

Which Plan Divides the Cliff the Way Geologists Divide Time?

Learning target: I can use evidence from a rock-layer record to argue where the boundaries of a time scale belong and explain why scientists organize Earth's history by events rather than by thickness or by convenient dates.

Claim, evidence, reasoning

About 45 min

Individual

MS-ESS1-4 · assesses

MS-LS4-1 · supports

writing

data analysis

Standards connections

MS-ESS1-4 (assesses, constructing an explanation from strata evidence for how the time scale organizes history; no period or epoch names are required): MS-ESS1-4 is a California Grade 8 performance expectation; this task produces evidence toward it from Grade 7 students. The CER asks for exactly what the PE states: a scientific explanation, based on evidence from rock strata, for how a geologic time scale is organized. The cliff and its numbers are invented, so the response relies on reasoning about strata, not on recalling the names of periods, which the assessment boundary excludes.

MS-LS4-1 (supports): MS-LS4-1 is a California Grade 8 performance expectation. The fossil-count drops in the record are the pattern students cite; no species or era names are involved.

Purpose: assess · **Time:** about 45 minutes · **Format:** individual

Answers with reasoning

The scenario

A county museum is building a walk-along exhibit beside a 124-meter cliff of layered rock. Visitors will climb a stairway from the oldest layer at the bottom to the youngest at the top, and the museum wants to paint the cliff's history as **chapters**, with a sign at each chapter boundary. Three staff members have proposed different ways to divide the cliff. The director has asked a geology student, Priya, to decide which plan matches the way scientists divide Earth's history on the geologic time scale, and to explain why with evidence from the cliff itself.

The three proposals — Plan A (equal thickness): divide the 124 m of rock into four chapters of 31 m each, so that each sign is the same distance up the stairway. **Plan B (fossil changes):** place a boundary wherever the fossils change sharply, which in this cliff happens at two thin dark lines (layers 4 and 9), making three chapters. **Plan C (dated layers):** place a boundary at each layer that has been dated in years, the lava flow (layer 1) and the two ash bands (layers 6 and 11), because those are the only places where the age is certain.

The cliff, layer by layer, bottom to top (teaching dataset)

Simulated teaching dataset: the numbers are invented to be realistic, not measured.

Layer (1 = bottom)	Rock	Thickness (m)	Kinds of fossils	Date in years, if any
1	lava flow (volcanic rock)	3.0	0	480 million years
2	limestone, sea shells	15.0	24	none
3	shale, sea shells	12.0	25	none
4	thin dark line	0.1	25 below, 9 above	none
5	sandstone, sea shells	30.0	9	none
6	white ash band	0.2	9	470 million years
7	limestone, sea shells	20.0	10	none
8	mudstone, sea shells	8.0	12	none
9	thin dark line	0.1	12 below, 5 above	none
10	sandstone, sea shells	25.0	5	none
11	gray ash band	0.3	5	380 million years
12	sandstone, fern leaves and footprints	10.3	6	none

Simulated data for teaching. 'Kinds of fossils' counts the different kinds of shelled sea animals (or, in the top layers, land plants and animals) found in that layer. Dates come from minerals in volcanic layers only.

Warm-up: organize the evidence

- Use the three dates to find how many years are recorded (a) between the lava flow and the first ash band (layers 2 to 5) and (b) between the two ash bands (layers 7 to 10). Then add the thicknesses of each group of layers. Show that thickness and time do not match.

Answer: (a) $480 - 470 = 10$ million years for layers 2 to 5, whose thickness is $15 + 12 + 0.1 + 30 = 57.1$ m (about 57 m). (b) $470 - 380 = 90$ million years for layers 7 to 10, whose thickness is $20 + 8 + 0.1 + 25 = 53.1$ m (about 53 m). The thinner group of layers took nine times longer to form: about 5.7 m per million years for the lower group versus about 0.6 m per million years for the upper group.

Why: The dates bracket each group; thickness divided by time gives very different rates, which is the evidence against Plan A.

