

Volcanic Eruptions and Earthquakes: Mastery Check

Learning target: I can show what I know about where and why eruptions and earthquakes happen, how magnitude and frequency data are used to forecast them, and how people reduce their harm.

Retrieval and mastery check

About 40 min

Individual

MS-ESS3-2 · assesses

MS-ESS2-3 · supports

independent practice

writing

Standards connections

MS-ESS3-2 (assesses, items q2, q4, q6, q7, q10 and the q12 synthesis): The forecasting items and the synthesis ask students to interpret precursor and frequency data, express a forecast as a likelihood over time rather than a date, and connect forecasts to mitigation, which is evidence toward the PE as written.

MS-ESS2-3 (supports): Items q1 and q11 use plate-boundary types from Lesson 16 to explain where magma forms and why earthquake depths differ. They check background knowledge rather than reconstructing past plate motions.

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

Answers with reasoning

Part A: Retrieval (items 1-11)

1. Which statement best explains why Mount Shasta and Lassen Peak exist in northern California? 2 pts

Answer: B. A plate sinking beneath North America releases water, which lets the hot mantle rock above it melt at a lower temperature.

Why: Shasta and Lassen are Cascade volcanoes above the Cascadia subduction zone. A describes the San Andreas, which has no volcanoes; C is the liquid-mantle misconception; D is false, since earthquakes do not melt rock into magma.

2. Over two months, a volcano observatory records the changes below. Which combination most strongly suggests that an eruption is becoming more likely? 2 pts

Answer: C. More and shallower earthquakes, more sulfur dioxide, and the ground rising.

Why: Several independent precursors changing together, with quakes moving upward, point to rising magma. B is a single signal, which can fade without an eruption; A shows decreasing unrest; D is a distant, single quake.

3. The 1700 Cascadia earthquake was about magnitude 9. (a) About how many times more energy does a magnitude 9 release than a magnitude 7? (b) Than a magnitude 6? Show the multiplication for both. 3 pts

Answer: (a) Two steps: $32 \times 32 = 1,024$, about 1,000 times more energy. (b) Three steps: $32 \times 32 \times 32 = 32,768$, about 32,000 times more energy.

Why: Each whole-number step multiplies energy by about 32.

Also acceptable: Accept 1,000 or 1,024 for (a) and about 32,000 or 32,768 for (b). Using 31.6 per step gives about 1,000 and 31,600, also correct.

4. True or false: 'The USGS gives the Bay Area a 72 percent chance of a magnitude 6.7 or larger earthquake between 2014 and 2043, so scientists know it will happen before 2030.' Circle your answer and explain. 3 pts

Answer: False. A 72 percent chance over 30 years means a large Bay Area quake is more likely than not during 2014-2043, but the forecast names no year. It could come at any time in that window, or not at all; nobody can say it will happen before 2030.

Why: This item checks the forecast-versus-prediction distinction at the heart of the PE's clarification statement.

Also acceptable: Accept 'about 28 percent of the time the window would pass without such a quake' as part of the explanation.

- Marks false
- Explains that the percentage is a likelihood over the whole window
- States that no year can be named

5. Explain the difference between an earthquake's focus and its epicenter. Then name the kind of seismic wave that reaches a distant seismometer first, and the kind that travels along Earth's surface. 3 pts

Answer: The focus is the place underground where the rock first slips; the epicenter is the point on the surface directly above the focus. Body waves (the P wave first) reach a distant seismometer first; surface waves travel along Earth's surface and arrive later.

Why: Students must locate the two points correctly and order the wave types.

Also acceptable: Accept 'P waves' for the first arrival.

- Focus underground, epicenter on the surface above it
- Body waves (or P waves) arrive first
- Surface waves travel along the surface

6. Which of these is an example of **mitigation** rather than forecasting? 2 pts

Answer: C. Setting a new hospital on base isolators.

Why: Base isolators reduce the harm of shaking, which is mitigation. A, B and D collect or analyze data used to forecast.

7. A region recorded 18 earthquakes of magnitude 5 or larger in 60 years. (a) What is their frequency per year? (b) If the rate stays the same, about how many should the region expect in the next 30 years? (c) Can you say which years they will happen in? Explain in one sentence. 3 pts

Answer: (a) $18 \div 60 = 0.3$ earthquakes per year. (b) $0.3 \times 30 = 9$ earthquakes expected in 30 years. (c) No; the rate gives how many to expect on average over the period, but earthquakes do not follow a schedule, so their years cannot be named.

Why: This applies frequency to a forecast window and checks that students keep the forecast probabilistic.

Also acceptable: Accept 'about 9'. For (c), accept any sentence that says the timing cannot be predicted.

8. Draw a side view of the ground during an earthquake. Show and label: the fault, the focus, the epicenter, arrows for body waves spreading through the ground in all directions, and an arrow for surface waves traveling along the surface. 4 pts

Answer: A side view with a slanting or vertical line labeled fault; a point on the fault below the surface labeled focus; a point on the surface directly above it labeled epicenter; curved arrows or rings spreading outward through the ground in every direction from the focus, labeled body waves; an arrow along the surface away from the epicenter labeled surface waves.

Why: The drawing shows the anatomy of an earthquake: where it starts, where that projects to the surface, and how energy leaves.

Also acceptable: Accept rings instead of arrows for body waves. Do not accept a focus drawn at the surface.

