

Three Cliffs, One Story: How Short Rock Records Become Deep Time

Learning target: I can explain, with evidence from a passage, how geologists join rock records from different places, attach ages in years to them, and use big changes in fossils to mark the boundaries of the geologic time scale.

Reading with evidence

About 35 min

Individual

MS-ESS1-4 · practice

MS-ESS2-2 · supports

reading

writing

Standards connections

MS-ESS1-4 (practice, the explanation half: how strata are read, joined and dated to build the scale): MS-ESS1-4 is a California Grade 8 performance expectation. This passage lays out the chain from rock layers to relative order, to matched sections, to pinned absolute ages, to fossil-defined boundaries; the questions ask students to reconstruct that explanation from evidence in the text, which is the reasoning the PE asks for.

MS-ESS2-2 (supports): The passage's 'missing pages' paragraph shows erosion and non-deposition acting over long time scales, which is background for the Grade 7 idea that surface processes operate at many time scales.

Purpose: build · **Time:** about 35 minutes · **Format:** individual

Answers with reasoning

Three Cliffs, One Story

[1] No single cliff shows the whole of Earth's history. Even the walls of the Grand Canyon, more than a mile deep, hold rock that formed between about 1.8 billion and about 270 million years ago, with gaps inside that span where stretches of time left no rock at all. So how did geologists build a time scale reaching back 4.54 billion years? The way you might rebuild a torn-up book from pages found in different houses: find the overlaps and stack the pages in order.

[2] Reading one cliff starts with a rule you know: where sediment layers lie undisturbed, the lowest settled first and is the oldest, and each layer above is younger. One kind of layer is especially valuable. When a volcano erupts, ash can fall across thousands of square kilometers in a few days and settle as a thin, pale band. That band marks a single moment, and because its minerals formed as the eruption cooled, a laboratory can measure its age in years.

[3] Joining cliffs depends on a second rule. A sediment layer spreads sideways as a broad sheet until it thins out or meets a barrier, so a layer in one cliff may continue underground to another cliff far away; geologists call this lateral continuity. Imagine three cliffs. The lowest layer of Cliff A, a distinctive ash band, is also the top layer of Cliff B, which continues down through five more layers. The lowest of those, a limestone packed with a particular set of shells, is the top layer of Cliff C. Match the shared layers and you can stack A on B on C into one column longer than any single cliff. Matching works best with layers

that are hard to confuse: an ash band with a unique chemistry, or fossils that always appear in the same order.

[4] The stacked column still has missing pages. A region may go millions of years without receiving sediment, or a layer may be worn away before the next one settles, so two layers that touch can be separated by a huge gap in time. Geologists notice these gaps where the fossils jump: the kinds of organisms change far more between two touching layers than they do anywhere else in the stack.

[5] Everything so far gives order, not years. Ages in years come from the datable layers, mainly ash bands and lava flows, and they are pinned into the stack like bookmarks. If an ash band near the bottom of a column measures 252 million years and another near the top measures 201 million years, every layer between them formed inside that window, even though none of them can be dated directly. The more bookmarks a column has, the tighter the ages of the pages between them.

[6] Chapter breaks came before the page numbers. By the middle of the 1800s, geologists had noticed that certain groups of fossils disappear together at particular levels, in rock from distant places. These were mass extinctions, when a large share of Earth's species died out in a geologically short time, and they became the natural boundaries of the time scale. The names of the eras and periods were in use for decades before anyone could attach a number to them. Absolute dating added the numbers later. The boundary at the end of the age of the dinosaurs is a thin clay layer found worldwide, rich in iridium, a metal common in asteroids; dating of nearby ash puts it at 66 million years ago. Because boundaries follow events, and events do not come at regular intervals, the units have very different lengths.

[7] One caution about the wall chart. The most recent eon, which began about 539 million years ago, usually fills most of the chart and is split into many named pieces. It is not most of Earth's history; it is about one-eighth of it. It gets the space because its rocks are widespread, well preserved and crowded with fossils of animals with shells and bones, which allows fine divisions. The three earlier eons, with scarce rocks and microscopic fossils, cover the other seven-eighths and are squeezed into a stub at the bottom. Drawn to scale, the chart would be almost all stub.

