

Is Mount Corva Waking Up? A Claim-Evidence-Reasoning Case

Learning target: I can use monitoring data and a volcano's eruption history to argue how likely an eruption is becoming and what a nearby town should do, without claiming to know the exact day.

Claim, evidence, reasoning About 45 min Individual MS-ESS3-2 · assesses data analysis writing

Standards connections

MS-ESS3-2 (assesses, forecasting an eruption from precursor data and using the forecast to choose mitigation): The clarification statement names volcanic eruptions as hazards preceded by phenomena that allow reliable forecasts. Students analyze three precursor signals and a volcanic history to forecast that an eruption is becoming more likely, choose an alert level, and justify mitigation for a town, which is direct evidence toward the PE.

Purpose: practice · **Time:** about 45 minutes · **Format:** individual

Answers with reasoning

The situation

Mount Corva is a tall, steep volcano in a chain of volcanoes above a subduction zone. Its magma is thick and sticky. The town of Pine Hollow, home to 4,000 people, sits in a river valley 12 km downhill from the summit. Scientists at a volcano observatory keep three kinds of instruments on Corva: seismometers that count small earthquakes and find their depth, gas sensors that measure sulfur dioxide (a gas released by magma), and GPS stations that measure whether the ground is rising. Twelve weeks ago, the numbers began to change.

Weekly monitoring data for Mount Corva (teaching dataset)

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

Week	Small earthquakes that week	Average quake depth (km)	Sulfur dioxide (tonnes per day)	Summit uplift since week 1 (mm)
1	4	9.5	40	0
2	5	9.2	35	1
3	3	9.6	45	0
4	6	9.0	40	2
5	14	8.1	60	5
6	22	7.4	95	11
7	31	6.5	160	19
8	47	5.8	240	30

Week	Small earthquakes that week	Average quake depth (km)	Sulfur dioxide (tonnes per day)	Summit uplift since week 1 (mm)
9	66	4.9	380	44
10	90	4.1	560	62
11	118	3.3	790	85
12	151	2.6	1050	112

Simulated data for teaching. Earthquake depth is the average depth below the summit of that week's quakes. Uplift is how much the summit has risen since week 1.

Two more pieces of evidence — The 2009 swarm. In 2009, earthquakes under Corva rose to about 40 per week for three weeks, all near 10 km deep. Sulfur dioxide stayed below 50 tonnes per day and the summit did not rise. The swarm faded and no eruption followed. **The deposits.** Layers of ash and pyroclastic-flow rock show that Corva has erupted explosively 6 times in the last 4,000 years. In 4 of those eruptions, pyroclastic flows rushed at least 15 km down the valley where Pine Hollow now stands.

Real reference: U.S. Geological Survey volcano alert levels (summarized)

Alert level	What it means
Normal	The volcano is in its typical background, non-eruptive state.
Advisory	The volcano shows signs of unrest above its known background level.
Watch	Unrest is heightened or escalating and the potential for eruption has increased, but the timeframe is uncertain; or a minor eruption is under way.
Warning	A hazardous eruption is imminent, under way or suspected.

Summarized from the USGS Volcano Hazards Program alert-level definitions for ground-based hazards.

Part A: Read the data

- Compare week 4 with week 12 for each measurement. For earthquakes and sulfur dioxide, find how many times larger the week 12 value is. For depth and uplift, find the difference. 4 pts

Answer: Earthquakes: 6 to 151; $151 \div 6 = 25.2$, about 25 times more. Depth: 9.0 km to 2.6 km; $9.0 - 2.6 = 6.4$ km shallower. Sulfur dioxide: 40 to 1,050 tonnes per day; $1,050 \div 40 = 26.25$, about 26 times more. Uplift: 2 mm to 112 mm; $112 - 2 = 110$ mm more uplift.

Why: Students must use division for the two counts that multiply and subtraction for the depth and uplift. All four signals changed strongly in the direction expected for rising magma.

