

The Boulder Field at Kestrel Creek: Sudden, Gradual, or Both?

Learning target: I can use several kinds of landscape evidence and a measured rate to construct an explanation of how a landform was made, at what time scale, and by which processes.

Claim, evidence, reasoning About 45 min Individual MS-ESS2-2 · assesses writing data analysis

Standards connections

MS-ESS2-2 (assesses): Students construct an explanation from evidence (deposit shape, a cliff scar, tree rings, a written record and a measured stream rate) for how geoscience processes changed a valley at two time scales: a landslide in minutes and stream erosion over centuries. This is the PE as written.

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

Answers with reasoning

The scenario

Kestrel Creek runs down a steep mountain valley. Where the valley opens out, the creek crosses a strange field of boulders about 600 m wide and 400 m long. Some boulders are the size of cars. A geology club spent a summer collecting evidence to answer one question: how and when was the boulder field made? Their notes are below.

Evidence collected by the club — **A.** The boulders are angular (sharp-edged, not rounded) and are mixed with gravel, sand and mud in no particular order. There are no layers and no sorting by size. **B.** On the cliff directly above the field there is a scar about 300 m wide where the rock is pale and bare. The cliffs on either side of the scar are darker and covered with lichen (a slow-growing crust of living things). **C.** The oldest trees growing on top of the boulders have 310 rings (cores taken in 2025). **D.** A church record from the valley, dated spring 1711, says that 'the mountain fell in the night and buried the lower meadow.' **E.** Kestrel Creek has cut a channel straight through the boulder field. The channel is now 1.500 m deep. The club measured its depth every year for ten years (dataset below). **F.** Downstream of the field, the creek has built a fan of rounded pebbles that grows a little after every spring flood.

Depth of the creek channel through the boulder field (teaching dataset)

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

Year	Channel depth (m)
2016	1.455
2017	1.46
2018	1.464

Year	Channel depth (m)
2019	1.47
2020	1.475
2021	1.479
2022	1.485
2023	1.49
2024	1.495
2025	1.5

Simulated measurements for teaching; depth measured each August at the same marked spot.

Warm-up: sort the evidence

- Which pieces of evidence suggest the boulder field was made **suddenly**? For each, say in a few words what it shows.

Answer: A (angular, unsorted, unlayered debris is what a landslide dumps all at once; water sorts and rounds material over time), B (a pale, lichen-free scar directly above the field shows where the rock came from, and the missing lichen means the surface is far younger than the cliffs beside it), and D (the 1711 record describes the mountain falling in one night).

Why: Three independent lines point to a single sudden event: the deposit's texture, its source scar and a written eyewitness record.

Also acceptable: Accept C as supporting 'sudden' if the student explains that trees could only start growing after the field was already there.

- Identifies A, B and D
- Gives a correct short reason for each

- Which pieces of evidence show **gradual** change happening at the field today? For each, name the process (weathering, erosion or deposition) and the agent.

Answer: E: erosion by water; the creek is cutting its channel deeper a few millimeters each year. F: deposition by water; the creek drops rounded pebbles in a fan downstream after each spring flood (and the rounding itself shows weathering of the pebbles as they tumble).

Why: Both show present-day gradual processes acting on the deposit; students should name the process and the agent, not just the letter.

Also acceptable: Credit a student who adds that the lichen growth in B is also a slow present-day process.

- Identifies E and F
- Names erosion for E and deposition for F with water as the agent

3. Use the dataset. Calculate the rate at which the creek deepens its channel, in millimeters per year. Then estimate how many years the creek has needed to cut the full 1.500 m channel at that rate. Show your work, and compare your estimate with evidence C and D.

Answer: Change in depth: $1.500\text{ m} - 1.455\text{ m} = 0.045\text{ m} = 45\text{ mm}$ over $2025 - 2016 = 9$ years. Rate: $45\text{ mm} \div 9\text{ years} = 5\text{ mm per year}$. Time to cut 1.500 m: $1,500\text{ mm} \div 5\text{ mm per year} = 300\text{ years}$. This matches evidence C (310 rings, so trees started growing about 1715) and evidence D (1711, which is 314 years before 2025): three separate clocks agree on about 300 years.

Why: The rate uses the full nine-year span. The age estimate assumes the creek cut at today's rate for the whole time; the match with the rings and the record is the evidence that the assumption is reasonable. Students who divide by 10 (readings) instead of 9 (years) get 4.5 mm per year and 333 years, still consistent. *Also acceptable: Accept 5 mm/yr and 300 years; accept 4.5 mm/yr and about 330 years if the student used 10 years and explains the choice.*

