

California Hazard Briefing: A Twelve-Card Jigsaw

Learning target: I can teach my group one kind of hazard evidence, combine it with my classmates' evidence to explain which California hazards can be forecast and how, and help my group justify mitigation choices.

Collaborative investigation

About 55 min

Jigsaw

MS-ESS3-2 · practice

MS-ESS2-2 · supports

MS-ESS2-3 · supports

collaboration

discussion

reading

Standards connections

MS-ESS3-2 (practice): Groups sort real evidence about California's volcanoes and faults into what allows short-term eruption forecasts, what supports long-term earthquake forecasts, and which technologies reduce harm. They reason with hazard data but do not analyze a dataset themselves, so the sheet practices the PE.

MS-ESS2-2 (supports): The stick-slip and creep card and the Long Valley card show processes that build slowly for decades and are released suddenly, the gradual-then-catastrophic pattern in this PE's clarification statement. Students use it as background and do not construct the full explanation.

MS-ESS2-3 (supports): Expert set C links hazards to the transform boundary, the Cascadia subduction zone and the exceptions (a hot spot and a fault inside a plate), using plate-boundary ideas from Lesson 16 as background.

Purpose: practice · **Time:** about 55 minutes · **Format:** jigsaw

Answers with reasoning

Twelve evidence cards (four expert sets of three)

1 A1. Lassen Peak, 1914 to 1917

Lassen Peak, at the southern end of the Cascade volcanoes in northern California, began a long series of steam explosions in May 1914. On May 22, 1915, it erupted explosively: an eruption column rose more than 9 km above the vent, and over those days a pyroclastic flow and fast mudflows swept the northeast slope, still called the Devastated Area. Ash fell hundreds of kilometers east, in Nevada. The area was thinly settled and no one died. Today the USGS California Volcano Observatory monitors Lassen with seismometers, GPS stations and gas measurements.

2 A2. Long Valley Caldera: decades of unrest

Long Valley Caldera near Mammoth Lakes is an oval hollow about 30 km long, left by a huge eruption about 760,000 years ago. In May 1980, four earthquakes of about magnitude 6 shook the area. Since then the caldera has had swarms of small quakes and periods when its center rose. Around 1990, carbon dioxide from magma deep below began seeping into the soil on Mammoth Mountain and killed patches of trees. More than 40 years of unrest have not led to an eruption. Unrest raises the chance of an eruption; it does not guarantee one.

3 A3. Sharing the warning: volcano alert levels

The U.S. Geological Survey uses four alert levels for volcanoes. Normal: typical background activity. Advisory: unrest above the volcano's usual background. Watch: heightened or escalating unrest with an increased chance of eruption, but uncertain timing (or a minor eruption under way). Warning: a hazardous eruption is about to happen, is happening, or is suspected. Levels are set from monitoring data, such as earthquake counts, ground swelling and gas. A volcano can stay at Advisory or Watch for months or years; the level describes its current state, not a countdown.

4 B1. Stick, slip and creep

Most sections of the San Andreas Fault are locked: friction holds them while the plates keep moving, and stress builds for decades or centuries until the rock slips in a large earthquake. A section in central California, roughly between San Juan Bautista and Parkfield, behaves differently. It creeps, sliding slowly and almost steadily a few centimeters a year. In nearby Hollister, curbs and walls that cross a creeping fault are slowly bent out of line. Creeping sections release stress gradually and produce many small earthquakes, but not great ones.

5 B2. The Bay Area's real forecast

USGS forecast for the San Francisco Bay region, 2014 to 2043, chance of at least one earthquake: magnitude 6.0 or larger, 98 percent; 6.7 or larger, 72 percent; 7.0 or larger, 51 percent; 7.5 or larger, 20 percent. The most likely single source of a magnitude 6.7 or larger is the Hayward-Rodgers Creek Fault (33 percent), not the more famous San Andreas (22 percent). The forecast combines fault maps, how fast each fault is loading with stress (measured with GPS) and the history of past earthquakes. It names no dates.

6 B3. A foreshock and an alarm

On July 4, 2019, a magnitude 6.4 earthquake struck near Ridgecrest in the Mojave Desert. About 34 hours later, a magnitude 7.1 struck the same area. Only after the second quake could scientists call the first one a foreshock; most moderate quakes are not followed by a larger one. Since 2019, ShakeAlert has sent earthquake alerts to phones in California. It does not predict quakes: sensors detect the first, mild waves of a quake that has already started, and alerts can arrive seconds before strong shaking. People very close to the start may get no warning.

7 C1. The San Andreas: a transform boundary

The San Andreas Fault runs more than 1,000 km through California, from Cape Mendocino to the Salton Sea area. Land west of it, including Los Angeles, moves northwest relative to land east of it; across the whole plate boundary, the motion is about 5 cm per year. Its earthquakes are shallow, mostly in the top 15 to 20 km of the crust, and no volcanoes line it. Great earthquakes ruptured hundreds of kilometers of it in 1857 (Fort Tejon, about magnitude 7.9) and 1906 (San Francisco, magnitude 7.9).

