

The Unlabeled Map: Find the Hidden Plate Boundaries

Investigation question: Using only the locations, depths and magnitudes of 40 earthquakes and the positions of 11 active volcanoes, where are the plate boundaries on this map, what kind is each one, and which towns face which hazards?

Evidence-based mystery

Groups of 4

1 session

Setup 5 · Activity 45 · Cleanup 3 min

MS-ESS3-2 · assesses

MS-ESS2-3 · supports

Scientific purpose

The regional planning office of a fictional coastal region has an earthquake catalog and a volcano list but no map of plate boundaries. Students plot every event on a grid, color earthquakes by depth and size them by magnitude, draw a depth cross-section across the most active zone, and reason from the patterns to the hidden boundaries and their types. They finish by forecasting which of four towns faces the greatest earthquake hazard and which faces volcanic hazards, and by recommending mitigation. The lab turns the lesson's Key Science Concept (which settings produce eruptions, earthquakes or both) into something students discover from data rather than read.

Why this helps students with this chapter

Reading that 'earthquakes happen at plate boundaries' is easy to memorize and easy to misapply. Plotting 51 points by hand makes the belts appear, makes the exceptions stand out, and forces students to use several kinds of evidence at once: depth, magnitude and the presence or absence of volcanoes. The cross-section shows, with no extra explanation, that the deepest earthquakes trace a sinking plate and that the largest earthquake is shallow, which corrects the textbook's 'convergent quakes are deep'. Ending with a town ranking keeps the focus of MS-ESS3-2: patterns in hazard data are used to forecast and to plan.

Standards connections

MS-ESS3-2 (assesses, the forecasting half: using the mapped locations, depths and magnitudes of past events to forecast where future earthquakes and eruptions are likely and to suggest mitigation): Students analyze simulated hazard data (locations, magnitudes, depths) to rank four towns by earthquake hazard, identify which face volcanic hazards, and recommend mitigation (q8, q9, q12). This produces direct evidence toward the forecasting part of the PE; Lab 3 adds the frequency data and the technology choice.

MS-ESS2-3 (supports, earthquake and volcano locations revealing ridges, trenches and boundaries as evidence of plate motion): The plotted belts reveal a spreading ridge, a trench with a sinking plate and a transform boundary, and the cross-section shows the direction one plate is moving. This supports the plate-motion evidence assessed in Lesson 16 but is not the main target here.

Roles (rotate each session)

- **North plotter:** Plots every earthquake and volcano with $y = 8$ or more on the group map, using the depth colors and magnitude sizes in the key.
- **South plotter:** Plots every earthquake and volcano with $y = 7$ or less, then checks five of the North plotter's points against the table.
- **Depth analyst:** Builds the cross-section from the earthquakes in the north band ($y = 8$ or more, $x = 10$ or more) and leads q3 and q4.
- **Skeptic and recorder:** Fills the classification table, asks 'what is the evidence?' for every interpretation, and records the group's town ranking with its reasons.

Materials

Item	Quantity	Per	Note
Recording sheet with the earthquake table, volcano table, town table, plotting key, map grid and cross-section grid	1	student	
Colored pencils: red, blue and black (one each)	1 set	group	Red for shallow (0-70 km), blue for intermediate (71-300 km), black for deep (over 300 km).
Ruler	1	group	
Pencil with eraser	1	student	
Highlighter for marking the boundaries the group decides on	1	group	
Transparent sheet or tracing paper for the teacher's answer overlay (optional)	1	class	

Estimated cost: 2 to 4 per class (estimate) (an estimate; Printing about 30 double-sided copies; colored pencils, rulers and highlighters are classroom stock.)

Safety

- Paper and pencil only; there are no physical hazards. If you use the floor-sized masking-tape grid option, keep walkways clear and have students step, not run, between points.
- The towns and region are fictional. If students ask about hazards where they live, point them to the official USGS and California Geological Survey hazard maps rather than drawing conclusions from this teaching dataset.

Teacher preparation and setup

1. Print the recording sheet double-sided. Plot the full dataset yourself once (about 15 minutes) so you can spot misplotted points quickly; the most common error is swapping x and y .

