

Where Can the Gym Go? Reading a Fault Trench Before Building

Learning target: I can use cross-cutting relationships in a trench log to decide whether a fault has moved recently, evaluate three building plans against criteria and constraints, and justify a recommendation.

Transfer and design

About 50 min

Pairs

MS-ESS1-4 · practice

MS-ESS2-2 · practice

MS-ETS1-2 · assesses

engineering design

data analysis

writing

Standards connections

MS-ESS1-4 (practice, the evidence-from-rock-strata half): MS-ESS1-4 is a California Grade 8 performance expectation that this Grade 7 lesson previews. Reading which sediment layers a fault breaks and which lie across it unbroken is relative dating applied to a real engineering question.

MS-ESS2-2 (practice): A fault that moves in sudden jumps separated by thousands of years is the Grade 7 PE's idea of processes that usually act gradually but are punctuated by catastrophic events; the trench shows the record of those jumps in a local feature.

MS-ETS1-2 (assesses, evaluating competing solutions against criteria and constraints): Students score three competing site plans in a systematic matrix against stated criteria and constraints and choose one, which is the practice this engineering PE describes.

Purpose: extend · **Time:** about 50 minutes · **Format:** pairs

Answers with reasoning

The problem

Alder Creek Middle School (invented) wants to build a new gym on an empty lot east of the main building. The lot is 120 m long from west to east and 60 m wide from north to south; the main building stands along the lot's west edge. A state map shows a fault trace crossing the lot from north to south, about 45 m from the west edge, but the map is only accurate to about 10 m either way. California's Alquist-Priolo Earthquake Fault Zoning Act does not allow a building for people to sit on top of an **active** fault, meaning one that has moved in roughly the last 11,700 years. The usual rule is a setback of 15 m (50 feet) on each side of an active fault trace. To find out whether the fault is active and exactly where it runs, the district dug a trench across the lot and logged the layers in its wall.

Criteria and constraints — Criteria (what a good plan does): 1. The gym is at least 15 m from the fault trace on every side. 2. Students can walk from the main building to the gym in under 90 seconds (about 100 m). 3. Total cost is as low as possible. Constraints (what cannot change): the gym is 40 m by 25 m and can be turned either way; it must fit inside the lot; the budget is 6.0 million dollars; the trench results below are the only fault evidence available.

Trench log (teaching data; layers listed from the ground surface downward)

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

Layer	Depth below surface (m)	Material	Age of charcoal in the layer	Broken by the fault?
1	0 to 0.4	Dark topsoil	none found	No; runs across unbroken
2	0.4 to 1.2	Tan silt	about 2,500 years	No; runs across unbroken
3	1.2 to 2.0	Gravel	about 9,000 years	Yes; offset 0.3 m
4	2.0 to 3.5	Gray clay	about 18,000 years	Yes; offset 0.9 m
5	3.5 to 5.0	Brown sand	none found	Yes; offset 0.9 m

The fault was found in the trench wall 52 m from the west edge of the lot. Charcoal ages come from a lab method for young carbon-containing material that this lesson does not cover; treat them as given. Offsets are how far the layer on one side of the fault sits above its match on the other side.

Part A: Is the fault active?

1. Which layers does the fault cut, and which lie across it unbroken? Using the law of cross-cutting relationships, state the youngest layer the fault is known to have moved and the oldest layer that proves it has not moved since. 2 pts

Answer: The fault cuts layers 3, 4 and 5; layers 1 and 2 lie across it unbroken. By cross-cutting relationships, the fault is younger than layer 3 (the youngest layer it moved) and older than layer 2 (the oldest unbroken layer), so the last movement happened after layer 3 formed and before layer 2 formed.

Why: Students must sort broken from unbroken and apply the rule in both directions.

Also acceptable: None.

- Layers 3, 4, 5 cut; 1 and 2 unbroken
- Youngest moved layer: 3
- Oldest unbroken layer: 2

2. Between what two ages did the fault last move? Explain how each limit comes from the trench log. 2 pts

Answer: Between about 9,000 and 2,500 years ago. The older limit comes from layer 3's charcoal (about 9,000 years): the fault moved after that layer existed. The younger limit comes from layer 2's charcoal (about 2,500 years): layer 2 is unbroken, so the fault has not moved since it was laid down.

