

Fossils Across a Line, and 4.54 Billion Years on a Meter Stick

Learning target: I can graph fossil counts across a boundary, calculate how much life changed and how fast it recovered, and convert Earth's history to a scale model to show how the eons really compare.

Data and graphing

About 45 min

Individual

MS-ESS1-4 · practice

MS-LS4-1 · practice

data analysis

independent practice

Standards connections

MS-ESS1-4 (practice, the scale, proportion and quantity reasoning behind the time scale): MS-ESS1-4 is a California Grade 8 performance expectation. Part A has students find the kind of fossil change that defines a boundary; Part B has them compute the true proportions of the eons, which is the quantitative reasoning behind 'how the geologic time scale is used to organize Earth's 4.6-billion-year history.' Eon names are given in a reference table, not recalled.

MS-LS4-1 (practice): MS-LS4-1 is a California Grade 8 performance expectation. Part A is a direct exercise in analyzing data for a pattern of extinction and recovery in the fossil record, using counts of 'kinds' rather than species names, within the assessment boundary.

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

Answers with reasoning

Part A: How many kinds of fossils in each layer?

A survey team sampled ten layers in a cliff, counted how many different kinds of shelled sea animals appeared as fossils in each layer, and estimated each layer's age from dated ash bands above and below. Layer 1 is the lowest (oldest). A thin dark line separates layer 5 from layer 6.

Kinds of fossils in ten sampled layers (teaching dataset)

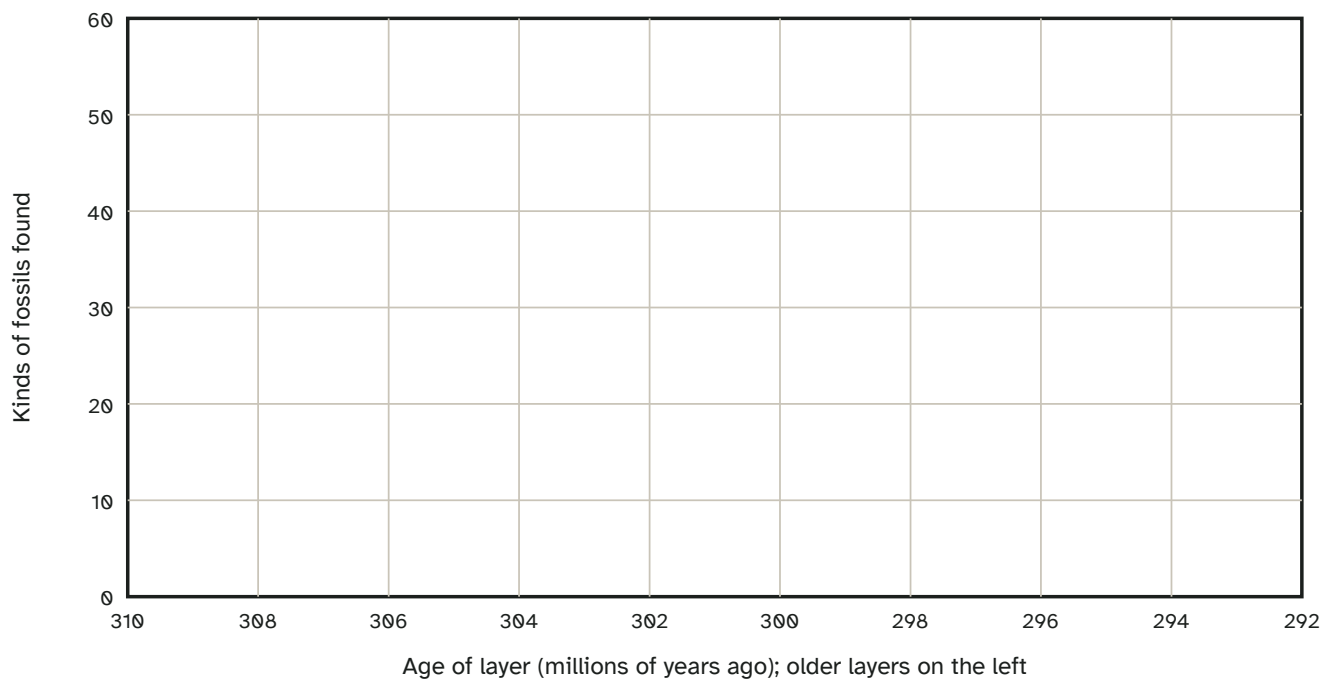
Simulated teaching dataset: the numbers are invented to be realistic, not measured.