2. Make an answer overlay on a transparency or tracing paper: the ridge along $x = 3$, the trench along $x = 10$ from $y = 8$ to $y = 16$, the transform along $x = 11$ from $y = 0$ to $y = 7$, the hot-spot cluster near $(6, 3)$ – $(6, 4)$, the cluster inside the continent near $(18, 4)$ – $(19, 5)$, and the small volcanic field near $(16, 3)$ – $(17, 2)$.
3. Decide whether to tell students before they start that the map is loosely modeled on a real region. The debrief works best if they discover the resemblance to western North America afterward.
4. Post the plotting key on the board: depth by color, magnitude by dot size (small below 5.0, medium 5.0 to 6.9, large 7.0 and above), volcanoes as triangles.

Investigation design

Independent variable	The part of the map (the tectonic setting), which students are trying to identify.
Dependent variable	The observed earthquake depths and magnitudes and the presence or absence of volcanoes in each line or cluster.
Controlled	The same catalog time span and recording threshold for the whole map; The same plotting key (color for depth, size for magnitude); The same grid scale (one square = 50 km); Every group uses the identical dataset
Trials	Forty earthquakes and eleven volcanoes are plotted once by each group, with a cross-check of ten points; interpretations are compared between groups.
Comparison	Each line or cluster is compared with the expected signature of a divergent, convergent (subduction), transform, hot-spot or within-plate setting.

Student procedure

1. Read the scenario and the plotting key together. Agree on the grid: x counts squares east, y counts squares north, and each square is 50 km. Ocean lies west of $x = 11$; land lies to the east.
2. Split the plotting: the North plotter takes every point with $y = 8$ or more and the South plotter every point with $y = 7$ or less. Plot each earthquake as a dot colored by depth and sized by magnitude, and each volcano as a small triangle. Write the ID beside every point.
3. Swap and check: each plotter checks five of the other's points against the table. Mark the four towns with a square and their initials.
4. Answer q1 and q2 as a group. Then look for lines and clusters of points. Lightly sketch where you think each boundary runs, but do not label it yet.
5. Depth analyst: plot the cross-section using every earthquake with $y = 8$ or more and $x = 10$ or more (distance east on the horizontal axis, depth on the vertical axis, deeper lower). The group answers q3 and q4.
6. Classify each line or cluster in the classification table: where it is, the earthquake depths, the largest magnitude, whether volcanoes are present, your interpretation, and the key evidence. Answer q5 and q6.
7. Highlight the boundaries you are confident about and leave dashed lines where you are unsure. Answer the analysis questions individually: the magnitude comparison (q7), the town forecast (q8) and the remaining questions.
8. Compare maps with one other group. Where your interpretations differ, decide which evidence would settle the disagreement.

Expected observations

- Thirty of the 40 earthquakes are shallow (red), 8 intermediate (blue) and 2 deep (black). All of the blue and black dots lie in the north-east band between $x = 13$ and $x = 17$.
- A straight north-south line of small, shallow earthquakes (magnitudes 4.1 to 5.2) with three volcanoes runs along $x = 3$.
- In the north, earthquakes deepen steadily eastward from about 20–25 km at $x = 10$ to 320–330 km at $x = 17$, about 43 km deeper per grid square; four volcanoes sit at $x = 13$ to 14, above the 90 to 140 km part of the slab.
- A line of shallow earthquakes (6 to 14 km) with magnitudes up to 7.4 and no volcanoes runs along $x = 11$ from $y = 0$ to $y = 7$.
- Isolated clusters appear in the ocean near (6, 3)–(6, 4) with two volcanoes and inside the continent near (18, 4)–(19, 5) with no volcanoes; a small volcanic field with tiny shallow earthquakes sits near (16, 3)–(17, 2).

Likely difficulties

- Swapping x and y while plotting. The cross-check step catches most of these; tell students to say 'east first, then north' aloud.
- Reading the cross-section's vertical axis upside down. Point out that 0 km is at the top and depth increases downward, like a real slice through Earth.
- Calling every line of earthquakes a subduction zone because 'that is where big earthquakes are'. Ask what the depths and the volcanoes say.
- Adding the magnitude factors instead of multiplying them in q7 (for example $3 \times 32 = 96$). Show the ladder 32, 1,024, 32,768.
- Treating the anomaly near (16, 3) as an error to ignore. Real data has exceptions; q10 asks students to reason about it.