Why: The window is bracketed by the dated broken layer above and the dated unbroken layer below.

Also acceptable: A student who notes that layer 2 could have been deposited some time after 2,500 years, so the real younger limit is a little looser, is being careful; accept.

- Window 9,000 to 2,500 years
- Each limit tied to the correct layer and whether it is broken

3. Layer 4 is offset 0.9 m but layer 3 is offset only 0.3 m. How much of the 0.9 m happened before layer 3 was deposited, and how much after? What does this tell you about the number of times the fault has moved? 2 pts

Answer: Before layer 3: $0.9\text{ m} - 0.3\text{ m} = 0.6\text{ m}$. After layer 3: 0.3 m. So the fault has moved at least twice: once between about 18,000 and 9,000 years ago (0.6 m, which offset layers 4 and 5 but not 3) and once between 9,000 and 2,500 years ago (0.3 m, which offset layers 3, 4 and 5 together).

Why: A layer records only the movement that happened after it was deposited; the difference in offsets isolates the earlier movement.

Also acceptable: Accept 'at least two' or 'two or more'; the 0.6 m could itself be several smaller movements.

- 0.6 m before, 0.3 m after
- At least two movements, with their time windows

4. Does the fault count as active under the 11,700-year rule? Explain using your answer to q2, and say why the exact location found in the trench (52 m) matters more than the map's 45 m. 2 pts

Answer: Yes. The last movement was after about 9,000 years ago, which is within the last 11,700 years, so the fault is active under the rule (even though it has not moved in the last 2,500 years). The trench location, 52 m, matters because the setback is measured from where the fault actually is; using the map's 45 m could put the setback band 7 m too far west and let a building sit within 15 m of the real trace.

Why: The key move is seeing that 'after 9,000 years ago' is inside the 11,700-year window regardless of the 2,500-year quiet period.

Also acceptable: None; 'not active because it has been quiet for 2,500 years' misreads the rule.

- Active, because the last movement is younger than 11,700 years
- Trench location is the measured one; the map could misplace the setback

Part B: Evaluate three plans

Three proposed site plans (distances measured from the lot's west edge)

Plan	Gym position and orientation	Nearest gym wall to the fault (at 52 m)	Walk from main building	Estimated cost	Notes
1	Centered on the lot, long side west-east: 40 m to 80 m	0 m (the fault runs under the gym)	40 m	5.1 million dollars	Flat ground; shortest utility lines
2	East side, long side west-east: 70 m to 110 m	18 m	70 m	5.3 million dollars	Flat ground; needs a longer path and utility line
3	West side, turned so the short side faces west-east: 5 m to 30 m	22 m	5 m	5.9 million dollars	Ground slopes; needs cutting and filling before building

5. Score each plan on each criterion: 2 = fully meets, 1 = partly meets, 0 = fails. Write 'X' in any cell where the plan breaks a constraint. Add a total for each plan. 4 pts

Answer: Plan 1: criterion 1 = 0 (fault under the gym), criterion 2 = 2 (40 m), criterion 3 = 2 (lowest cost); constraint broken: X (a building for people on an active fault is not allowed); total 4 but disqualified. Plan 2: criterion 1 = 2 (18 m), criterion 2 = 2 (70 m), criterion 3 = 1 (middle cost); no constraint broken; total 5. Plan 3: criterion 1 = 2 (22 m), criterion 2 = 2 (5 m), criterion 3 = 0 (highest cost, 5.9 million, close to the budget); no constraint broken; total 4.

Why: Plan 1 fails the law regardless of its score. Plans 2 and 3 both meet the setback; cost separates them. Accept criterion 3 scores of 1 and 0 for Plans 2 and 3 or 2 and 1 if the student explains the scale, as long as Plan 2 scores higher on cost than Plan 3.

