

# Forecasting a Fault: How California Plans for Quakes No One Can Predict

**Learning target:** I can use evidence from a text to explain the difference between predicting and forecasting an earthquake, and how forecasts built from hazard data guide ways to reduce harm.

Reading with evidence

About 40 min

Individual

MS-ESS3-2 · practice

MS-ESS2-3 · supports

reading

writing

## Standards connections

**MS-ESS3-2 (practice):** Students read how scientists turn data on the locations, magnitudes and frequencies of past earthquakes into a probability forecast, and how that forecast shaped California's building rules and warning technology. They interpret the reasoning in the text rather than analyzing a dataset themselves, so this sheet practices the PE; W5 and W6 assess it.

**MS-ESS2-3 (supports):** The passage explains California's earthquakes as the result of two plates sliding past each other at a plate boundary, the idea students built in Lesson 16. It uses that plate motion as background and does not ask students to reconstruct past plate motions.

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

## Answers with reasoning

### Forecasting a Fault

[1] **(1)** On October 17, 1989, about 60,000 fans were settling in at San Francisco's Candlestick Park for a World Series game. At 5:04 p.m. the stadium began to sway. For roughly fifteen seconds, the magnitude 6.9 Loma Prieta earthquake shook the Bay Area. A section of the Bay Bridge's upper deck dropped onto the deck below, and a double-decker freeway in Oakland collapsed. No one had warned the city. That is normal for earthquakes.

[2] **(2)** California sits on the boundary between two tectonic plates. West of the San Andreas Fault system, the Pacific Plate is grinding northwest past the North American Plate at a few centimeters per year, about as fast as your fingernails grow. The fault's rough sides lock together while the plates keep moving, so the rock on both sides slowly bends and stores energy, like a ruler bent between your hands. When the stress becomes greater than the friction holding the fault, the rock suddenly slips. The spot underground where the slip begins is the focus, and the stored energy rushes outward as seismic waves. Then the fault locks again and the cycle restarts.

[3] **(3)** A prediction would name the place, size and time of a coming earthquake closely enough to act on, such as 'a magnitude 7 in the East Bay next Tuesday.' No scientist has ever made a reliable prediction like that. Researchers have tested animal behavior, well water and electrical signals, but none shows up dependably before earthquakes. Some large quakes do follow smaller foreshocks, yet a foreshock looks like any other small quake until the bigger one arrives. Volcanoes are different: rising magma usually announces itself with swarms of small quakes, extra gas and swelling ground. Faults give

no such dependable signal, so scientists make forecasts instead. A forecast gives the chance that an earthquake of a certain size will strike a region during a span of years.

[4] **(4)** Forecasts are built from patterns in data. Scientists map active faults and measure how fast each one is loading with stress, with GPS stations. They study the record of past earthquakes: seismograph readings from the last century, written accounts from before that, and soil layers that were torn and shifted by prehistoric quakes. They also count how often quakes of each magnitude occur. Magnitude is a number that describes an earthquake's size, and the scale is logarithmic. Each step up by one whole number means about 32 times more energy released, so a magnitude 7 releases about 1,000 times the energy of a magnitude 5. Small quakes are far more common: for each step up in magnitude, there are roughly ten times fewer quakes.

[5] **(5)** In 2015, the U.S. Geological Survey and its partners combined this evidence into a statewide forecast. It gave a 72 percent chance that the San Francisco Bay Area will have at least one earthquake of magnitude 6.7 or larger in the 30 years starting in 2014, and a 60 percent chance for the Los Angeles region. For California as a whole, the chance was greater than 99 percent. None of these numbers names a year. A 72 percent chance in 30 years means a large Bay Area quake is more likely than not in that window, but it could arrive in the first year, in the last year, or not at all before 2044.

[6] **(6)** Forecasts tell communities where to spend money and effort. To mitigate a hazard means to reduce the harm it causes, since nobody can stop the shaking itself. After a 1933 earthquake near Long Beach wrecked many school buildings, California passed the Field Act, which requires public schools to be built to stronger standards. A 1972 law keeps most new homes off the traces of active faults. Older freeways have been strengthened, and the Bay Bridge's eastern span was replaced by a new one, opened in 2013 and designed for the strongest shaking expected in about 1,500 years. Since 2019, the ShakeAlert system has sent phone alerts in California after a quake starts, giving people seconds of notice before strong shaking reaches them. It is a fast alarm, not a prediction.