Structured debrief

1. Lay one group's map under your overlay. Name the five settings the groups found: a spreading ridge along $x = 3$, a subduction zone with its trench along $x = 10$ in the north, a transform boundary along $x = 11$ in the south, a hot spot near (6, 3)–(6, 4), and a fault zone inside the continent near (18, 4)–(19, 5). Ask which evidence was most decisive for each: depth for the subduction zone, missing volcanoes for the transform, isolation for the hot spot.
2. Reveal the inspiration: the map is loosely modeled on western North America. The northern trench and its volcano chain resemble the Cascadia subduction zone and the Cascade volcanoes; the southern transform resembles the San Andreas Fault; the point where they meet resembles Cape Mendocino; the inland cluster resembles faults inside a plate such as the New Madrid zone; the hot spot stands in for Hawaii (which is really thousands of kilometers away). The small volcanic field near (16, 3) is a stand-in for Long Valley Caldera, which is not on a plate boundary and is linked to stretching of the crust east of the Sierra Nevada.
3. Use the cross-section to correct the textbook gently: the largest earthquake on the map, E14 (magnitude 8.7), was only 25 km deep, right at the trench, while the two deepest (E39 at 330 km and E29 at 320 km)

were magnitude 6.6 and 5.0. Subduction zones produce both kinds.

4. Close on forecasting: the map tells you where hazards are likely and what kinds, not when. Ask what extra data a planner would want before building in Port Halden (how often big earthquakes have struck in the past, from geology; tsunami heights; soft ground). Lab 3 adds exactly that kind of data.

Recording sheet: what students fill in

Lab 1 recording sheet: The Unlabeled Map

The planning office of a **fictional** coastal region has lost its map of plate boundaries. It still has a sample of 40 earthquakes from its 100-year catalog and a list of the 11 volcanoes that have erupted in the last 10,000 years. Your job is to rebuild the boundary map from the data alone and then advise four towns. Every number on this sheet is a **teaching dataset** invented for this lab. On the grid, x counts squares east and y counts squares north; each square is 50 km. Ocean lies west of x = 11 and land lies east of it.

Earthquake sample (40 events)

Simulated teaching dataset: the numbers are invented to be realistic, not measured.

ID	x (east)	y (north)	Depth (km)	Magnitude
E1	8	13	15	4.0
E2	11	10	30	7.1
E3	12	11	55	5.4
E4	12	15	60	6.2
E5	17	2	6	4.2
E6	14	15	140	5.6
E7	10	15	20	6.8
E8	16	11	240	5.5
E9	14	11	135	6.4
E10	3	12	6	4.1
E11	3	7	7	4.4
E12	16	14	250	6.1
E13	11	0	11	5.0
E14	10	12	25	8.7
E15	11	5	10	7.4
E16	1	1	10	3.4
E17	11	7	12	5.6

ID	x (east)	y (north)	Depth (km)	Magnitude
E18	11	2	14	6.1
E19	3	15	8	4.6
E20	18	4	12	6.6
E21	11	6	8	4.4
E22	11	1	6	3.8
E23	15	10	185	5.3
E24	13	12	8	3.9
E25	12	4	10	4.5
E26	6	4	10	6.3
E27	3	9	10	5.2
E28	15	13	190	5.8
E29	17	10	320	5.0
E30	11	14	35	5.9
E31	6	3	6	4.0
E32	19	5	8	4.4
E33	13	13	95	6.0
E34	3	4	9	4.8
E35	13	9	90	5.1
E36	11	3	9	4.9
E37	16	3	5	3.5
E38	18	5	10	5.8
E39	17	13	330	6.6
E40	7	3	5	3.6

Simulated teaching data for a fictional region. Depth is the depth of the focus below the surface.

Active volcanoes (erupted within the last 10,000 years)

Simulated teaching dataset: the numbers are invented to be realistic, not measured.

ID	x (east)	y (north)
V1	6	3
V2	13	9

ID	x (east)	y (north)
V3	3	14
V4	17	2
V5	16	3
V6	14	15
V7	3	10
V8	14	11
V9	13	13
V10	6	4
V11	3	5

Simulated teaching data for a fictional region.