8 C2. Cascadia: a subduction zone

For about 1,000 km, from Cape Mendocino in northern California to Vancouver Island in Canada, the Juan de Fuca Plate and the smaller Gorda Plate sink beneath North America. Water released by the sinking plate helps mantle rock melt, feeding the Cascade volcanoes, including Mount Shasta and Lassen Peak. The locked boundary last broke on January 26, 1700, in an earthquake of about magnitude 9. No one in the region wrote it down, but its tsunami was recorded in Japan, and drowned coastal forests in Oregon and Washington died that same winter.

9 C3. Exceptions to the pattern

The Hawaiian volcanoes sit more than 3,000 km from the nearest plate boundary. They are fed by a hot spot: a plume of unusually hot rock rising from deep in the mantle, which partly melts as it nears the surface. In the central United States, far from any plate boundary, the New Madrid seismic zone produced three earthquakes of about magnitude 7 or larger in 1811 and 1812, along old faults inside the North American Plate. Most hazards follow plate boundaries, but not all.

10 D1. Rules that came after disasters

On March 10, 1933, a magnitude 6.4 earthquake near Long Beach damaged or destroyed many school buildings; it struck after school hours. A month later, California passed the Field Act, which requires public schools to be built to stronger standards. In 1971, the magnitude 6.6 San Fernando earthquake collapsed parts of two hospitals. California then passed a 1972 law keeping most new homes and offices off the traces of active faults and a 1973 law requiring new hospitals to be built to keep working after an earthquake.

11 D2. Making structures stronger

Engineers retrofit (strengthen) older structures: steel jackets wrapped around concrete freeway columns, bolts that tie houses to their foundations, and braces inside walls. Base isolators, thick pads of rubber and steel set under a building, let the ground move beneath it while the building moves less; San Francisco City Hall was fitted with them after it was damaged in 1989. The new eastern span of the Bay Bridge, opened in 2013, was designed to reopen quickly after the strongest shaking expected in about 1,500 years.

12 D3. How strong is strong enough?

Making every structure survive the strongest possible shaking with no damage would cost far more than any community can pay, so engineers set targets by importance. An ordinary farm-road bridge only needs to stay standing in rare, strong shaking, even if it must close afterward. A main-road bridge should still carry emergency vehicles. A lifeline, such as the only bridge on the route to a hospital, must stay open with only minor damage. Each higher target means more steel, more concrete, more design work and more money.

Part A: Expert round

1. Your expert set: _____. Write the single most important idea from each of your three cards in your own words (one sentence each). Then write one question your home group is likely to ask and your answer to it. 3 pts

Answer: Set A: Lassen erupted explosively in 1915 after a year of steam explosions; Long Valley has had decades of unrest without eruption, so unrest raises the chance but does not guarantee an eruption; alert levels turn monitoring data into a public signal and describe the current state, not a countdown. Set B: locked sections store stress and fail in large quakes while creeping sections release it gradually; the Bay Area forecast gives chances over 30 years, not dates, and the Hayward-Rodgers Creek Fault is the most likely source; a foreshock can be recognized only afterward, and ShakeAlert detects a quake already under way. Set C: the San Andreas is a transform boundary with shallow quakes and no volcanoes; Cascadia is a subduction zone that feeds volcanoes and produced a magnitude 9 in 1700; hot spots and in-plate faults are exceptions. Set D: laws after disasters require stronger schools and hospitals and keep homes off fault traces; retrofits and base isolators make structures stronger; engineers match the target to the structure's importance because higher targets cost more.

Why: Each expert should reduce each card to its central idea and anticipate a question; the sample shows the central idea for every card.

Also acceptable: Accept any accurate key idea per card; wording will vary.

- One accurate key idea for each of the three cards in the student's set
- A likely question with a correct answer

Part B: Home group task

1. Each expert teaches the three cards in two minutes or less, in the order A, B, C, D. Listeners may ask one question each.
 2. Fill in the briefing table together. Every cell must name at least one card number as evidence.
 3. Read the county decision, discuss for five minutes, and agree on three projects. Record the reasons and the card numbers that support them.
 4. Check that every member can explain one row of the table without looking at the cards. Your teacher may call on anyone.
2. Group answer: complete the hazard briefing. 6 pts