Also acceptable: Accept 25 or 25.2 and 26 or 26.3.

2. The quakes are getting shallower each week. What does that suggest is happening to the magma? 2 pts
Explain why rising magma would cause small earthquakes.

Answer: Magma is moving upward toward the surface. As it pushes into the rock, it cracks and breaks the rock around it, and each small break is a small earthquake. Because the breaking moves up with the magma, the quakes get shallower week by week (from 9.0 km to 2.6 km).

Why: Shallowing seismicity is one of the clearest signs of ascending magma. The answer must link the quakes to rock breaking as magma forces its way up.

Also acceptable: Accept 'magma pushing the rock apart' or 'pressure from magma moving up cracks the rock'.

- Says the magma is rising
- Explains that magma breaking or forcing apart rock causes the quakes
- Uses the shallowing depths as evidence

3. The 2009 swarm did not end in an eruption. Name two ways the data from the last twelve weeks are different from 2009, and explain why those differences matter. 3 pts

Answer: In 2009 only the earthquakes changed: sulfur dioxide stayed below 50 tonnes per day, the summit did not rise, and the quakes stayed near 10 km deep. Now all signals are changing together: sulfur dioxide is about 26 times higher, the summit has risen 110 mm, and the quakes have climbed to 2.6 km deep. More gas and swelling show that magma is actually arriving near the surface, not just that rock is shifting deep down.

Why: One signal can rise for many reasons; several independent signals rising together, plus shallowing, make magma ascent the best explanation.

Also acceptable: Accept 'the quakes are 4 times more frequent than the 2009 peak' (151 versus about 40 per week) as one difference.

- Two specific differences with data (gas, uplift or depth)
- Explains that multiple signals together point to rising magma

Part B: Your argument

Answer: Claim: An eruption of Mount Corva is becoming much more likely over the coming weeks, so the observatory should raise the alert level to Watch: unrest is escalating and the potential for eruption has increased, but the timing is uncertain. Evidence: (1) Earthquakes rose from 6 per week in week 4 to 151 in week 12, about 25 times more, and their average depth became shallower, from 9.0 km to 2.6 km below the summit. (2) Sulfur dioxide rose from 40 to 1,050 tonnes per day, about 26 times more. (3) The summit has risen 112 mm since week 1. (4) In 2009, only the earthquake count rose, to about 40 per week at 10 km depth, with no gas increase or uplift, and no eruption followed. (5) Corva has erupted explosively 6 times in 4,000 years, and in 4 eruptions pyroclastic flows reached at least 15 km down the valley. Reasoning: The quakes show rock breaking as magma forces its way upward, and their rising position shows the magma climbing. More sulfur dioxide means gas is escaping from magma that is close to the surface, and uplift means magma is collecting under the summit and pushing it up. One signal alone can be a false alarm, as in 2009, but three independent signals rising together and accelerating make rising magma the best explanation. Even so, these signals tell us the likelihood is rising, not the day: magma can stall for weeks, and unrest can fade. Because Corva's magma is thick and sticky, any eruption is likely to be explosive, and its history shows pyroclastic flows reaching farther than the 12 km to Pine Hollow, so the town is in danger if Corva erupts the way it has before.

Why: This is the solved model response. The PE asks students to use precursor data to forecast an event and to inform mitigation; the claim must be probabilistic and tied to an alert level, and the reasoning must link each signal to magma and the history to the town's risk.

Also acceptable: Warning is acceptable if the student argues that the accelerating, very shallow quakes and rapid uplift mean an eruption is imminent, and still avoids naming a day. Advisory is too low for escalating unrest across all three signals; Normal is incorrect.