Towns

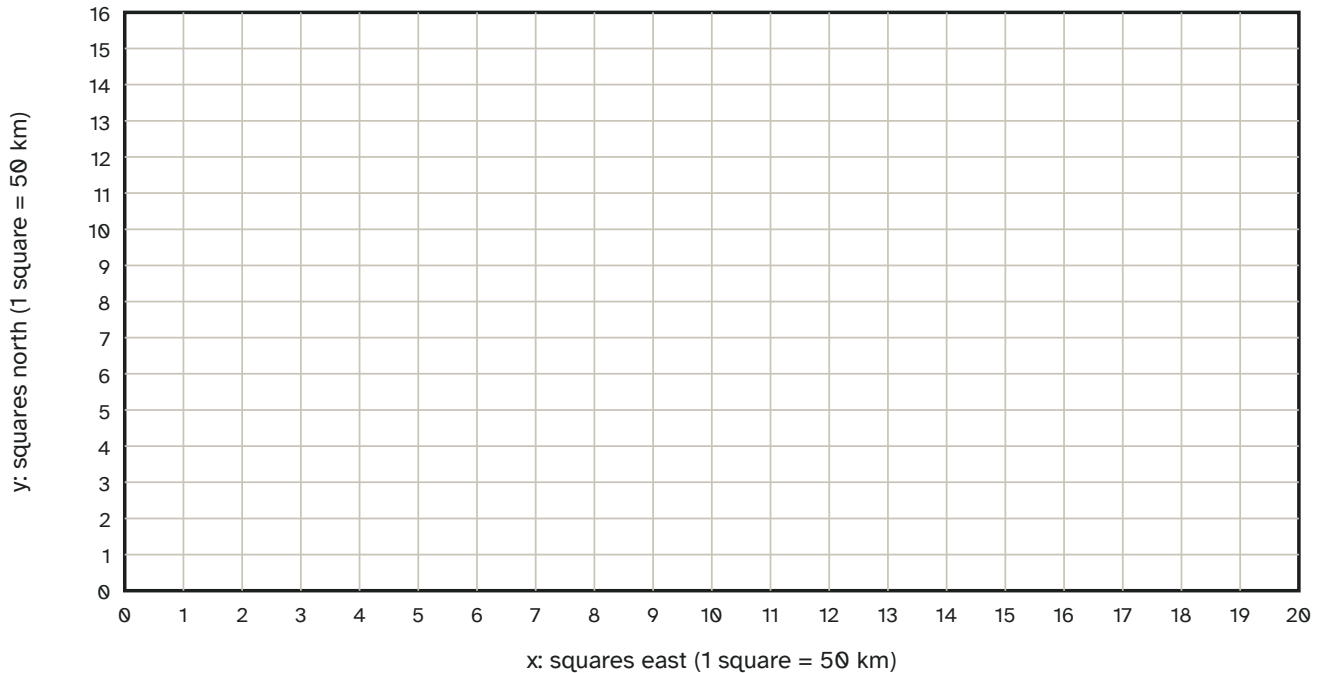
Simulated teaching dataset: the numbers are invented to be realistic, not measured.

Town	x	y	Notes
Port Halden	11	13	Harbor city on the coast
Kettle Bay	12	4	Town just inland from the coast
Ash Hollow	14	12	Farming town in the mountains
Plainview	19	12	Inland city on a wide plain

Fictional towns placed for this teaching dataset.

Plotting key — Earthquake color by depth: red = shallow (0 to 70 km), blue = intermediate (71 to 300 km), black = deep (more than 300 km). **Earthquake size by magnitude:** small dot = below 5.0, medium dot = 5.0 to 6.9, large dot = 7.0 or more. **Volcano:** a small triangle. **Town:** a small square with its initials. Write the ID next to every point.

Map grid: plot every earthquake, volcano and town



1. Describe the overall pattern on your map. Where are the earthquakes and volcanoes concentrated, and where are they rare?

Answer: Most earthquakes and volcanoes fall along a few narrow lines: a north-south line along $x = 3$ in the ocean, a wide band in the north-east from $x = 10$ to $x = 17$, and a line along $x = 11$ in the south. A few small clusters sit away from the lines (near (6, 3), near (18, 5) and near (16, 3)). Large areas have almost no events, such as the open ocean between $x = 4$ and $x = 9$ (apart from the cluster near (6, 3) and one small earthquake) and the land in the far north-east, east of $x = 17$.

Why: Students should describe belts plus a few clusters and name at least one empty area.

Also acceptable: Credit descriptions that use compass directions instead of coordinates if the locations are clear.