## Questions: answer from the passage

1. According to paragraph 3, what is the difference between an earthquake **prediction** and an earthquake **forecast**?

2 pts

**Answer:** B. A prediction names when, where and how big a quake will be; a forecast gives the chance of a quake of a certain size in a region over a span of years.

**Why:** Paragraph 3 defines a prediction as naming place, size and time closely enough to act, and a forecast as a chance for a region during a span of years. A reverses the role of data; C and D invent distinctions the passage does not make.

2. Paragraph 2 compares a locked fault to a bent ruler. Explain the comparison in your own words: what is being bent, what is stored, and what event matches the ruler snapping back? Cite the paragraph. 3 pts

**Answer:** The rock on both sides of the locked fault is like the ruler: it slowly bends (deforms) because the plates keep moving while the fault is stuck. Energy is stored in the bent rock as stress builds. When the stress becomes greater than the friction holding the fault, the rock suddenly slips, like the ruler snapping back, and the stored energy is released as seismic waves (paragraph 2).

**Why:** The analogy maps bending to slow deformation, stored energy to stress, and the snap to the sudden slip that starts at the focus.

*Also acceptable: Accept 'elastic energy' or 'strain' for stored energy. Accept 'friction is overcome' as the trigger.*

- Identifies the rock beside the fault as what bends
- Says energy or stress is stored while the fault is locked
- Matches the snap to the sudden slip (the earthquake) and the release of seismic waves
- Cites paragraph 2

3. Why can't scientists use foreshocks as a warning system? Cite the sentence in paragraph 3 that explains the problem, then explain it in your own words. 2 pts

**Answer:** The key sentence: a foreshock looks like any other small quake until the bigger one arrives (paragraph 3). Most small quakes are not followed by anything larger, so nobody can tell which small quake is a foreshock until after the main quake has already happened. A warning system built on foreshocks would raise false alarms constantly and still miss quakes that have no foreshocks.

**Why:** Students should see that a foreshock is a label applied in hindsight, so it cannot be used for advance warning.

*Also acceptable: Accept 'not every big quake has foreshocks' as a second, supporting reason.*

- Cites the paragraph 3 sentence about foreshocks looking like other small quakes
- Explains that a foreshock can be identified only after the larger quake

4. Use paragraph 4. (a) How many times more energy does a magnitude 8 earthquake release than a magnitude 6? Show the multiplication. (b) If a region has about 200 magnitude 4 quakes in a century, about how many magnitude 6 quakes would you expect in the same century? 3 pts

**Answer:** (a)  $32 \times 32 = 1,024$ , about 1,000 times more energy (two whole-number steps from 6 to 8). (b)  $200 \div 10 = 20$  magnitude 5 quakes;  $20 \div 10 = 2$  magnitude 6 quakes. About 2 in the century.

**Why:** Paragraph 4 gives about 32 times the energy per whole step and about ten times fewer quakes per whole step. Both parts require applying the factor twice.

*Also acceptable: Accept 1,000 or 1,024 for (a). For (b), accept 'about 2' or 'a few'; do not accept 100 (dividing by 2 or subtracting).*

5. Paragraph 4 lists three kinds of records of past earthquakes. Which two of them come from before seismographs existed, and why do scientists need records that old to forecast large quakes on one fault? 2 pts

**Answer:** Written accounts from before seismographs and soil layers torn and shifted by prehistoric quakes. Large earthquakes on a single fault can be a century or more apart, so a seismograph record of about 100 years may contain only one large quake or none; older records show how often the big ones really happen.

**Why:** The point is that the frequency of rare, large events can be estimated only from a record much longer than the event spacing.

*Also acceptable: Accept 'we need more than one or two big quakes to find a pattern' as the reason.*

- Names written accounts and prehistoric soil layers
- Explains that large quakes on one fault are too far apart for the short instrument record

6. A family in Oakland reads the 72 percent forecast in paragraph 5. Write one thing the number **does** tell them and one thing it **does not** tell them. Cite the paragraph. 3 pts

**Answer:** Does tell them: a magnitude 6.7 or larger quake somewhere in the Bay Area is more likely than not between 2014 and 2043, so they should prepare and expect strong shaking during their lifetime. Does not tell them: the year, month or day of the quake, exactly where in the region it will strike, or how strong the shaking will be at their house (paragraph 5).

**Why:** Paragraph 5 stresses that the numbers name no year. Students should separate likelihood over a window from timing.