Layer (1 = bottom)	Estimated age (millions of years ago)	Kinds of fossils found	Rock type
1	310	48	limestone
2	308	50	limestone
3	306	49	shale
4	304	51	shale
5	302	50	limestone

Layer (1 = bottom)	Estimated age (millions of years ago)	Kinds of fossils found	Rock type
6	300	14	shale (just above the dark line)
7	298	16	shale
8	296	19	limestone
9	294	23	limestone
10	292	27	sandstone

Simulated data for teaching. The ages are estimates bracketed by dated ash bands; the pattern is modeled on real extinction-and-recovery records.

Kinds of fossils versus age of layer



1. Calculate the percentage drop in kinds of fossils from layer 5 to layer 6. Formula: $(\text{before} - \text{after}) \div \text{before} \times 100$. Show your work.

Answer: $(50 - 14) \div 50 \times 100 = 36 \div 50 \times 100 = 0.72 \times 100 = 72$ percent.

Why: Layer 5 has 50 kinds, layer 6 has 14; the change is 36 kinds, which is 72 percent of the starting count.

Also acceptable: Accept 72% with the three steps shown in any order.

2. Describe the shape of your graph in three parts: before the dark line, at the dark line, and after it. Use numbers from the data.

Answer: Before the dark line (310 to 302 Ma) the line is nearly flat, wobbling between 48 and 51 kinds. At the dark line it drops almost vertically, from 50 to 14 kinds in the space between two touching layers. After the line (300 to 292 Ma) it rises steadily but slowly, from 14 to 27 kinds, and has not returned to the earlier level by the top layer.

Why: Three parts with numbers: flat, sudden drop, slow recovery.

Also acceptable: Accept 'cliff' or 'step' for the drop.

- Flat before, with the 48-51 range
- Sudden drop at the line, with 50 to 14
- Slow rise after, with 14 to 27 and not yet recovered

3. Calculate the average rate of recovery from layer 6 to layer 10, in kinds of fossils gained per million years. Show your work.

Answer: Change in kinds: $27 - 14 = 13$ kinds. Change in time: $300 - 292 = 8$ million years. Rate: $13 \div 8 = 1.6$ kinds per million years (1.625 before rounding).

Why: Rate is the change in count divided by the elapsed time; the direction (ages getting smaller as time passes) can confuse students, so check that they used 8 million years, not a negative number.

Also acceptable: Accept 1.6 or 1.63 kinds per million years.

4. If recovery continued at the rate from q3, how many million years after layer 10 would it take to reach 50 kinds again, and what would that layer's age be? Show your work.

Answer: Kinds still needed: $50 - 27 = 23$ kinds. Time needed: $23 \div 1.625 = 14.2$ million years (14.4 million years if 1.6 is used). Age of that layer: $292 - 14.2 =$ about 278 million years ago.

Why: Extends the linear recovery; the subtraction from 292 is necessary because ages count backward from the present. Students should notice that recovery takes longer than the drop by a huge factor.

Also acceptable: Accept 14 to 14.4 million years and an age of 277 to 278 Ma, depending on rounding.

5. A geologist wants to divide this cliff's history into two chapters. Where should the boundary go, and why? Use the word *evidence* and at least one number.

Answer: At the dark line between layers 5 and 6. The evidence is that 72 percent of the kinds of fossils vanish there (50 to 14), the largest change anywhere in the record; the layers on each side of it differ far more than any other two neighboring layers (which differ by 1 to 4 kinds). Boundaries on the time scale go where the record shows a major change in life.

Why: The chapter boundary follows the event, just as era and period boundaries follow mass extinctions.

Also acceptable: Accept 'between 302 and 300 million years ago.'