Questions: cite the passage

1. According to paragraph 1, give two reasons why even the Grand Canyon cannot show the whole of Earth's history.

Answer: (1) Its rocks cover only part of Earth's history, from about 1.8 billion to about 270 million years ago, so the earliest and the most recent time are not there. (2) There are gaps inside that span where stretches of time left no rock at all.

Why: Both reasons are stated in paragraph 1: a limited span and gaps within the span.

Also acceptable: Accept 'it does not reach back to 4.54 billion years' as the first reason.

- Names the limited age span
- Names the gaps within the span

2. Using the ages in paragraph 1, calculate how many years of history the Grand Canyon's rocks span (ignoring gaps). Then calculate what percentage of Earth's 4.54-billion-year history that is. Show your work.

Answer: Span: 1,800 million years – 270 million years = 1,530 million years (about 1.53 billion years).

Percentage: $1,530 \div 4,540 \times 100 = 33.7$ percent, about one-third of Earth's history.

Why: Converting 1.8 billion to 1,800 million keeps the units matched. The result shows that even a famous deep record is a fraction of the whole.

Also acceptable: Accept 34 percent or 'about a third.' Accept 1.53×10^9 years for the span.

3. Paragraph 2 says a volcanic ash band is 'especially valuable.' Give the two reasons the passage gives, in your own words.

Answer: An ash band settles across a huge area in a few days, so it marks one single moment that is the same everywhere the ash fell; and its minerals formed as the eruption cooled, so a lab can measure its age in years.

Why: Paragraph 2 gives both: a time marker and a datable layer.

Also acceptable: Accept 'it can be matched between places' as part of the first reason.

- Says the ash marks a single moment across a wide area
- Says its minerals can be dated in years

4. Describe how the three cliffs in paragraph 3 are joined into one column. Name the two shared layers, say which cliff goes on top, and state the rule that allows a layer in one cliff to be matched with a layer in another.

Answer: Cliff A goes on top. Its lowest layer, a distinctive ash band, is the top layer of Cliff B, so B is stacked under A. The lowest layer of B, a limestone with a particular set of shells, is the top layer of Cliff C, so C goes under B. The rule is lateral continuity: a sediment layer spreads sideways as a sheet and may continue underground from one cliff to another, so the same layer can be recognized in both places. Matching uses layers that are hard to confuse, such as an ash band with a unique chemistry or a fossil sequence in a fixed order.

Why: Students must track the two overlaps (ash band A/B; limestone B/C) and name lateral continuity. The order A on B on C follows from each shared layer being the bottom of the upper cliff and the top of the lower one.

Also acceptable: A labeled sketch of the three stacked cliffs with the shared layers marked is acceptable in place of prose, if the rule is written out.

- Names the ash band as the A/B link and the shell limestone as the B/C link
- States A on top, then B, then C
- Names lateral continuity and explains it as a layer continuing sideways

5. What is a 'missing page' in paragraph 4, and what clue in the fossils tells a geologist that one is there? Quote the clue.

Answer: A missing page is a stretch of time with no rock in that place, because no sediment was deposited or because a layer was worn away before the next one settled. The clue: 'the kinds of organisms change far more between two touching layers than they do anywhere else in the stack.'

Why: The jump in fossils across a contact is the field clue to a time gap.

Also acceptable: Accept 'the fossils jump' as the quotation.

- Defines the gap as missing time with a cause (no deposition or erosion)
- Quotes or closely paraphrases the fossil jump

6. In paragraph 5, a layer lies between an ash band dated 252 million years and one dated 201 million years. What can a geologist say about that layer's age, and what can she *not* say? Explain what the passage means by 'bookmarks.'

Answer: She can say the layer formed sometime between 252 and 201 million years ago, inside that window. She cannot say exactly when within the window, because the layer itself cannot be dated. The bookmarks are the dated ash bands: they are pinned into the stack at known ages and bracket the undated layers between them, and more bookmarks give tighter brackets.

Why: This is the bracketing idea: absolute ages on a few layers constrain the relative ages of the rest.