Also acceptable: A student who scores Plan 3's walk higher than Plan 2's (both under 100 m, but 5 m is much shorter) is making a defensible refinement; accept if explained.

- Plan 1 marked X and 0 on criterion 1
- Plans 2 and 3 score 2 on criterion 1
- Cost ranking: Plan 2 above Plan 3
- Totals computed

6. Which plan do you recommend? If two plans tie or come close, explain what tipped your decision and which criterion you treated as most important. 2 pts

Answer: Plan 2. It meets the setback with 18 m, meets the walking criterion (70 m is under 100 m), and costs 600,000 dollars less than Plan 3. Plan 3 is also legal and has a much shorter walk, so a student who weights the walk most heavily may choose Plan 3; the decision must name the deciding criterion. Plan 1 cannot be chosen.

Why: Either Plan 2 or Plan 3 is acceptable with a clear tipping criterion; Plan 1 is not.

Also acceptable: Plan 3 with the argument that the sloping ground is a one-time cost and daily walking time matters for years is a strong answer.

- Chooses Plan 2 or Plan 3
- Names the criterion that tipped the decision
- Rejects Plan 1 for breaking the constraint

7. Plan 2's nearest wall is 18 m from the trench location of the fault. Suppose a second trench 30 m to the north found the fault at 58 m instead of 52 m. Would Plan 2 still meet criterion 1? Show the subtraction and state what you would recommend. 2 pts

Answer: $70\text{ m} - 58\text{ m} = 12\text{ m}$, which is less than 15 m, so Plan 2 would no longer meet criterion 1 at that end of the lot. Recommendation: shift the gym east (for example to 75 m to 115 m, giving 17 m) if it still fits inside the 120 m lot, or dig a third trench to pin the trace along the whole length of the planned wall before deciding.

Why: The point is that a fault trace is a line across the lot, not a single point, so one trench may not be enough.

Also acceptable: Switching to Plan 3 is an acceptable recommendation if the student checks that 58 m still leaves Plan 3 at 28 m from the fault.

- 12 m, fails the 15 m setback
- A sensible fix: move the gym east or trench again

Part C: Site plan and justification

8. Draw the lot to scale (1 cm = 10 m): a 12 cm by 6 cm rectangle. Mark the main building along the west edge, the fault trace at 52 m, a shaded 15 m setback band on each side of the fault, and your recommended gym as a rectangle in the correct position and orientation. Label the distance from the gym's nearest wall to the fault. 3 pts

Answer: A 12 cm by 6 cm rectangle; main building drawn along the west (left) edge; a vertical fault line at 5.2 cm from the left; a shaded band from 3.7 cm to 6.7 cm (15 m each side); the recommended gym as a 4 cm by 2.5 cm rectangle for Plan 2 (from 7.0 cm to 11.0 cm, long side west-east) or a 2.5 cm by 4 cm rectangle for Plan 3 (from 0.5 cm to 3.0 cm, long side north-south); the nearest-wall distance labeled (18 m or 22 m).

Why: Check scale, the fault at 52 m, the setback band width (30 m total), and that the gym lies entirely outside the band.

Also acceptable: A student who shades a slightly wider band 'to be safe' and says so is applying good engineering judgment.

- Correct scale and lot size
- Fault at 52 m with a 15 m band on each side
- Gym outside the band in the chosen plan's position and orientation
- Distance labeled

9. Write a paragraph for the school board (five to seven sentences) that: states whether the fault is active and the trench evidence for it, in words a non-scientist can follow; recommends a plan; explains what the plan gives up compared with the others; and names one more piece of evidence the district should gather before building. 5 pts

Answer: Example: 'The trench shows the fault is active. The fault has broken the three deepest layers, and the layer just above them, which contains charcoal about 9,000 years old, is broken too, so the fault has moved within the last 9,000 years. The two top layers, including one about 2,500 years old, are not broken, so it has not moved since then. Because 9,000 years is inside the 11,700-year limit in state law, no building for people can sit on the fault, and we recommend Plan 2 on the east side of the lot, 18 m from the fault. Plan 2 costs about 600,000 dollars less than Plan 3 but gives up the short five-meter walk; Plan 1 is not allowed. Before building, the district should dig a second trench along the planned gym wall to confirm the fault's position there.'