Answer: Volcano eruption: setting — Lassen and Shasta sit above the Cascadia subduction zone, where water from the sinking plate helps rock melt (C2); Long Valley is in stretching crust east of the Sierra Nevada (A2). Forecast weeks ahead: often yes, because rising magma causes measurable quakes, swelling and gas (A1, A2, A3), but unrest can last years without eruption (A2). Long-term basis: past eruptions recorded in deposits and history, such as Lassen 1915 (A1). Mitigation: monitoring with seismometers, GPS and gas sensors and alert levels (A1, A3). San Andreas or Hayward earthquake: setting — transform boundary where plates slide past each other; locked sections store stress (C1, B1). Forecast weeks ahead: no; foreshocks are recognized only afterward and ShakeAlert gives only seconds (B3). Long-term basis: fault maps, GPS loading rates and past quakes, giving 30-year chances (B2). Mitigation: building rules, retrofits, base isolators, keeping homes off fault traces, early-warning alerts (D1, D2, B3). Great Cascadia earthquake: setting — the locked boundary of a subduction zone (C2). Forecast weeks ahead: no (B3 applies to all faults). Long-term basis: geologic evidence of past great quakes such as the 1700 tsunami records and drowned forests (C2). Mitigation: stronger buildings and bridges matched to importance (D2, D3), early warning (B3).

Why: The table makes the PE's central contrast visible: eruptions are often forecast from precursors, earthquakes only as long-term chances, and each hazard has matching mitigation.

Also acceptable: Accept the D1 hospital law or D3 lifeline targets for the Cascadia mitigation. Accept 'stretching crust' or 'not at a boundary' for Long Valley.

- Correct plate setting for each row
- Volcano row says often forecastable from precursors, with the caution from A2
- Both earthquake rows say not forecastable days to weeks ahead
- Long-term forecast bases are correct for each row
- A matching mitigation in each row
- Card numbers cited in every cell

3. Group answer: The fictional Sierra Coast County lies near an active fault and a restless volcano. 5 pts
This year it can pay for only **three** of these six projects, which cost about the same: (a) retrofit three older public school buildings; (b) add GPS and gas sensors to the volcano; (c) strengthen the only bridge on the hospital route to the lifeline target; (d) strengthen all 40 farm-road bridges to the lifeline target; (e) a campaign to sign residents up for ShakeAlert phone alerts; (f) a map that keeps new homes off active fault traces. Choose three, give a reason and a card number for each, and explain why your group rejected project (d).

Answer: Example: We chose (a) retrofit the schools, because D1 shows that a 1933 quake destroyed many school buildings and California now requires schools to be stronger, and B2 shows a strong quake is likely within decades; (c) strengthen the hospital-route bridge, because D3 says a lifeline must stay open after strong shaking and B2 shows strong shaking is likely; (b) add GPS and gas sensors to the volcano, because A1, A2 and A3 show that eruptions are forecast from swelling and gas, and without the sensors the county could miss the warning signs. We rejected (d) because D3 says a farm-road bridge only needs to stay standing; building 40 of them to the lifeline target would use money needed for the schools and hospital route without saving many more lives.

Why: Any three projects can earn credit if each is justified with card evidence. Rejecting (d) applies the importance-based targets on card D3.

Also acceptable: Strong alternatives include (f), because a zoning map is a lasting, inexpensive rule (D1), and (e), because ShakeAlert is already running and only needs sign-ups (B3). A group that keeps (d) must explain how it outweighs the lifeline bridge and schools, which is unlikely.

- Three projects chosen
- Each choice has a reason and a card number
- Rejection of (d) uses D3's importance and cost reasoning

Part C: Individual accountability (complete alone)

4. Explain why scientists can often forecast an eruption weeks ahead but cannot forecast the day of a San Andreas earthquake. Cite one card from set A and one from set B. 3 pts

Answer: Before an eruption, magma rising underground causes measurable changes: small earthquakes, swelling ground and more gas. Lassen gave a year of steam explosions before its 1915 eruption (A1), and alert levels are set from exactly these measurements (A3). Before an earthquake, stress builds silently in locked rock (B1), and no reliable warning sign is known: even a foreshock can be identified only after the bigger quake (B3). So earthquakes can only be forecast as chances over decades (B2).

Why: The answer must give a mechanism for each side: moving magma produces signals; stress in locked rock does not.

Also acceptable: Accept citing A2 for the existence of measurable unrest.

- Explains that moving magma produces measurable signals, citing an A card
- Explains that no reliable earthquake precursor is known, citing a B card
- States that earthquakes are forecast as long-term chances

5. Long Valley Caldera has been restless for more than 40 years without erupting (card A2). Does that mean its monitoring has failed? Explain using card A3. 2 pts

Answer: No. Monitoring has done its job: it detected the quakes, uplift and gas and told people the caldera is restless. Card A3 says alert levels describe a volcano's current state and can stay raised for months or years; they are not a countdown. Unrest raises the chance of an eruption but does not guarantee one, so a long period without eruption is consistent with good monitoring.

Why: This targets the idea that a forecast is wrong if the event does not happen soon.

Also acceptable: Accept an answer that says the monitoring is what lets scientists say the caldera has not moved toward eruption.

