

Four People Who Learned to Tell Time in Stone

Learning target: I can explain, with evidence from a passage, how the rules for ordering rock layers were discovered and why absolute dating was needed to turn that order into years.

Reading with evidence

About 35 min

Individual

MS-ESS1-4 · supports

reading

writing

Standards connections

MS-ESS1-4 (supports): MS-ESS1-4 belongs to California Grade 8 in the Preferred Integrated model; this lesson previews it in Grade 7. The passage gives the history and logic behind reading rock strata, which is background for constructing explanations from them rather than evidence toward the PE itself.

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

Answers with reasoning

Four People Who Learned to Tell Time in Stone

[1] In 1666 a Danish doctor named Nicolas Steno was working in Florence, Italy, when fishermen brought in the head of an enormous shark. Steno dissected it and noticed that its teeth looked exactly like the 'tongue stones' that people dug out of rock on the island of Malta. He argued that the stones were shark teeth that had been buried in sediment and turned to rock. That raised a bigger question. How does loose sediment become solid rock with objects trapped inside it, and how do the layers end up stacked the way they are?

[2] In 1669 Steno published a short book with his answer. He reasoned that sediment settles out of water one layer at a time, so each layer must be younger than the one beneath it. He reasoned that settling sediment spreads out flat, so a layer that is now steeply tilted must have been moved after it hardened. And he reasoned that a layer keeps spreading sideways until something stops it, so matching layers on two sides of a valley were once joined. Today these three ideas are called superposition, original horizontality and lateral continuity. Steno never saw the Grand Canyon, yet his rules work there and everywhere else, because gravity and water behave the same way in every place and in every century.

[3] More than a hundred years later, a Scottish farmer and doctor named James Hutton took Steno's rules to a sea cliff. In 1788 he and two friends sailed along the coast of Scotland to a place called Siccar Point. There they saw gray layers standing nearly on end, worn flat across their tops, with red layers lying gently across them. Hutton read the scene as a sequence. The gray layers formed flat, were tilted upright, were worn down, and then were buried by red sand. Each step takes an enormous amount of time. One of his friends later wrote that looking at the cliff made the mind 'grow giddy.' Hutton could not say how many years the cliff recorded, but he was sure the number was far larger than anyone had imagined.

[4] In the 1790s an English surveyor, William Smith, was planning canals through the countryside. He noticed that each rock layer held its own set of fossils, and that the same layers, with the same fossils, appeared in the same order wherever he dug. A fossil shell could tell him which layer he was standing

on, even many miles away. Smith used this to produce, in 1815, the first geological map of an entire country, England and Wales. His idea that fossil species appear in a fixed order is what this lesson calls the law of fossil succession.

[5] Steno, Hutton and Smith could put events in order, but none of them could give a date in years. That had to wait for the discovery of radioactivity. In 1907 an American chemist, Bertram Boltwood, measured the amounts of uranium and lead in several minerals. Because uranium turns into lead at a steady rate, the ratio of the two worked like a clock. His samples came out between about 400 million and 2.2 billion years old, far older than most scientists then expected. In 1913 a young English geologist, Arthur Holmes, published a book arguing from such measurements that Earth was at least 1.6 billion years old.

[6] The clock kept being read more carefully. In 1956 the American chemist Clair Patterson measured lead in meteorites, which formed at the same time as Earth, and reported an age of 4.55 billion years. That number has barely changed since. Notice what each person added. Steno gave rules for order. Hutton showed that the order implied vast time. Smith showed that fossils let you match layers across a whole country. Boltwood, Holmes and Patterson turned 'older' and 'younger' into years. Geologists today use all of these tools together: relative dating to build the sequence of events, and absolute dating of igneous rock to pin that sequence to a calendar.

Questions: cite the passage

1. According to paragraph 1, what did Steno observe, and what bigger question did the observation raise? 2 pts

Answer: Steno observed that the teeth of a dissected shark looked exactly like the 'tongue stones' dug out of rock on Malta, and concluded the stones were buried shark teeth. The bigger question was how loose sediment becomes solid rock with objects inside it and how the layers end up stacked.

Why: Both halves are in paragraph 1; the question is the bridge to the rules in paragraph 2.

Also acceptable: Accept 'how do things get buried in rock' as the question.

- Shark teeth matching the tongue stones
- The question about sediment turning to layered rock

2. Paragraph 2 gives three rules. In your own words, state the rule that explains why a steeply tilted layer must have been moved after it formed, and give its modern name. 2 pts

Answer: Settling sediment spreads out flat, so if a layer is now steeply tilted, something must have moved it after it hardened. Modern name: the principle of original horizontality.

Why: The student must restate the rule rather than copy it and must connect it to its name.

Also acceptable: None; superposition and lateral continuity do not explain tilt.

- Rule restated in own words (sediment settles flat; tilt came later)
- Named original horizontality

3. How many years passed between Steno's book and Hutton's visit to Siccar Point? How many years passed between Steno's book and Patterson's measurement? Show both subtractions. 2 pts

Answer: $1788 - 1669 = 119$ years. $1956 - 1669 = 287$ years.

Why: Both dates come from the passage (paragraphs 2, 3 and 6). Check that the student used 1669 (the book), not 1666 (the shark).

Also acceptable: If a student uses 1666 for the shark observation, the answers are 122 and 290; accept with a note that the question asked about the book.

