

Three Lives of a Quartz Grain: Reading a Rock's History

Learning target: I can use evidence from a passage to explain how one piece of rock material can pass through igneous, sedimentary and metamorphic stages, and which energy source drives each change.

Reading with evidence

About 40 min

Individual

MS-ESS2-1 · practice

reading

writing

Standards connections

MS-ESS2-1 (practice): The passage follows one grain through melting, crystallization, weathering, sedimentation and deformation, the exact processes the PE's clarification names, and asks students to tie each to its energy source. It builds the ideas for the model without yet asking students to construct one.

Purpose: build · **Time:** about 40 minutes · **Format:** individual

Answers with reasoning

Three Lives of a Quartz Grain

[1] Pick up a single grain of sand from a river bar and hold it up to the light. If it is clear and glassy, it is probably quartz, one of the toughest common minerals on Earth. That tiny grain may be older than any mountain you can see, and it may have been part of at least two different rocks. Geologists cannot watch a grain's whole story unfold, because most of it happened too slowly, too deep underground or too long ago. But by reading the clues in rocks and applying the rock cycle, they can reconstruct a history like the one that follows. Treat it as a true-to-life example, not a report on one real grain.

[2] The grain's first life began far underground, inside a body of magma the size of a city. Heat from Earth's interior had melted older rock to make the magma, and the magma was wrapped in warm rock that let its heat escape only slowly. As the melt cooled over roughly a million years, atoms of silicon and oxygen locked together in a repeating pattern, and quartz crystals grew until they pressed against the crystals of other minerals growing beside them. The result was granite, an intrusive igneous rock with interlocking crystals large enough to see. Our grain was one of those crystals, a few millimeters across, sitting several kilometers below the surface.

[3] The granite did not stay buried. Over tens of millions of years, tectonic forces pushed the region upward while rain, rivers and ice stripped away the rock on top. Eventually the granite lay in the open air. There, water seeped into cracks and froze on cold nights, wedging the rock apart. Rainwater reacted with the feldspar crystals and slowly turned them into soft clay, but the quartz resisted. One day the grain fell free of the crumbling granite. A stream carried it downhill, bumping it against other grains until its corners were worn round, and dropped it on a river delta when the current slowed. Every step of this second life ran on energy from the Sun, which drives the rain, the rivers and the wind, and on gravity, which pulled water and grains downhill.

[4] On the delta the grain was buried. Layer after layer of newer sand and mud piled on top, about 2,000 meters of it, accumulating at an average rate of about 0.1 millimeter per year. The weight of those layers squeezed the grains together, pushing out water, in the step called compaction. Water moving between the grains left behind thin coats of minerals that glued neighbor to neighbor, the step called cementation. The loose sand had become sandstone, a sedimentary rock, with the original layers still visible and our grain still round, still quartz, and still recognizable.

[5] The grain's third life began when two plates collided and the sandstone was dragged much deeper. The temperature climbed to several hundred degrees Celsius and the pressure from the rock above and the sideways squeeze of the collision became enormous. The rock never melted; if it had, the layers and the grains would have been destroyed and a new igneous rock would have formed. Instead, while the rock stayed solid, the atoms at the edges of each quartz grain rearranged and the grains grew into one another until the old round outlines disappeared. The sandstone had become quartzite, a metamorphic rock, by recrystallization. The energy for this change came again from Earth's interior and from the motion of the plates.

[6] Today that quartzite forms a ridge, because uplift has brought it to the surface once more and it resists weathering better than the softer rocks around it. But resisting is not the same as lasting forever. Frost and rain are loosening grains from the ridge, and a stream at its base is carrying them away. Our grain may be buried into a new sandstone, squeezed into a new quartzite, or carried into a zone where it finally melts and starts the whole story again as magma. The rock cycle has no required order and no finish line; the only rule is that each change needs the right energy, from the Sun at the surface or from Earth's interior below.

Questions: cite the passage

1. According to paragraph 1, why can geologists not simply watch a grain's history happen? Give the three reasons the passage lists.