Also acceptable: Accept 'younger than 252 and older than 201.'

- Gives the window 252 to 201 million years
- Says the exact age within the window is unknown
- Explains bookmarks as dated layers that bracket the others

7. Paragraph 6 says 'Chapter breaks came before the page numbers.' Explain what was done first and what was done later, with a quotation from the paragraph that supports your answer.

Answer: First, in the 1800s, geologists placed the boundaries of the time scale where groups of fossils disappear together (mass extinctions) and named the eras and periods. Later, absolute dating attached numbers to those boundaries. Supporting quotation: 'The names of the eras and periods were in use for decades before anyone could attach a number to them,' or 'Absolute dating added the numbers later.'

Why: The sequence (fossil boundaries first, numbers later) is the historical point of paragraph 6 and corrects the belief that the time scale was measured first and named afterward.

Also acceptable: Accept the iridium-layer sentence as the quotation if the student explains that the 66-million-year number came from dating nearby ash.

- Boundaries from fossil disappearances came first
- Numbers from absolute dating came later
- A supporting quotation from paragraph 6

8. A classmate looks at the wall chart and says, 'The most recent eon must be most of Earth's history, because it takes up most of the chart.' Using evidence from paragraph 7 and at least one other paragraph, explain why the chart is drawn that way and what the classmate has misunderstood.

Answer: The chart gives the most recent eon the most space because its rocks are widespread, well preserved and full of fossils of animals with shells and bones, which lets geologists split it into many named pieces (paragraph 7). Space on the chart shows how finely a stretch of time can be divided, not how long it lasted. The classmate has confused size on the page with length of time: the most recent eon is only about one-eighth of Earth's history, and the three earlier eons cover the other seven-eighths. Supporting evidence from elsewhere: boundaries are placed at events, not at equal intervals, so units have very different lengths (paragraph 6); and old rock is scarce because much of it has been destroyed or left no record (paragraphs 1 and 4).

Why: Full credit requires the reason for the chart's layout, the correct fraction, and a second paragraph's evidence. Watch for answers that only say 'the chart is not to scale' without explaining why.

Also acceptable: A student who computes $539 \div 4,540 \approx 12$ percent to support the one-eighth figure is going beyond the passage correctly.

- Explains the chart's layout by fossil richness and preservation
- States that space is not time, with the one-eighth figure
- Uses evidence from at least one other paragraph

Teacher notes

The passage is about 700 words. Facts are current: Grand Canyon rock spans about 1.8 billion to about 270 million years (the Kaibab rim layer; National Park Service), the most recent eon began about 539 million years ago (538.8 Ma on the 2024 international chart; the textbook says 541), the end-Cretaceous boundary clay is iridium-rich and dated to 66 million years, and the one-eighth fraction ($539 \div 4,540 \approx 12$ percent) corrects the textbook's 'about 10 percent' (p. 107). The three cliffs in paragraph 3 are a teaching illustration, not real sites; say so if students ask. Paragraph 7 deliberately explains the chart's layout by fossil richness and preservation rather than the textbook's claim that most crustal rock formed in the current eon, which is not accurate (the ancient cores of the continents are Precambrian). The dates 252 and 201 million years in paragraph 5 are real boundary ages used only as an example of bracketing.

Scaffold offered to students: Two-column notes as you read

On scrap paper, make two columns headed 'What geologists do' and 'What it tells them.' After each paragraph, add one line to each column (for example: 'read layers bottom to top' and 'which page is older'). By paragraph 7 you will have the whole method in order, and questions 4, 6 and 7 can be answered from your notes. For the percentage in q2, divide the smaller number by the larger one and multiply by 100.

Extension: How many bookmarks is enough?

Suppose a column of twenty layers has only two datable ash bands, one at the bottom (400 million years) and one at the top (300 million years). Then a third ash band is found in the middle and dates to 390 million years. Write a short paragraph explaining how the third bookmark changes what can be said about the layers above and below it, and why the layers were not deposited at a steady rate. Then propose one other kind of layer, besides ash, that a geologist might be able to date, and explain your choice.