4. List the four events Hutton read at Siccar Point (paragraph 3) in order. Beside each event, name the rule from paragraph 2 that supports it, or write 'cutting' if the event is one feature cutting across another. 4 pts

Answer: 1. The gray layers formed flat: original horizontality (and superposition for their internal order). 2. They were tilted upright: original horizontality says the tilt came after the layers formed. 3. Their tops were worn flat: cutting (the worn surface cuts the tilted layers, so it is younger than them). 4. Red sand buried the worn surface: superposition (the red layers are on top, so they are youngest).

Why: The order is given in paragraph 3. Step 3 is the one a student may struggle to label; the worn surface is a feature that cuts across the gray layers, so 'cutting' is the expected label.

Also acceptable: Labeling step 1 with superposition alone is acceptable. Labeling step 4 with lateral continuity is not; the red layers' position on top is the point.

- Four events in the correct order
- Each event labeled with a rule or 'cutting'
- Tilt linked to original horizontality and burial linked to superposition

5. What did William Smith notice that allowed a single fossil shell to tell him which layer he was standing on? Quote the words from paragraph 4. 2 pts

Answer: He noticed that 'each rock layer held its own set of fossils' and that the same layers with the same fossils 'appeared in the same order wherever he dug.' (paragraph 4)

Why: Either quotation shows the idea that fossils are tied to specific layers in a fixed order.

Also acceptable: A paraphrase such as 'the fossils came in the same order everywhere he looked' earns full credit if the paragraph number is given.

- Quotes or closely paraphrases paragraph 4
- Captures the idea that each layer has its own fossils in a fixed order

6. Paragraph 5 says the ratio of uranium to lead 'worked like a clock.' Using the passage, explain what property makes something usable as a clock. 2 pts

Answer: Something works as a clock when it changes at a steady, known rate. The passage says uranium turns into lead 'at a steady rate,' so the ratio of lead to uranium tells how much time has passed since the mineral formed.

Why: The key word is steady (constant) rate; a clock whose speed changed would be useless.

Also acceptable: 'Predictable' or 'always the same speed' are acceptable synonyms for steady.

- Identifies a steady or constant rate as the property
- Connects the ratio to elapsed time

7. Holmes argued in 1913 for at least 1.6 billion years. Patterson reported 4.55 billion years in 1956. About how many times larger is Patterson's number? Round to one decimal place and show the division. 2 pts

Answer: $4.55 \div 1.6 = 2.84$, which rounds to about 2.8 times larger.

Why: Simple division; both values are in the passage. Accept 2.8 or 2.9 depending on rounding of the intermediate step.

Also acceptable: A student who notes that Holmes said 'at least' and so the true ratio could be smaller is thinking carefully; still expect the 2.8 calculation.

8. The last paragraph says geologists use all of these tools together. Using evidence from at least two different paragraphs, explain what relative dating alone leaves out and what absolute dating alone leaves out. 4 pts

Answer: Relative dating alone gives order but no years: paragraph 3 says Hutton 'could not say how many years the cliff recorded,' and paragraph 5 says that of Steno, Hutton and Smith, 'none of them could give a date in years.' Absolute dating alone gives a number for one igneous rock but not the story around it: paragraph 6 says geologists use relative dating 'to build the sequence of events' and absolute dating 'to pin that sequence to a calendar,' and paragraph 5 shows that the uranium clock works only on minerals that contain uranium, which is why order still has to come from the layers. Each method supplies what the other lacks.

Why: Full credit requires both gaps (no years; no sequence) with evidence from at least two paragraphs.

Also acceptable: A student who adds, from the lesson, that absolute dating works on igneous rock and most layers are sedimentary has used outside knowledge correctly; credit it alongside the passage evidence.

- Relative dating lacks years, with a citation
- Absolute dating lacks the sequence or applies only to certain rocks, with a citation
- Evidence from at least two different paragraphs

Teacher notes

The passage is about 660 words. All names and dates are historically established: Steno's shark dissection (1666) and his book (1669); Hutton, John Playfair and James Hall at Siccar Point (1788), with Playfair's later 'grow giddy' remark; William Smith's canal work in the 1790s and his 1815 map of England and Wales; Boltwood's uranium-lead ages (1907, roughly 400 million to 2.2 billion years); Holmes's 1913 book 'The Age of the Earth' (about 1.6 billion years); Patterson's 1956 meteorite age of 4.55 billion years, which is why the lesson's '4.6 billion' is a rounded figure. The passage calls Smith's idea what the textbook calls the law of fossil succession; most geologists say 'principle of faunal succession.' If students ask why a meteorite tells Earth's age, say meteorites are leftover pieces from the time the planets formed.

Scaffold offered to students: Timeline first

Before answering, draw a line across scrap paper and mark these dates from the passage: 1666, 1669, 1788, 1815, 1907, 1913, 1956. Above each date write the person's name and, in three or four words, what they added (for example, '1669 Steno: rules for order'). Questions 3, 4 and 8 become much easier once the timeline is in front of you.

Extension: A rule that still works

Paragraph 2 says Steno's rules work everywhere 'because gravity and water behave the same way in every place and in every century.' This is an assumption geologists make about the past. Write a paragraph explaining what would go wrong with relative dating if the assumption were false, and describe one observation a geologist could make today that supports the assumption (hint: watch sediment settle in a jar, a pond or a flooded street).