- Says monitoring has not failed
- Uses A3's point that levels describe the current state, not a countdown
- Says unrest raises the chance without guaranteeing an eruption

6. Use card B1 to explain why the creeping section of the San Andreas produces many small earthquakes but not great ones. 2 pts

Answer: A creeping section slides slowly and almost steadily, so stress never builds up for long. It is released a little at a time in many small slips and small quakes. Great earthquakes need a locked section that stores stress for decades or centuries and then releases it all at once.

Why: This applies the stick-slip model: the size of the release depends on how much stress is stored.

Also acceptable: Accept 'the fault never gets stuck long enough to store a lot of energy'.

- Creep releases stress gradually
- Large quakes need stress stored on a locked section

7. Card B2 gives a 98 percent chance for magnitude 6.0 or larger but only 20 percent for 7.5 or larger. Explain the pattern using what you know about the frequency of small and large earthquakes. 2 pts

Answer: Small earthquakes are far more frequent than large ones; for each step up in magnitude there are roughly ten times fewer. So it is almost certain that at least one magnitude 6 will happen in 30 years, but much less likely that one of the rare magnitude 7.5 quakes will.

Why: This connects the forecast table to the frequency-magnitude pattern.

Also acceptable: Accept the ten-times-fewer rule stated as 'bigger quakes are much rarer'.

- States that larger quakes are much less frequent
- Connects lower frequency to lower probability in the same time window

8. Nobody in the Pacific Northwest wrote down the 1700 earthquake (card C2). How do scientists know its date and size, and why do records like these matter for forecasting the next one?

2 pts

Answer: The tsunami it caused was written down in Japan, which fixes the date, and drowned coastal forests in Oregon and Washington died that same winter. The size of the tsunami and the length of coast that sank show it was about magnitude 9. Records like these extend the history of great quakes far beyond written records in the region, so scientists can estimate how often great Cascadia earthquakes happen and the chance of the next one.

Why: Long-term forecasts depend on knowing the frequency of rare, large events, which requires geologic and distant historical records.

Also acceptable: Accept 'tree rings in the dead forests' as part of the dating evidence.

- Names the Japanese tsunami records and the drowned forests
- Explains that these records extend the history needed to estimate frequency

Scoring rubric

Criterion	4 • Exemplary	3 • Proficient	2 • Developing	1 • Beginning
Expert teaching	Teaches all three cards accurately within the time, states why each matters for the briefing, and answers a group question correctly.	Teaches all three cards accurately but runs long or does not connect them to the briefing.	Reads the cards aloud or teaches one card inaccurately.	Does not teach the cards.
Hazard briefing accuracy	Every cell accurate and supported by a card number; the forecast column clearly separates eruptions from earthquakes.	One or two cells incomplete or missing a card number; forecast column correct.	Several cells inaccurate, or the table says earthquakes can be forecast days ahead.	Table mostly blank or inaccurate.
County decision	Three projects justified with specific card evidence; the rejection of (d) uses importance-based targets and cost.	Three projects justified; one reason lacks a card or the (d) reasoning is thin.	Projects chosen with general reasons and no card evidence.	No decision or no reasons.
Individual accountability (Part C)	All five answers accurate, cite cards from sets other than the student's own, and show understanding of the group's reasoning.	Four of five accurate with evidence.	Two or three accurate; others restate card text without reasoning.	Part C mostly blank or inaccurate.

Teacher notes

Print and cut the twelve cards and give each student one expert set of three. Facts were checked against USGS, the California Volcano Observatory and the San Francisco Bay region forecast fact sheet (2014-2043). Points to watch: the creeping section in Hollister that offsets curbs is the Calaveras Fault, part of the San Andreas system, which is why card B1 says 'a creeping fault'; the 1700 Cascadia date comes from Japanese tsunami records and tree rings; the New Madrid magnitudes are estimates from historical accounts; ShakeAlert public phone alerts in California began in 2019. Card D3's three importance levels match the chapter's performance-target table (slide 24 and the labs). The county decision connects to the slide 25 discussion about why not every bridge is built to the lifeline target. Keep the discussion at the level of community mitigation; this sheet does not give personal emergency instructions.

Scaffold offered to students: Teaching your cards in two minutes

Use this plan for each card: 'This card is about _____. The key fact is _____. It matters for our briefing because it shows _____.' Point to the column of the briefing table your card helps with. If you are listening, write the card number next to any fact you will use, so you can cite it later.

Extension: Write the county's public notice

Write a 150-word public notice for Sierra Coast County explaining the three projects your group chose. Readers are residents, not scientists. Explain what the county can and cannot know about each hazard, use the words *forecast* and *mitigate* correctly, and avoid any statement that sounds like a prediction of a date. Then trade notices with another group and mark any sentence that overstates what science can tell.