Also acceptable: Accept 57 m and 53 m without the 0.1 m lines. Accept the rates expressed as 'about 10 times' or '9 times' slower.

2. Ignoring the lava flow (molten rock holds no fossils), list every place in the cliff where the number of kinds of fossils changes by more than 3 from one layer to the next. For each, give the layer numbers and the change.

Answer: Two places. Layers 3 to 5 across the dark line at layer 4: 25 to 9, a drop of 16 kinds. Layers 8 to 10 across the dark line at layer 9: 12 to 5, a drop of 7 kinds. Every other step changes by 3 or fewer (for example 24 to 25, 9 to 9, 10 to 12, 5 to 6).

Why: Both sharp changes coincide with the thin dark lines, which is the evidence for Plan B.

Also acceptable: Accept 'layer 4' and 'layer 9' as the locations with the before/after counts.

- Both dark lines identified with layer numbers
- Both changes computed (16 and 7)

3. Look at the fossil counts just below and just above each ash band (layers 6 and 11). Does anything happen to life at the dated layers? What does that tell you about what an ash band records?

Answer: Nothing happens to life at the dated layers. Across the ash band at layer 6 the count goes 9 to 9 to 10; across the ash band at layer 11 it goes 5 to 5 to 6. An ash band records a single eruption that put down a thin layer in days without changing what lived there; its value is that it can be dated, not that it marks a change.

Why: This is the evidence against Plan C: dated layers are bookmarks, not events in the history of life.

Also acceptable: Accept 'the eruption did not cause an extinction here.'

- Uses the counts around both ash bands
- Concludes that ash bands record a moment, not a change in life

Your argument

Answer: Claim: Plan B, boundaries at the two fossil changes (layers 4 and 9), divides the cliff the way scientists divide Earth's history. Evidence: (1) The kinds of fossils drop from 25 to 9 across layer 4 and from 12 to 5 across layer 9, the only two changes larger than 3 anywhere in the cliff; these are sudden losses of most kinds of life, like the mass extinctions that mark boundaries on the real time scale. (2) Against Plan A: thickness is not time. Layers 2 to 5 (57 m) formed in 10 million years (480 to 470), while layers 7 to 10 (53 m) formed in 90 million years (470 to 380); equal 31-m chapters would make the lowest chapter about 5 million years long and the third chapter about 50 million years long, and Plan A's boundaries at 31 m and 62 m would fall inside layer 5 and layer 7, where nothing happened. (3) Against Plan C: across the ash band at layer 6 the fossil count goes 9 to 9 to 10, and across layer 11 it goes 5 to 5 to 6; the dated layers show no change in life. Reasoning: Scientists organize the geologic time scale by major events recorded in rock strata, above all the disappearance of many kinds of fossils in a mass extinction; boundaries go where the record of life changes, and that is why eras and periods have very different lengths. Thickness cannot be the rule because sediment piles up at very different rates (in this cliff, about 5.7 m per million years in the lower group and about 0.6 m per million years in the upper group), so equal thickness is not equal time. The dated layers are not boundaries but bookmarks: they attach ages in years to the stack, so that each of Priya's event boundaries can be given an age range (the first between 480 and 470 million years, the second between 470 and 380 million years). The real time scale works the same way: its boundaries were set by fossil changes first, and absolute dates were added later.

Why: This is the solved model response. Full credit requires Plan B, at least three evidence items with layer numbers and data, evidence against both rejected plans, and reasoning that states the boundaries-at-events rule, addresses thickness versus time, and gives the dated layers a role.

Also acceptable: A student who claims Plan B but argues that Plan C's dated layers 'could also be used as sub-boundaries for labeling ages' is reasoning well and should not lose credit. A student who claims Plan C because 'only the dates are certain' has confused measuring time with organizing it; the evidence section may still earn credit.