Answer: Most of the history happened too slowly, too deep underground, or too long ago for anyone to watch it.

Why: Paragraph 1 lists exactly those three reasons; the point is that geologists must reconstruct the story from clues.

Also acceptable: Accept close paraphrases such as 'takes too long' and 'happens underground where we cannot see.'

- Names all three: too slow, too deep, too long ago

2. Paragraph 2 explains why the granite's crystals were large. Quote the words that give the reason, and state the rule in your own words.

Answer: Quote: the magma 'was wrapped in warm rock that let its heat escape only slowly' and 'cooled over roughly a million years.' Rule: the slower melted rock cools, the more time crystals have to grow, so the larger they get.

Why: Students should connect slow cooling (time) to crystal size, the chapter's central igneous rule.

Also acceptable: Quoting 'quartz crystals grew until they pressed against the crystals of other minerals' is acceptable if paired with the slow-cooling idea.

- Quotes or closely paraphrases the slow-cooling sentence
- States the slow cooling = large crystals rule

3. List, in order, the two things that had to happen (paragraph 3) before weathering could attack the granite. Why were both necessary?

Answer: First, tectonic forces pushed the region upward (uplift); second, rain, rivers and ice stripped away the rock on top (erosion of the overlying rock). Both were needed because the granite formed several kilometers underground; uplift alone would leave it buried, and removing the cover alone would not happen without the land rising to where surface processes could reach it.

Why: Students often credit only erosion or only uplift. The passage presents both working together over tens of millions of years.

Also acceptable: Accept 'the land rose and the rock above wore away' in either order if the student says they worked together.

- Names uplift
- Names removal of the overlying rock
- Explains that the granite started deep, so both were needed

4. Paragraph 3 says the feldspar turned to clay but 'the quartz resisted.' Which kind of weathering is that sentence describing, and which kind is the freezing water describing? Use evidence from the paragraph.

Answer: Feldspar turning to clay is chemical weathering: rainwater reacted with the mineral and changed it into a different substance. Water freezing in cracks is physical weathering: it wedged the rock apart into pieces without changing what the pieces are made of.

Why: The passage uses 'reacted' for the chemical case and 'wedging the rock apart' for the physical case.

Also acceptable: Accept 'mechanical weathering' for physical weathering.

- Clay = chemical weathering, citing 'reacted'
- Freezing = physical weathering, citing 'wedging apart'

5. Paragraph 4 says about 2,000 meters of sediment piled up at an average of about 0.1 millimeter per year. Calculate about how many years the burial took. Show every step, including the unit conversion from meters to millimeters.

Answer: Convert: $2,000 \text{ m} \times 1,000 \text{ mm per m} = 2,000,000 \text{ mm}$. Time = $2,000,000 \text{ mm} \div 0.1 \text{ mm per year} = 20,000,000 \text{ years}$ (about 20 million years).

Why: Thickness divided by rate gives time, once the units match. A common error is dividing 2,000 by 0.1 and reporting 20,000 years; that answer forgot the conversion.

Also acceptable: Accept 2×10^7 years. A student who converts the rate to 0.0001 m per year and divides 2,000 by it also gets 20,000,000 years.

6. Name the two steps (paragraph 4) that turned loose sand into sandstone, and explain what each one does to the grains.

Answer: Compaction: the weight of the overlying layers squeezed the grains together and pushed out the water between them. Cementation: water moving between the grains left thin coats of minerals that glued neighboring grains together.

Why: Both steps are needed; squeezing alone leaves loose packed sand, and glue alone would leave a weak, open rock.

Also acceptable: Accept 'pressed' for squeezed and 'cement' for glue.

- Names compaction with squeezing by weight
- Names cementation with mineral glue from water

7. Paragraph 5 insists that 'the rock never melted.' Using evidence from the paragraph, explain how you can tell the sandstone became metamorphic rock rather than igneous rock, and what would have been different if it had melted.