- Names at least two lines or belts with coordinates
- Mentions clusters away from the lines
- Names an area with few or no events

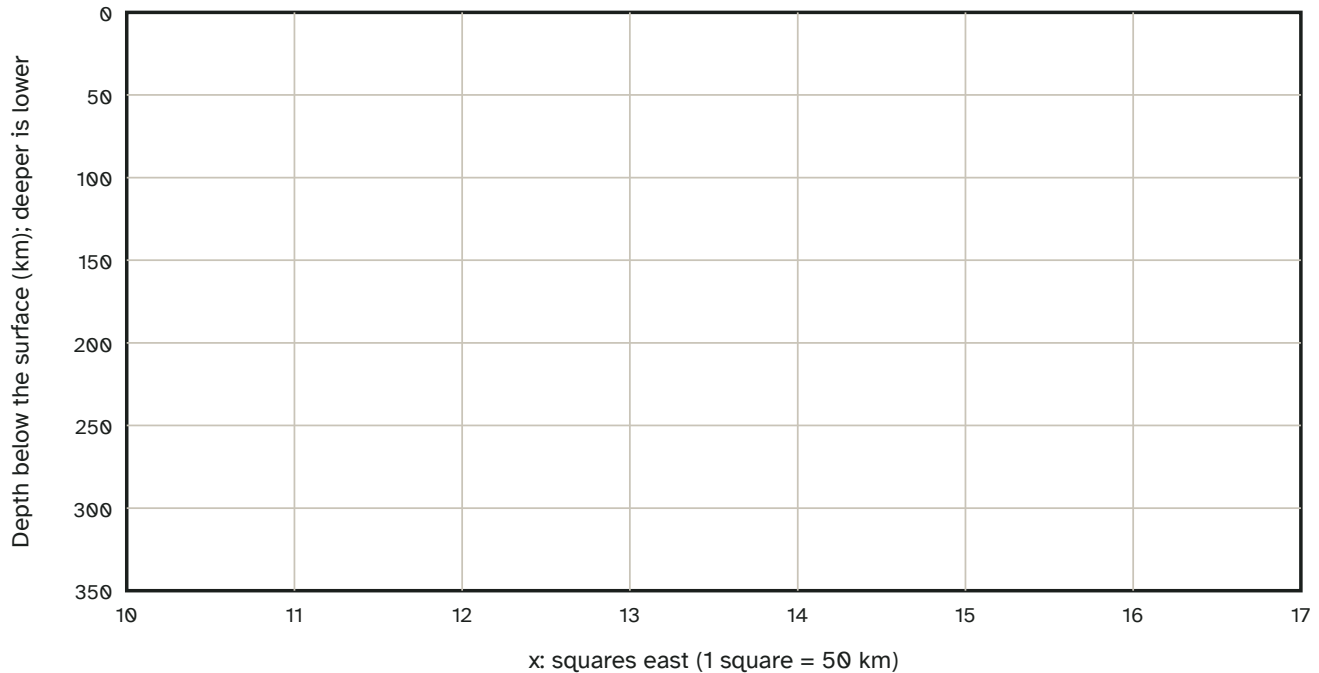
2. Look at the points along $x = 3$. Describe their depths, their magnitudes and the volcanoes there. What kind of boundary runs along $x = 3$? Give your evidence.

Answer: Along $x = 3$ the earthquakes are all shallow (6 to 10 km) and fairly small (magnitudes 4.1 to 5.2), and three volcanoes (V3, V7, V11) sit right on the line. Shallow, small earthquakes plus volcanoes in the ocean fit a divergent boundary: a spreading ridge where plates pull apart and the drop in pressure lets mantle rock melt.

Why: Thin, hot crust at a ridge cannot store much stress, so its earthquakes stay small and shallow; decompression melting feeds the volcanoes.

- Quotes the depth range and the magnitude range
- Notes the volcanoes on the line
- Identifies a divergent boundary (spreading ridge)

Cross-section: depth of every earthquake with $y = 8$ or more and $x = 10$ or more



3. Describe the shape the points make on your cross-section. In which direction do the earthquakes get deeper, and by about how many kilometers per grid square? What does this tell you is happening to one of the plates?