- Boundary at the dark line (between layers 5 and 6)
- Uses the word evidence and a number (72 percent, 50 to 14, or 36 kinds)
- Says boundaries go at major changes in the record

6. The drop happens between two layers that touch. Describe two different histories that could produce the same drop (one in which the organisms really disappeared quickly, and one in which something is wrong with the record), and say what evidence would tell the two apart.

Answer: History 1 (real sudden extinction): most kinds died out within a short time, perhaps after a huge eruption or impact, so the layer right above the line simply records what survived. History 2 (a gap in the record): the organisms may have disappeared slowly over millions of years, but the layers from that time were never deposited here or were worn away, so two layers that touch are separated by missing time and the gradual change looks like a cliff. Evidence that tells them apart: look at other regions for layers from the missing time (if they show the drop happening slowly, it is a gap here); check whether the dated ash bands bracket the line tightly (a tight bracket rules out a long gap); look for signs of erosion at the line (channels, pebbles, a weathered surface); and look for a worldwide marker at the same level, such as an ash or unusual chemistry, which supports a real sudden event.

Why: This is the core critical-thinking move of the chapter: a sharp change in strata is either an event or a gap, and geologists test which by comparing sites and tightening the dates.

Also acceptable: A student who proposes that the survey team simply missed fossils in layer 6 (sampling error) has a third valid history; credit it if a test is proposed (sample more rock from layer 6).

- Describes a real sudden extinction
- Describes a time gap (missing layers) making a gradual change look sudden
- Names at least one test that distinguishes them (other sites, tighter dates, erosion signs, global marker)

Part B: Earth's history on a one-meter strip

The table gives current reference values for the four eons and the three eras of the most recent eon. Imagine a paper strip exactly 1.00 meter (100 cm) long that represents all 4,540 million years, with Earth's formation at the left end and today at the right end.

Eons and eras (real reference values, rounded to the nearest million years)

Unit	Began (millions of years ago)	Ended (millions of years ago)	Length (millions of years)
Hadean Eon	4540	4000	540
Archean Eon	4000	2500	1500
Proterozoic Eon	2500	539	1961
Phanerozoic Eon	539	0	539
Paleozoic Era (in the Phanerozoic)	539	252	287
Mesozoic Era (in the Phanerozoic)	252	66	186
Cenozoic Era (in the Phanerozoic)	66	0	66

7. Find the scale of the strip: how many centimeters represent 100 million years? Show your work. (Hint: 100 cm stands for 4,540 million years.)

Answer: $100 \text{ cm} \div 4,540 \text{ million years} = 0.0220 \text{ cm per million years}$. For 100 million years: $0.0220 \times 100 = 2.2 \text{ cm}$. So 2.2 cm represents 100 million years.

Why: The whole-strip ratio gives the scale; multiplying by 100 gives a convenient unit.

Also acceptable: Accept 2.2 cm, or 2.20 cm, per 100 million years; accept 0.022 cm per million years as the scale.

8. Complete the table using your scale from q7. The four lengths should add up to 100 cm (allow rounding).

Answer: Hadean: $540 \text{ million years} \times 0.0220 \text{ cm} = 11.9 \text{ cm}$. Archean: $1,500 \times 0.0220 = 33.0 \text{ cm}$. Proterozoic: $1,961 \times 0.0220 = 43.2 \text{ cm}$. Phanerozoic: $539 \times 0.0220 = 11.9 \text{ cm}$. Total: $11.9 + 33.0 + 43.2 + 11.9 = 100.0 \text{ cm}$.

Why: Each length is the eon's duration times the scale. Exact values: 11.89, 33.04, 43.19, 11.87, summing to 100.0 cm. The check row catches a wrong scale.

Also acceptable: Accept totals between 99.5 and 100.5 cm from rounding.

9. Calculate the percentage of Earth's history that belongs to the Phanerozoic Eon, to the nearest whole percent. The textbook says 'about 10 percent.' Is that a fair rounding? Explain.

Answer: $539 \div 4,540 \times 100 = 11.87 \text{ percent}$, which rounds to 12 percent (about one-eighth). 'About 10 percent' is a loose rounding: it is in the right range, but 12 percent is closer, and the difference matters because 10 percent sounds like one-tenth while the true value is nearly one-eighth.