Why: Score with the rubric. The paragraph must translate cross-cutting into plain words (broken versus unbroken layers), state the window, recommend a plan, state the trade-off, and propose more evidence.

Also acceptable: Recommending Plan 3 with the walk as the deciding factor is acceptable. Proposing to date a layer between layers 2 and 3 to narrow the window is an excellent further-evidence suggestion.

- Fault called active, with the broken/unbroken evidence and the 9,000-year limit
- A legal plan recommended
- The trade-off stated against the other plans
- One further piece of evidence named (second trench, more charcoal dates, map check)

Scoring rubric

Criterion	4 • Exemplary	3 • Proficient	2 • Developing	1 • Beginning
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Reading the trench (relative dating)	Correctly sorts broken from unbroken layers, brackets the last movement between 9,000 and 2,500 years, computes the two movements (0.6 m and 0.3 m), and concludes the fault is active with the 11,700-year rule.	Brackets the last movement correctly and calls the fault active; the two-movement calculation is missing or has an arithmetic slip.	Identifies which layers are broken but reverses a limit or decides the fault is inactive because of the 2,500-year quiet period.	Does not use broken versus unbroken layers.
Systematic evaluation of plans	Matrix complete with consistent scores, Plan 1 disqualified by the constraint, totals correct, and the decision names the tipping criterion.	Matrix complete and Plan 1 disqualified; the tipping criterion is implied rather than named.	Matrix partly filled or scores inconsistent with the plan table; Plan 1 not clearly disqualified.	A plan chosen without a matrix.
Site plan sketch	To scale, fault at 52 m, 15 m band on each side, gym fully outside the band in the chosen plan's position, distance labeled.	One element slightly off (band width, scale or label) but the gym is clearly outside the setback.	Gym drawn but overlaps the band, or the fault is misplaced.	Sketch missing or not to scale with no fault or band.
Justification for a non-scientific audience	Plain-language evidence (broken versus unbroken layers and their ages), a recommendation, the trade-off, and a specific further-evidence request, in five to seven clear sentences.	All four parts present but one is thin, or the language relies on undefined terms such as 'cross-cutting'.	Recommendation given with evidence but no trade-off or no further evidence.	Recommendation without evidence.

Teacher notes

The school, lot, trench and plans are invented. The legal framework is real: California's Alquist-Priolo Earthquake Fault Zoning Act (1972) prohibits structures for human occupancy across the trace of an active fault, defines active as having moved in Holocene time (about the last 11,700 years), and a 50-foot (15 m) setback is the common default; students do not need any of these numbers beyond what the sheet gives. Trenching across a fault and dating charcoal in the broken and unbroken layers is exactly how geologists establish a fault's recent history. The charcoal ages are radiocarbon dates; the lesson does not cover carbon-14, so the sheet calls it a method for young carbon-containing material and treats the ages as given. Lesson pages used: Section 5 on faults (printed 96-97, PDF 132-133) and the superposition logic of Section 2 (printed 93, PDF 129).

Scaffold offered to students: Read the trench like a cliff

The trench wall is a tiny version of the road cuts in this chapter. The rule is the same: a fault is younger than every layer it breaks and older than every layer that lies across it unbroken. Mark each row of the log with B (broken) or U (unbroken). The last movement happened after the youngest B layer formed and before the oldest U layer formed. For the matrix, do criterion 1 first; any plan that fails it is out, whatever its other scores.

Extension: Narrowing the window

The trench shows the fault last moved between about 9,000 and 2,500 years ago, a window of 6,500 years. Describe what a geologist could look for in a deeper or longer trench to narrow that window (think about finding and dating a layer between layers 2 and 3, or a thin layer that is broken by only a tiny amount). Then explain why the district would care whether the last movement was 8,900 years ago or 2,600 years ago, even though both count as active.