Answer: The points form a band that slopes downward toward the east: about 20-25 km deep at $x = 10$, about 90-95 km at $x = 13$, about 185-190 km at $x = 15$ and 320-330 km at $x = 17$. That is about $(325 - 22.5) / 7 =$ about 43 km deeper per grid square. The earthquakes are tracing a plate that is sinking eastward beneath the continent: a subduction zone with its trench near $x = 10$.

Why: Earthquakes inside a sinking plate deepen with distance from the trench. The average depths per square are 22.5, 32.5, 57.5, 92.5, 137.5, 187.5, 245 and 325 km.

- Describes a band deepening to the east
- Gives a rate of roughly 40 to 45 km per square (accept 35 to 50)
- Concludes the western (oceanic) plate is sinking eastward beneath the continent

4. About how deep is the sinking plate beneath the chain of volcanoes at $x = 13$ to 14 ? Explain why the volcanoes form above the sinking plate at that depth instead of right at the trench.

Answer: Under $x = 13$ to 14 the sinking plate is about 90 to 140 km deep (E35 90 km, E33 95 km, E9 135 km, E6 140 km), roughly 100 km. At the trench the plate is still shallow and cool, so it has not released much water. Deeper down, heat and pressure drive water out of the sinking plate into the hot mantle rock above it; the water lowers that rock's melting temperature, magma forms and rises, and the volcanoes appear above that depth, about 150 to 200 km inland of the trench.

Why: This applies the 'add water' route to melting. The textbook describes crustal material lowering the melting temperature; water is the main ingredient.

- Gives a depth of roughly 90 to 140 km (accept about 100 km)
- Explains that water released from the sinking plate lets the mantle rock above it melt at a lower temperature
- Explains why this does not happen right at the trench

Classification table

Line or cluster	Where (coordinates)	Earthquake depths	Largest magnitude	Volcanoes?	Interpretation	Key evidence
1						
2						
3						
4						
5						
6						

5. The earthquakes along $x = 11$ south of $y = 8$ have no volcanoes near them. What kind of boundary is this, and why does it have no volcanoes?

Answer: A transform boundary, where the plates grind sideways past one another. Its earthquakes are all shallow (6 to 14 km) and some are large (E15, magnitude 7.4), but there are no volcanoes because sliding plates neither add water to the mantle nor lower the pressure on it, so no rock melts.

Why: Shallow quakes, large magnitudes possible, no volcanoes is the transform signature, like the San Andreas Fault.

- Identifies a transform boundary
- Cites shallow depths and the large magnitude
- Explains no melting, so no volcanoes

6. Two volcanoes and three earthquakes cluster near (6, 3) and (6, 4), far from any line of points. What setting explains them? What evidence supports your answer?

Answer: A hot spot: a plume of unusually hot rock rising from deep in the mantle under the middle of a plate. Evidence: two active volcanoes (V1 at (6, 3), V10 at (6, 4)) and shallow earthquakes (E26, E31, E40; 5 to 10 km, up to magnitude 6.3) in the ocean, with no line of points connecting them to any boundary.

Why: Volcanoes far from any boundary are the signature of a hot spot; earthquakes near hot-spot volcanoes can be strong, as on the island of Hawaii.

- Identifies a hot spot
- Cites the volcanoes and their isolation from the boundaries
- Mentions the shallow earthquakes

Analysis questions: answer key

7. Earthquakes E15 (magnitude 7.4) and E21 (magnitude 4.4) both happened on the line along $x = 11$. How many times more ground motion did E15 produce on a seismogram, and about how many times more energy did it release? Show your work.

Answer: The difference is $7.4 - 4.4 = 3$ magnitude steps. Ground motion: $10 \times 10 \times 10 = 1,000$ times. Energy: about $32 \times 32 \times 32 = 32,768$, so about 32,000 times (10 to the power 4.5 = about 31,600).

Why: Each step multiplies ground motion by 10 and energy by about 32, and the factors multiply.

- Finds a 3-step difference
- 1,000 times the ground motion
- About 30,000 to 33,000 times the energy, with work shown

8. Forecast: rank Port Halden, Kettle Bay, Ash Hollow and Plainview from greatest to least earthquake hazard. For each town, name its main hazard or hazards (shaking, tsunami, volcanic) and cite the data that support your ranking.

