. Any answer with a reason tied to the table earns credit.

**Why:** This is a prediction; it is compared with the calculation in q3.

- Names a pair of layers
- Gives a reason based on the pattern of X's

- Our committee's rule for a boundary-sized loss (write it as a number that can be checked):

**Answer:** Any checkable numeric rule, for example 'at least one-third of the groups lost', 'at least 25 percent lost' or 'at least two groups lost'. A rule such as 'a big drop' is not acceptable because it cannot be checked.

**Why:** The point of the lab is deciding with stated criteria. The rule must be recorded before calculating.

- Rule is numeric (percent or count)
- Rule was recorded before the tally

## Analysis questions: answer key

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3. Between which two layers is the largest loss? Give the number of groups lost, the number in the layer below, and the percent lost, with the calculation.

**Answer:** Between layers 5 and 6. Layer 5 has 8 groups; layer 6 has 4; the groups lost are G1, G2, G3 and G5, so 4 lost. Percent lost =  $4 \div 8 \times 100 = 50$  percent.

**Why:** Computed against the layer below (8), not against the current layer or the full set of 12.

*Also acceptable: Accept 'half' with the division shown.*

4. Between which two layers is the second-largest loss? Show the percent calculation. Did it pass your rule?

**Answer:** Between layers 9 and 10. Layer 9 has 6 groups; G8 and G9 are lost, so 2 lost. Percent lost =  $2 \div 6 \times 100 = 33$  percent (33.3). Whether it passed depends on the committee's rule; it passes any rule of one-third or less, or of two groups.

**Why:** Note that layer 10 still has 5 groups because G12 appeared; students must count losses, not just the change in totals (6 to 5 looks like one group).

*Also acceptable: Accept 33, 33.3 or 'one-third'.*

5. One group, the armored fish, disappears between layers 7 and 8 (a 20 percent loss). Give one reason a committee might count this as a boundary and two reasons it might not, including a cause other than extinction that could make one group vanish from a layer.

**Answer:** For counting it: it is a real disappearance of a whole group that never returns, and a committee with a rule of 'two or fewer groups' or '20 percent' would include it. Against: it is one group out of five, far smaller than the other two drops, and a single group's absence can have causes other than extinction: the environment at this site changed (for example the water became too shallow or the area became land, so armored fish lived on elsewhere but not here), or the layer simply did not preserve fish fossils. One site cannot tell these apart; geologists check many sites before drawing a line.

**Why:** Students must give one reason for and two against, one of which is a non-extinction cause.

- Gives a reason for counting it
- Gives a reason against based on its size relative to the others
- Names a non-extinction cause (environmental change or preservation)

6. Which group is present in every layer, and which group survives both of the large losses after first appearing? What can and cannot be concluded about a group that survives?

**Answer:** G4 (hinged shells) is present in all twelve layers. G7 (seed ferns) first appears in layer 4 and survives both large losses. Surviving tells us the group kept existing through the events, perhaps because it was widespread or tolerant of change; it does not tell us the group was unchanged, that no species within it died out, or that it was unaffected: the table records only presence or absence of the whole group.

**Why:** The presence/absence table hides everything inside a group; this is the limitation to name.

- Identifies G4 and G7
- States one thing survival shows and one thing it cannot show

7. Look at where new groups first appear. Describe the pattern you see after each large loss, and give an explanation for it.

**Answer:** After the 50 percent loss at layer 6, a new group (G9) appears at layer 7 and another (G10) at layer 8, then G11 at layer 9. After the 33 percent loss at layer 10, G12 appears in the same layer. New groups tend to appear in the layers right after large losses. Explanation: a mass extinction empties roles in the environment (food sources, places to live), and surviving groups evolve new forms that fill them, so diversity recovers and the groups that recover are different from the ones lost.

**Why:** This is the recovery pattern seen after real mass extinctions, such as mammals diversifying after the non-bird dinosaurs disappeared.

- Describes new appearances following the large losses with examples from the table
- Explains it as survivors evolving into roles left empty

8. Your boundaries are in layer order only. If you could measure an absolute age from two volcanic ash beds in this sequence, where would you want them, and what would each date let you say that you cannot say now?

**Answer:** Ideally one ash bed between layers 5 and 6 and one between layers 9 and 10, as close to each loss as possible. A date at 5-6 would let the committee say when the largest loss happened in years and how long the span from layer 1 to 5 lasted at most; a date at 9-10 would do the same for the second loss and give the span 6 to 9 a length in years. Together they would give the whole sequence a scale in years instead of just order, and would let the sequence be matched with sequences elsewhere by age. Without them the committee can only say older or younger.