- Fault drawn and labeled
- Focus on the fault below the surface
- Epicenter on the surface directly above the focus
- Body waves spread in all directions from the focus
- Surface waves shown traveling along the surface

9. Why does thick, gas-rich magma tend to erupt explosively, while runny magma usually pours out as lava flows? 3 pts

Answer: Thick magma does not flow easily, so the gas dissolved in it cannot escape as the magma rises. Pressure builds until the rock above gives way and the gas expands violently, blasting out ash, rock and pyroclastic flows. Runny magma lets its gas bubble out gently, so it pours out as lava.

Why: Explosiveness depends on gas content and on whether the gas can escape, which depends on how thick (viscous) the magma is.

Also acceptable: Accept 'like shaking a soda bottle with a cap on' as an analogy if the trapped-gas mechanism is also stated.

- Thick magma traps gas
- Trapped gas builds pressure that is released explosively
- Runny magma lets gas escape so lava flows out

10. What does an earthquake hazard map show? 2 pts

Answer: B. How likely each area is to have strong shaking, based on known faults and the locations, frequencies and magnitudes of past quakes.

Why: Hazard maps show likelihood, not dates or exact locations of future events. A and D describe predictions no one can make; C confuses hazard with past deaths.

11. Earthquakes on the San Andreas Fault are shallow, but earthquakes in a subduction zone such as Cascadia can be both shallow and deep. Explain why. 3 pts

Answer: At the San Andreas, the plates slide past each other sideways and neither plate goes down, so all the faulting is in the shallow crust, mostly within about 15 to 20 km. In a subduction zone, the shallow locked contact between the plates makes shallow quakes, and the sinking plate keeps cracking as it goes deeper beneath the continent, so quakes also start far below the surface.

Why: Depth depends on whether a plate carries the faulting down into the mantle.

Also acceptable: Accept an answer that omits the shallow subduction quakes for partial credit only; full credit needs both.

- Transform boundary: sideways motion, faulting only in shallow crust
- Subduction: shallow quakes on the locked contact
- Subduction: deep quakes inside the sinking plate

Part B: Synthesis

12. A friend says: 'Scientists warned people before Mount St. Helens erupted, so they should be able to warn us before the next big California earthquake too.' Write a response that (1) explains why eruptions can often be forecast from precursor events, (2) explains why earthquakes cannot be predicted, (3) describes what an earthquake forecast **can** tell people, and (4) gives two specific ways California reduces earthquake harm. 6 pts

Answer: Example: 'Volcanoes and faults behave differently. Before Mount St. Helens erupted, magma was rising into the mountain. It cracked rock, causing swarms of small earthquakes, and pushed the north side outward by up to about 1.5 meters a day. Those precursor events let scientists forecast that an eruption was likely and close the area, though they could not name the day. A fault gives no such signal. The rock sits locked while stress builds silently, and no reliable warning sign has been found; even a foreshock can be recognized only after the big quake. What scientists can do is forecast the chance of an earthquake: using fault maps, GPS measurements and the magnitudes and frequencies of past quakes, the USGS gives the Bay Area a 72 percent chance of a magnitude 6.7 or larger between 2014 and 2043. California uses forecasts like that to reduce harm. The Field Act requires stronger public schools, and ShakeAlert sends phone alerts once a quake has started, giving seconds to take cover.'

Why: This synthesis assesses the PE's central contrast and its link to mitigation.

Also acceptable: Accept other accurate mitigation examples: retrofits, base isolators, the 1,500-year Bay Bridge span, keeping homes off fault traces, the hospital law. Accept Lassen or a generic volcano in place of Mount St. Helens if the precursor explanation is accurate.

- Explains that rising magma produces measurable precursors (earthquakes, swelling or gas)
- States that earthquakes have no known reliable precursor, so they cannot be predicted
- Describes a forecast as a probability over a span of time, ideally with real numbers
- Gives two specific, accurate mitigation examples
- Clear, accurate response addressed to the friend

Teacher notes

Points: Part A 30, Part B 6, total 36. Items q2, q4, q6, q7, q10 and q12 carry the MS-ESS3-2 evidence; q1 and q11 check plate-setting background; q3 and q9 check the magnitude and eruption-style ideas the chapter teaches. In q5, accept 'body waves' or 'P waves' for the first arrival; the chapter notes that S waves, also body waves, can be damaging near the source, so do not accept any answer claiming body waves are harmless.

For q12, the strongest responses use real numbers (the 72 percent Bay Area forecast, the St. Helens bulge rate) and avoid 'predict' for both hazards; a response that says scientists can predict eruptions exactly should lose the first criterion. The extension asks students to write a distractor-based item, a good follow-up to W7.

Scaffold offered to students: Retrieval cues

Read only if you are stuck. Magnitude: one step = about 32 times the energy; two steps = about 1,000. Frequency = number of events ÷ number of years. Magma forms where water from a sinking plate lowers the melting temperature, where pressure drops as plates pull apart, or above a hot spot. For q12, plan four sentences first: one per numbered part.

Extension: Design one more question

Write one new multiple-choice question about this chapter that would catch a student who thinks 'a magnitude 6 is only a little stronger than a magnitude 5'. Give four options, make every wrong option a mistake a real student might make, and write a key that explains why each wrong option is wrong.