Answer: Greatest to least: Port Halden and Kettle Bay (either order with a reason), then Ash Hollow, then Plainview. Port Halden (11, 13): the largest earthquake on the map, E14 magnitude 8.7, was only 25 km deep about 70 km away at (10, 12), one square diagonally, with E7 (6.8) and E30 (5.9) nearby; it is on the coast beside the trench, so tsunami is also a hazard, and ash could reach it from volcanoes about 100 km east. Kettle Bay (12, 4): beside the transform, with shallow earthquakes including E15 (magnitude 7.4, 10 km deep) about 70 km away and E25 (4.5) at the town itself; shaking is the main hazard. Ash Hollow (14, 12): between volcanoes V8 and V9, so volcanic hazards (ash, pyroclastic flows, mudflows) are its main danger; its earthquakes are mostly 95 to 140 km deep (E33 6.0, E9 6.4) plus a small shallow one (E24), so shaking is moderate. Plainview (19, 12): the nearest earthquakes are 320-330 km deep (E39 6.6, E29 5.0), more than 300 km from the town, so shaking would be weak; no volcanoes nearby.

Why: Shaking hazard depends on magnitude, distance and depth together. Deep earthquakes are farther from the surface, so their shaking is weaker. Either Port Halden or Kettle Bay may be ranked first: Port Halden has the biggest nearby earthquake and tsunami exposure; Kettle Bay has strong, frequent shallow quakes close by.

Also acceptable: Ash Hollow ranked second can earn credit if the student argues that its combined volcanic and earthquake hazards outweigh Kettle Bay's, while acknowledging its earthquakes are deeper.

- Plainview ranked last with depth or distance as the reason
- Port Halden and Kettle Bay ranked above Ash Hollow
- Names tsunami for Port Halden and volcanic hazards for Ash Hollow
- Cites at least one specific earthquake ID or volcano per town

9. A planner says the land around (18, 5) is safe for a new hospital because it is far from every plate boundary. Use the data to respond.

Answer: The planner is wrong. The cluster at (18, 4)-(19, 5) contains E20 (magnitude 6.6, 12 km deep), E38 (5.8) and E32 (4.4), all shallow. Faults inside a plate can store stress and release it in strong earthquakes, as the New Madrid zone in the central United States did in 1811-1812. Being far from a boundary lowers the frequency of earthquakes but does not remove the hazard.

Why: Within-plate faults are the exception the lesson highlights. A shallow magnitude 6.6 is capable of serious damage.

- Cites the cluster's magnitudes and shallow depths
- Explains faults inside plates can produce strong earthquakes
- Concludes the site is not safe without further study or strong design

10. Volcanoes V4 and V5 and two small, shallow earthquakes near (16, 3) and (17, 2) do not sit on any of the boundaries you found. Propose two possible explanations and name one kind of data that would help you decide between them.

Answer: Possible explanations: (1) a hot spot under the continent; (2) the crust is being stretched and thinned there, which lets hot rock below rise and partly melt (the real-world stand-in, Long Valley Caldera, is explained this way); (3) an unrecognized boundary or the edge of the subduction zone's influence. Useful data: whether the crust there is spreading apart (GPS measurements of ground motion), the chemistry and ages of the volcanic rocks, whether older volcanoes form a chain (as a hot spot track would), or seismic images of hot rock beneath the area.

Why: Students are reasoning about an anomaly; any two plausible, distinct explanations with a sensible test earn credit.

Also acceptable: Credit 'an error in the data' as one explanation only if the student also proposes a geologic one and a way to check.

- Two distinct, plausible explanations
- One specific kind of data and how it would distinguish them

11. The catalog covers only 100 years. Explain why a part of the map with no large earthquakes in the catalog could still have one in the future. Use one of the boundaries you found as an example.

Answer: Large earthquakes on a fault can be centuries apart, so a 100-year catalog can miss them completely. For example, the subduction zone in the north could have a magnitude 9 earthquake every few hundred years; a 100-year sample might show only moderate ones, as Cascadia's did before geologists found evidence of the 1700 earthquake. A quiet stretch in the record does not mean a fault is safe; it may be locked and storing stress.

Why: The point is the mismatch between short records and long recurrence intervals.

- States that large earthquakes can recur less often than once per century
- Uses one boundary on the map as an example
- Notes that a quiet record does not mean low hazard

12. Recommend one way to mitigate the main hazard at Port Halden and one way to mitigate the main hazard at Ash Hollow. Explain how each would reduce harm.