Your argument

Answer: Claim: The boulder field was made suddenly by a landslide from the cliff above, in a single night about 300 years ago (spring 1711), and since then Kestrel Creek has been gradually cutting through it and carrying its pieces downstream. Evidence: (1) The debris is angular, unsorted and unlayered (A): sudden. (2) A 300 m wide pale scar with no lichen sits directly above the field (B): sudden, and younger than the surrounding cliffs. (3) The 1711 record says the mountain fell in the night (D): sudden, and gives a date 314 years before 2025. (4) The oldest trees on the field have 310 rings (C): an age; the surface has been stable for at least 310 years. (5) The channel deepens 5 mm per year, and $1,500\text{ mm} \div 5\text{ mm/yr} = 300\text{ years}$ (E): gradual, and an age. (6) A pebble fan grows downstream after every flood (F): gradual deposition. Reasoning: Landslides we can watch today drop angular, unsorted rock in minutes and leave fresh scars, so a deposit with those features was made by a landslide, whether last year or three centuries ago. Streams we can measure today cut and round rock a little at a time, so the channel and the pebble fan are the slow work of water on the deposit. Three independent clocks (310 rings, the 1711 record at 314 years, and 300 years from the measured rate) agree within about 15 years, which is strong evidence that the field appeared about 300 years ago and that the creek's rate has stayed roughly steady since. The same valley therefore records both a sudden change (minutes) and a gradual one (centuries), and the sudden event set up the gradual one by giving the creek a pile of loose rock to cut through.

Why: This is the solved model response. Full credit requires a two-part claim with time scales, at least four evidence items with numbers and labels (sudden, gradual or age), and reasoning that invokes present-day processes and reconciles the three clocks.

Also acceptable: A student who claims the landslide was triggered by an earthquake or a storm is adding an untested idea; accept if labeled as a possibility. A claim that the creek built the boulder field ignores A, B and D and cannot earn credit for the claim, though evidence organization may earn partial credit.

- Claim names a landslide (sudden) and stream erosion since (gradual) with a date or age
- At least four evidence items with numbers where available
- Each evidence item labeled sudden, gradual or age
- Reasoning uses present-day processes (uniformitarianism) to connect evidence to claim
- Reasoning explains how the three clocks fit together

4. Suppose next summer the club finds a tree growing on the boulders with 450 rings. Would that force you to change your claim? Explain what the new evidence would mean and what you would check next.

Answer: Yes, it would challenge the claim. A tree with 450 rings growing on the boulders would mean the surface was already there by about 1575, before 1711, so the field could not have been made in 1711 (or the boulder under the tree is older than the rest). Next checks: confirm the tree is rooted in the deposit and not on older ground poking through; look for two separate deposits (an older slide and a 1711 slide) with different weathering; re-examine whether the 1711 record could describe a second, smaller event.

Why: The point is that claims are revisable and that a single conflicting clock calls for more checking rather than instant abandonment.

Also acceptable: Accept 'the claim would need two landslides' as a revised claim with a check.

- Recognizes that 450 rings conflicts with 1711
- Proposes at least one specific follow-up check

Scoring rubric

Criterion	4 • Exemplary	3 • Proficient	2 • Developing	1 • Beginning
Claim	States both parts (sudden landslide about 300 years ago; gradual stream erosion since) with a time scale for each.	States the landslide with a date or age; the gradual part is missing or has no time scale.	Names a landslide or stream erosion without a time scale, or mixes the two without separating them.	No claim, or a claim contradicted by the evidence (for example, the creek built the field).
Evidence	Four or more specific items with numbers where they exist, each labeled sudden, gradual or age.	Four items, but one lacks its number or label.	Two or three items, or items copied from the notes without saying what they show.	Evidence missing, invented, or contradicting the notes.
Reasoning	Uses present-day processes to connect each kind of evidence to the claim, and reconciles the three clocks explicitly.	Uses present-day processes and connects evidence to the claim, but treats the clocks separately or mentions only two.	Restates the evidence without explaining how processes link it to the claim.	No reasoning, or reasoning that misuses a process (for example, 'water sorted the boulders').
Scientific language and accuracy	Uses weathering, erosion, deposition, rate, sudden and gradual correctly; the rate calculation is correct with units.	Terms mostly correct; one slip (for example, 'weathering carried the pebbles') or a unit missing.	Several terms used loosely; the rate is stated without units or work.	Scientific language absent or consistently wrong.

Teacher notes

Kestrel Creek is fictional; the scenario was built so that three independent clocks agree: the channel rate (5 mm per year $\times$ 300 years = 1.5 m), the tree rings (310, so germination about 1715, a few years after the slide, which is realistic) and the 1711 record (314 years before 2025). A 5 mm per year cutting rate through loose debris is realistic. The texture evidence is sound: landslide deposits are angular and unsorted, while stream deposits are rounded and sorted. Lichen-free rock as a sign of a young surface is a real field method. The warm-up q3 is the sheet's rate calculation; check that students use 9 years, not 10. In the debrief, emphasize

that the agreement of the clocks is the strongest part of the argument and that q4 shows how one new clock could reopen the case.

Scaffold offered to students: An evidence grid before writing

On scrap paper, make a table with the six letters A to F down the side and three columns: 'Sudden?', 'Gradual?', 'Tells the age?'. Put a check in every column each piece of evidence supports and write two or three words saying why (for example, A: sudden, 'no sorting, no layers'). Evidence that tells an age gives you a number of years; write that number. Your claim is the story that fits every row, and each row becomes one evidence sentence in your CER.

Extension: What the creek will do next

The boulder field is about 400 m long and the creek channel through it is 1.5 m deep after about 300 years. The mountain above still has steep, cracked rock. Write a prediction for the valley 3,000 years from now that uses the measured rate (how deep would the channel be, and why might the rate not stay constant?) and includes the possibility of another sudden event. Then explain which of the two futures (another landslide, or 3,000 more years of slow cutting) would change the valley more, and why that is not a simple question.