Why: This recomputes the textbook's figure with current numbers; the prior review flagged the book's 'about 10 percent' as low.

Also acceptable: Accept 'fair but rough' or 'not fair, it should say about 12 percent' if the reasoning is given.

- Correct calculation giving 12 percent
- A judgment about the rounding with a reason

10. Modern humans have existed for about 300,000 years (0.3 million years). How long is that on the strip, in millimeters? Show your work and compare the result to the width of a pencil line (about 0.5 mm).

Answer: $0.3 \text{ million years} \times 0.0220 \text{ cm per million years} = 0.0066 \text{ cm} = 0.066 \text{ mm}$. That is about one-eighth the width of a pencil line (0.5 mm), far too thin to draw.

Why: Conversion: $0.0066 \text{ cm} \times 10 = 0.066 \text{ mm}$. The comparison to a pencil line is the point: all of human existence vanishes inside the line marking 'today.'

Also acceptable: Accept 0.07 mm; accept 'about a tenth of a pencil line.'

11. On most classroom charts the Phanerozoic Eon takes up about three-quarters of the space. Using your numbers from q8 and q9, explain what the strip shows that the chart hides, and give one good reason the chart is drawn the way it is anyway.

Answer: The strip shows that the Phanerozoic is only 11.9 cm of 100 cm, about 12 percent, and the three earlier eons fill the other 88 cm; the Archean alone is nearly three times as long as the Phanerozoic. The chart hides that by giving the Phanerozoic three-quarters of the space. The chart is drawn that way because the Phanerozoic's rocks are well preserved and full of fossils of animals with hard parts, so geologists have divided it into many eras, periods and epochs that all need room to be labeled, while the earlier eons have few divisions. The chart shows how finely time can be divided, not how much time there is.

Why: Full credit requires the strip's numbers, the contrast with the chart, and the fossil-richness reason for the chart's layout.

Also acceptable: Accept 'the chart is drawn by how much we know, not by how long it lasted.'

- Uses the strip lengths or the 12 percent
- States that the earlier eons are most of Earth's history
- Gives the fossil-richness or label-space reason for the chart's layout

Teacher notes

Part A is simulated. The 72 percent drop and the slow recovery are modeled on the shape of real mass-extinction records (the end-Permian event removed most marine species and full recovery of diversity took millions of years), but the ages 310 to 292 Ma are arbitrary and do not mark a real extinction; say so if a student tries to name the event. Part B uses current reference values: Earth 4,540 million years (USGS), eon boundaries at 4,000 and 2,500 million years, the base of the Phanerozoic at 538.8 (rounded to 539; the textbook's 541 is dated), the Paleozoic-Mesozoic boundary at 251.9 (252) and the Mesozoic-Cenozoic boundary at 66.0 million years, all from the International Chronostratigraphic Chart. The Hadean's start is taken as Earth's formation; some charts begin it at 4,567 million years, the age of the solar system. The extension's Cenozoic strip has a scale of 1.52 cm per million years, placing primates at 16.7 cm from the left end (83.3 cm from today), the Antarctic ice sheet at 48.5 cm from the left (51.5 cm from today), the ice-age cycles 3.9 cm from today, and humans 0.45 cm from today, finally drawable.

Scaffold offered to students: Percent and rate, one step at a time

Percent change: subtract to find the change, divide the change by the starting number, multiply by 100.

Example with made-up numbers: 40 to 10 is a change of 30; $30 \div 40 = 0.75$; $0.75 \times 100 = 75$ percent.

Rate: divide the change in fossils by the change in time; the unit is 'kinds per million years.' Scale: if 100 cm stands for 4,540 million years, then 1 million years is $100 \div 4,540$ cm, which you can multiply by any number of million years.

Extension: Zooming in on the last centimeter

Design a second strip that shows only the Cenozoic Era (the last 66 million years) stretched to a full meter. Calculate the new scale in centimeters per million years, then place three events on it with calculations: the first primates at about 55 million years ago, the growth of a permanent Antarctic ice sheet at about 34 million years ago, and the start of the current ice-age cycles at about 2.6 million years ago. Finally, calculate how long 300,000 years is on this second strip and explain why scientists use nested time scales (a strip inside a strip) instead of one strip for everything.