Answer: The passage says the rock 'stayed solid' while the atoms at the grain edges rearranged and the grains grew into one another, which is recrystallization, the metamorphic process. The evidence that it did not melt is that the change happened to existing grains: their outlines merged but the rock kept its identity as a quartz-rich rock. If it had melted, the passage says the layers and grains 'would have been destroyed,' and the melt would have cooled into a new igneous rock with brand-new crystals instead of regrown old ones.

Why: Full credit requires the solid-state point, the recrystallization description and the contrast with what melting would have done.

Also acceptable: A student who adds that the temperature was 'several hundred degrees,' below the melting point of the rock, is using the passage well.

- Cites 'the rock never melted' or 'stayed solid'
- Describes grains growing into each other (recrystallization)
- Explains that melting would destroy layers and grains and make igneous rock

8. Make a two-column list of every change the grain went through and the energy source behind it, citing the paragraph for each. Then use your list and paragraph 6 to explain why the passage says the rock cycle 'has no required order.'

Answer: List: magma to granite by cooling and crystallization, energy from Earth's interior (paragraph 2); granite to the surface by uplift and removal of cover, energy from Earth's interior (plate forces) and the Sun (rain, rivers, ice) (paragraph 3); granite to loose grain by weathering, Sun (paragraph 3); grain carried and dropped by erosion and deposition, Sun and gravity (paragraph 3); sand to sandstone by compaction and cementation, gravity (weight of layers) and water (paragraph 4); sandstone to quartzite by recrystallization under heat and pressure, Earth's interior and plate motion (paragraph 5); quartzite back to loose grains by weathering, Sun (paragraph 6). The passage says there is no required order because paragraph 6 lists three different futures for the same grain (new sandstone, new quartzite, or melting into magma), which means the grain does not have to go igneous, then sedimentary, then metamorphic, then back. Any rock can take any route as long as the right energy is available.

Why: The list should show at least five changes with a paragraph and energy source each. The explanation must connect the three possible futures in paragraph 6 to the idea of a branching cycle rather than a loop.

Also acceptable: A student who groups uplift with the interior only (not the Sun) is acceptable; the Sun's role there is in removing the cover, which some students will list separately as weathering and erosion.

- At least five changes listed with paragraph numbers
- Each change has an energy source (Sun/gravity or Earth's interior)
- Explanation cites the alternative futures in paragraph 6
- States that any rock type can become any other type

Teacher notes

The passage is about 700 words and is accurate where the textbook simplifies: metamorphism happens in solid rock, quartzite forms by recrystallization of quartz sandstone, and the rock cycle is presented as branching with three possible futures. The numbers (a million years of cooling, 2,000 m of burial, 0.1 mm per year, several hundred degrees Celsius) are realistic teaching values, not measurements of a specific place; say so if students ask. Burial rates vary widely in nature, from under 0.01 to over 1 mm per year, so the q5 answer is an example calculation, not a universal figure. Quartz's resistance to chemical weathering and feldspar's conversion to clay are standard geology. The passage avoids naming the exact minerals of granite beyond quartz and feldspar so that the lesson stays within the PE's assessment boundary, which excludes mineral identification.

Scaffold offered to students: Mark the three lives

Before answering, draw three boxes on scrap paper labeled Life 1, Life 2 and Life 3. In each box write the rock type the grain was part of (igneous, sedimentary, metamorphic), the paragraph where that life is described, and one word for the energy source (interior or Sun). Most questions can be answered by going to the right box and rereading that paragraph. For q5, write the numbers with units first: 2,000 m and 0.1 mm per year. You cannot divide meters by millimeters until both are the same unit.

Extension: The same story, different grain

Rewrite paragraphs 3 and 4 for a feldspar grain from the same granite instead of a quartz grain. Use the passage's clue that rainwater turns feldspar into clay. Decide what kind of sediment the feldspar becomes, what kind of sedimentary rock that sediment would make (fine-grained, not sandstone), and whether the grain would still be 'recognizable' after burial. Then explain in two sentences why two grains that started in the same rock can follow different routes through the rock cycle.