Answer: Port Halden (strong shaking and tsunami): examples include strengthening or retrofitting buildings and the harbor to modern codes, mapping and marking tsunami evacuation routes to high ground, and keeping hospitals and schools out of the tsunami zone. Ash Hollow (volcanic hazards): examples include monitoring the volcanoes (seismometers, gas sensors, GPS) to forecast eruptions, using a hazard map to keep homes out of valleys where mudflows and pyroclastic flows travel, and planning evacuations.

Why: Mitigation must fit the hazard: building design and tsunami planning for the coast, monitoring and land-use planning for the volcano town.

- One mitigation matched to Port Halden's hazard
- One mitigation matched to Ash Hollow's hazard
- Each explains how it reduces harm

Individual evidence of learning

Each student submits their own copy of the plotted map (half plotted by them, half checked), the classification table, and individual answers to q7 through q12. The town ranking in q8 and the planner response in q9 are the strongest individual evidence for MS-ESS3-2 because each must cite specific earthquakes, depths, magnitudes or volcanoes.

Assessment criteria

Criterion	Proficient looks like
Accurate plotting	At least 36 of 40 earthquakes and all 11 volcanoes plotted in the correct square with the correct color and size; the cross-section includes the 17 north-band earthquakes with depth increasing downward.
Boundary classification	Identifies the ridge, subduction zone and transform boundary with correct types, and the hot spot and within-plate cluster as exceptions, each supported by at least two kinds of evidence (depth, magnitude, volcanoes).
Cross-section reasoning	States that earthquakes deepen eastward by roughly 40-45 km per square, concludes that the western plate is sinking eastward, and links the volcanoes to the 90-140 km depth of the slab.
Logarithmic comparison	Computes 1,000 times the ground motion and about 32,000 times the energy for a 3-step difference, with the multiplication shown.
Forecast and mitigation	Ranks the towns with Port Halden and Kettle Bay highest and Plainview lowest, names the right hazard types for each, cites specific data, and recommends mitigation matched to the hazard.

Accessibility adaptations

- Provide an enlarged grid (A3 or 11 x 17 inches) and pre-cut sticky dots in three colors and three sizes for students with fine-motor or vision needs.
- Offer a version of the earthquake table sorted into the two plotting halves with the y = 8 dividing line drawn on the map.

- Provide sentence frames for the classification table: 'The quakes here are ___ and the largest is ___, and there are/are no volcanoes, so this is a ___ boundary.'
- Allow the town forecast (q8) to be given orally or recorded, with the student pointing to the evidence on the map.

Low-cost alternative

No materials beyond printing are needed. If colored pencils are short, use symbols instead of colors: an open circle for shallow, a filled circle for intermediate and a filled square for deep. A floor-sized grid made with masking tape and sticky notes turns the plotting into a whole-class activity.

Model limitations

This lab has not been physically tested with a class as written; timings are estimates. The region, towns and every number are simulated. Real boundaries are wider zones with many parallel faults, not single grid lines, and a real 100-year catalog for a region this size would hold thousands of earthquakes, not 40; the sample was chosen to make the patterns readable. Real subduction zones also have offshore earthquakes in the bending plate and inland crustal faults. The map is flat and ignores Earth's curvature. The hot spot is placed far closer to the subduction zone than Hawaii is to North America. Use the map to practice reasoning from patterns, not as a picture of any real place.

Teacher notes

All data are simulated for a fictional region; the earthquake and volcano IDs were shuffled so the table does not reveal the groups. Grouping for reference: ridge E10, E11, E19, E27, E34 and V3, V7, V11; subduction slab E2, E3, E4, E6, E7, E8, E9, E12, E14, E23, E28, E29, E30, E33, E35, E39, with the crustal E24 under volcanoes V2, V6, V8, V9; transform E13, E15, E17, E18, E21, E22, E36 plus E25 just east of the line; hot spot E26, E31, E40 and V1, V10; continental cluster E20, E32, E38; volcanic field E5, E37 and V4, V5; isolated events E1 and E16 (small earthquakes away from boundaries happen in real catalogs too). In the debrief, connect the map to California: Cascadia in the north, the San Andreas in the south, Cape Mendocino where they meet, and Long Valley as the inland volcanic exception.