**Why:** Students should place the dates at the boundaries and explain the difference between order and years.

- Places the ash beds at or near the two large losses
- States that dates give years and durations, while layers alone give only order

9. A neighboring committee used a different rule and drew three boundaries instead of two. Can both committees be doing science correctly? What would settle the disagreement?

**Answer:** Yes. Both committees used the same data and the same calculations; they differ only in the threshold for 'boundary-sized', which is a judgment that must be stated and applied consistently. Science requires the rule to be explicit and checkable, not that everyone picks the same rule. What would settle it: more evidence, such as other sites, to see whether the 20 percent loss shows up everywhere (a real event) or only here (a local change or poor preservation), and agreement among researchers on a shared rule, which is how the real time scale is maintained by an international commission that revises boundaries as evidence improves.

**Why:** Connects the lab to the real process: evidence, stated criteria, more data, community agreement, revision.

- Says both can be correct because both apply a stated rule
- Explains what would settle it (more sites or an agreed rule)

10. Of the twelve fossil groups, how many are present in layer 12, and what percent of all twelve is that? How many groups appeared somewhere in the sequence and later vanished? Show your work.

**Answer:** Layer 12 contains 5 groups (G4, G7, G10, G11, G12).  $5 \div 12 \times 100 = 41.7$  percent, about 42 percent. Groups that appeared and later vanished: G1, G2, G3, G5, G6, G8 and G9, which is 7 groups.

**Why:** Checks reading across the whole table. The seven vanished groups are the four lost at layer 6, one at layer 8 and two at layer 10.

*Also acceptable: Accept 42 percent or 'about 40 percent' with the division; accept 'five-twelfths'.*

## Individual evidence of learning

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Each student submits their own tally table, line graph, decision table, q1 and q2, and written answers to q3 through q10. The tally table and q3-q4 are the evidence for the data-analysis practice; q5 and q9 are the evidence for reasoning about criteria and judgment; q7 is the evidence for recognizing the recovery pattern in the fossil record.

## Assessment criteria

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| Criterion                     | Proficient looks like                                                                                                                                                                                                           |
|-------------------------------|---------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| <b>Calculation</b>            | All twelve counts and all three loss percentages correct (50, 20 and 33 percent), computed against the layer below.                                                                                                             |
| <b>Graph</b>                  | Line graph correctly plotted with all drops labeled by percent and new appearances marked.                                                                                                                                      |
| <b>Decision with criteria</b> | A checkable rule recorded before calculating, applied consistently to all three candidates, with the decision statement naming what was uncertain.                                                                              |
| <b>Pattern reasoning</b>      | Describes that new groups appear after each large loss and explains it as survivors diversifying into roles left empty; distinguishes extinction from environmental change or poor preservation as causes of a group's absence. |

## Accessibility adaptations

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- Provide the presence table in large print with each group's row shaded alternately, and allow a highlighter to mark each layer's column while counting.
- Give a tally table with layers 1 to 5 completed for students who need more support, and reduce the dataset to layers 1 to 8 (one large loss and one small one) if time is short.
- Allow the decision statement to be spoken and recorded, and provide the sentence frame 'We drew a boundary between layers \_\_\_ and \_\_\_ because \_\_\_ percent of groups were lost, which passes our rule of \_\_\_.'
- Pair the data-reader role with a student comfortable reading aloud, and offer a word strip for present, absent, lost, appear, percent and boundary in students' home languages.

## Low-cost alternative

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Project the presence table instead of printing it and have students draw the tally table and graph on notebook paper with a ruler; the calculations and decision are unchanged.

## Model limitations

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The dataset is invented and far tidier than any real sequence: every group is either clearly present or clearly absent, no layer is missing, and the losses are concentrated in single steps. Real fossil records have gaps, rare groups that are missed by chance, and disappearances spread over several layers, which is why geologists compare many sites before drawing a boundary. Group names are made up to avoid teaching species names; the two large losses mimic the end-Permian and end-Cretaceous events in size order only. This activity has not been physically tested by the authors.

## Teacher notes

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Grade the tally table first against the expected Observations counts; errors in percent lost almost always come from dividing by the wrong layer. For q2, do not penalize a strict or lenient rule, only a rule that is not numeric or was written after the fact. For the decision table, the three candidates are 5-6, 7-8 and 9-10; a committee that lists a layer with only new appearances has confused gains with losses. Keep two contrasting decision statements for the slide 25 discussion.