- Claim names Plan B
- At least three evidence items with layer numbers and numbers from the table
- Evidence against Plan A (thickness versus time) and Plan C (no change at dated layers)
- Reasoning states that time-scale boundaries follow major changes in the record (mass extinctions)
- Reasoning explains thickness is not time and gives the dated layers a role as age markers

4. Priya's plan has chapter boundaries without exact ages. Using the dates in the table, write the age range that each of her two boundaries must fall inside, and explain how the dated layers made that possible.

Answer: First boundary (layer 4): between 480 million years (lava flow below it, layer 1) and 470 million years (ash band above it, layer 6). Second boundary (layer 9): between 470 million years (layer 6 below) and 380 million years (layer 11 above). The dated layers bracket each boundary: a boundary must be younger than any dated layer below it and older than any dated layer above it.

Why: This closes the loop: events set the boundaries, dates bracket them. The first boundary is tightly bracketed (a 10-million-year window), the second loosely (90 million years).

Also acceptable: Accept 'younger than 480 and older than 470' phrasing.

- Both ranges correct
- Explains bracketing by the dated layers above and below

Scoring rubric

Criterion	4 • Exemplary	3 • Proficient	2 • Developing	1 • Beginning
Claim	Names Plan B in one clear sentence that says what the plan does (boundaries at the fossil changes).	Names Plan B without saying what it does, or with a minor contradiction elsewhere.	Names Plan C, or names Plan B with reasoning that actually supports another plan.	No claim, or Plan A, or a claim unrelated to the evidence.
Evidence	Three or more pieces of evidence with layer numbers and data values, including evidence against both rejected plans.	Three pieces with data, but evidence against only one rejected plan.	One or two pieces of evidence, or evidence stated without layer numbers or values.	Evidence missing, invented, or contradicting the table.
Reasoning	States the boundaries-at-events rule, explains why thickness is not time using the rates, and explains the dated layers' role as age markers that bracket the boundaries.	States the rule and addresses one of the two required points (thickness or dated layers).	Restates evidence without a rule, or states a rule without connecting it to the cliff.	No reasoning, or reasoning that treats thickness or dates as the organizing principle.
Scientific language and accuracy	Uses strata, superposition, mass extinction, absolute dating and relative order correctly; all numbers taken correctly from the table.	Terms mostly correct with one slip (for example 'the ash caused the extinction').	Several terms misused or several numbers misread.	Scientific language absent or consistently wrong.

Teacher notes

The cliff is invented; the dates 480, 470 and 380 million years are plausible Paleozoic values but mark no real event, and the fossil 'kinds' are deliberately generic. The design has three built-in contrasts: the two dark lines carry the only large fossil changes; the two ash bands carry no change; and the two dated intervals have very different deposition rates (about 5.7 versus 0.6 m per million years), so that each rejected plan fails on its own evidence. The common wrong claim is Plan C, from students who equate 'certain' with 'important'; q3 is designed to surface that before the CER. Model response for the extension: the scale between the ash bands is 53.1 m over 90 million years, about 0.59 m per million years, so the 400-million-year sign would go about 11.8 m below layer 11 (20 million years × 0.59 m), but the rate could have varied, which is exactly why real ages between dated layers are estimates. This sheet is the chapter's main written assessment for MS-ESS1-4; keep the rubric with the student work.

Scaffold offered to students: Evidence grid before writing

On scrap paper, make a grid with Plans A, B and C across the top and three rows: 'fossil changes', 'thickness versus time', and 'dated layers'. In each box write one fact from the table that supports or hurts that plan (for example, under Plan A and 'thickness versus time': '57 m took 10 million years but 53 m took 90 million years'). The plan with support in every row is your claim; the facts in the other columns are your evidence against the rejected plans.

Extension: When Plan C would be right

The museum's second exhibit is not about chapters but about *when* things happened: a sign every 10 million years. Explain why the dated layers would now be essential, how you would estimate where the 400-million-year sign goes using the two ash bands (layers 6 and 11) and the thicknesses between them, and why that estimate could be badly wrong. Then write two sentences on how the real geologic time scale uses both kinds of information: events for boundaries, dated layers for numbers.