*Also acceptable: Accept 'it does not promise a quake will happen at all' as a 'does not tell' statement, since 28 percent of the time the window could pass without one.*

- One accurate 'does tell' statement about likelihood over the 30-year window
- One accurate 'does not tell' statement about timing or exact location
- Cites paragraph 5

7. Paragraph 6 describes four ways California reduces earthquake harm. Complete the table. 4 pts

**Answer:** Field Act: building rule; reduces collapse of public school buildings and harm to students. 1972 fault-trace law: land-use rule; keeps homes from being torn apart where the ground itself breaks and shifts along a fault. New Bay Bridge east span: replacing (strengthening) a structure; keeps a major bridge usable and prevents a deck collapse like 1989. ShakeAlert: warning technology; gives seconds to act (take cover, slow trains, stop machinery) before strong shaking arrives.

**Why:** Each item matches one type named in the header, and the harm column must connect to the specific structure or people protected.

*Also acceptable: Accept 'strengthening' or 'replacing' for the bridge. For ShakeAlert, accept 'fewer injuries from falling objects' or 'protects people and machines'.*

- All four types correct
- Each harm statement is specific to that item

8. A website headline says: **'Scientists Predict the Big One Will Hit the Bay Area Soon.'** Use evidence from at least two different paragraphs to explain what is wrong with the headline. Then write a more accurate headline of no more than 15 words.

4 pts

**Answer:** The headline uses 'predict' and 'soon', but paragraph 3 says no scientist has ever reliably predicted when an earthquake will strike, and that scientists make forecasts instead. Paragraph 5 says the forecast is a 72 percent chance of a magnitude 6.7 or larger quake in the Bay Area over 30 years and names no year, so 'soon' is not supported. Better headline: 'Big Bay Area Quake More Likely Than Not by 2044, Scientists Forecast.'

**Why:** Full credit requires correcting both 'predict' and 'soon' with evidence from two paragraphs and producing a headline that states a probability over a time window.

*Also acceptable: Accept headlines such as '72% Chance of Major Bay Area Quake Within 30 Years' or 'Bay Area Faces Likely Strong Quake in Coming Decades'.*

- Explains that earthquakes are forecast, not predicted (paragraph 3)
- Uses the 72 percent in 30 years figure or the 'names no year' point (paragraph 5)
- New headline states likelihood and a time span without a specific date
- Headline is 15 words or fewer

## Teacher notes

The passage is original and runs about 686 words. Facts were checked against USGS and Caltrans sources: Loma Prieta (October 17, 1989, 5:04 p.m., magnitude 6.9, about 15 seconds of strong shaking, Bay Bridge upper-deck section and Cypress Street Viaduct collapses); the UCERF3 forecast published in 2015 (magnitude 6.7 or larger in 2014-2043: 72 percent San Francisco Bay region, 60 percent Los Angeles region, more than 99 percent statewide); the Field Act (1933, after the March 10, 1933 Long Beach earthquake); the Alquist-Priolo Earthquake Fault Zoning Act (1972); the new east span (opened 2013, designed for the strongest motions expected in about 1,500 years); and ShakeAlert public phone alerts in California (2019). 'About 32 times the energy per whole step' is  $10$  to the power 1.5 (31.6); the ground-motion amplitude recorded on a seismogram rises about 10 times per step. The 'ten times fewer per step' rule is an average pattern (the Gutenberg-Richter relation), not an exact law. Loma Prieta struck on a fault within the San Andreas system, which is why paragraph 2 says 'fault system'. Expect students to treat 72 percent as 'it will happen'; q6 and q8 target that.

### Scaffold offered to students: Find it, then say it

Before you answer, find the paragraph. Use these frames: 'In paragraph \_\_, the writer says that \_\_. This means \_\_.' For q4, remember that each whole-number step multiplies the energy by about 32 and divides the number of quakes by about 10, so two steps multiply by 32 twice and divide by 10 twice. For q7, the four types are already named in the column heading; match each law or project to one type.

### **Extension: Why fifteen seconds, and why so far away?**

The Loma Prieta epicenter was in the Santa Cruz Mountains, nearly 100 km south of the Oakland freeway that collapsed. Some of the worst damage happened on soft, wet ground near the bay, where shaking grows stronger. Research how loose, water-soaked soil can make shaking worse (look up *liquefaction* and *site amplification* on a USGS page). Then write a paragraph explaining why a hazard map for a city might show different risk on two streets that are the same distance from a fault.