- Claim says eruption likelihood is rising and names an alert level (Watch, or Warning with justification)
- Claim avoids naming a date
- At least three evidence items with numbers from the dataset
- Evidence includes the 2009 comparison and a deposit fact
- Reasoning links quakes, depth, gas and uplift to rising magma
- Reasoning explains why multiple signals beat one and why no date can be given
- Reasoning connects thick magma and past flow distance to Pine Hollow's risk

Part C: From forecast to action

4. Name two mitigation steps Pine Hollow's leaders should take now, before any eruption begins. For each, say which piece of evidence makes it necessary. 3 pts

Answer: Examples: (1) Prepare and publish an evacuation plan and routes for the valley, because 4 of Corva's 6 explosive eruptions sent pyroclastic flows at least 15 km down the valley, beyond the town at 12 km. (2) Close the upper valley and trails near the summit, because the quakes are now only 2.6 km deep and the summit has risen 112 mm. Other steps: set up an alert system so the observatory can reach every resident quickly, move hospital patients and school buses into a ready plan, add more monitoring stations so changes are seen sooner.

Why: Mitigation reduces harm without stopping the hazard. Each step must be justified by a specific piece of evidence.

Also acceptable: Accept moving people from the valley floor to higher, side ground if tied to pyroclastic-flow paths.

- Two realistic mitigation steps taken before an eruption
- Each linked to a specific piece of evidence (flow distance, rising signals, thick magma)

5. The mayor asks the observatory, 'On what day will it erupt?' Write a two- or three-sentence answer that is honest and still useful. 2 pts

Answer: Example: 'We cannot tell you the day; magma can stall for weeks or the unrest could still fade. What we can tell you is that all three warning signs are rising fast, so an eruption is far more likely now than it was a month ago, and Pine Hollow is in the path of past pyroclastic flows. Please put the evacuation plan in place now so the town can move quickly when we raise the alert.'

Why: Students should model honest scientific communication: decline to predict a date, state the trend and its meaning, and give an action that matches the forecast.

Also acceptable: Accept answers that mention the alert level or promise updates as the data change.

- Declines to give a date and says why
- States that the likelihood is rising, with a reason
- Gives a clear action

Scoring rubric

Criterion	4 • Exemplary	3 • Proficient	2 • Developing	1 • Beginning
Claim	States that eruption likelihood is rising, names a justified alert level, and is worded as a forecast with no date.	States that an eruption is more likely and names an alert level, but wording slips toward certainty or the level is weakly justified.	States that Corva will erupt, or names a date or an alert level that does not fit escalating unrest.	No claim, or a claim unrelated to the data.
Evidence	Three or more accurate data points with numbers, including the 2009 comparison and a deposit fact.	Three accurate data points, but the 2009 comparison or the deposit fact is missing.	One or two data points, or data described without numbers.	No evidence from the tables, or inaccurate numbers.
Reasoning about the signals	Links quakes, shallowing depth, gas and uplift to rising magma; explains why several signals together are stronger than one; explains why no date can be given.	Links at least two signals to magma and explains either the multiple-signal idea or the no-date idea.	Restates the evidence with little explanation of what it means about magma.	No reasoning, or reasoning that contradicts the evidence.
Connecting forecast to risk and mitigation	Uses thick magma and past flow distance to explain Pine Hollow's risk, and Part C steps are each tied to specific evidence.	Explains Pine Hollow's risk, but one mitigation step is not tied to evidence.	Mentions the town or mitigation without connecting to the history or the data.	No connection between the forecast and what the town should do.

Teacher notes

The Corva dataset, the 2009 swarm and the deposit record are invented but follow real precursor patterns: increasing and shallowing earthquakes, rising sulfur dioxide and summit uplift, as at Mount St. Helens in 1980 and Pinatubo in 1991. The alert-level table summarizes the real USGS ground-based alert levels (Normal, Advisory, Watch, Warning); the aviation color code is not used here. Watch is the best-fit answer because the definition explicitly covers escalating unrest with an uncertain timeframe; Warning is a defensible answer when argued from acceleration. The lesson text says scientists can 'predict' eruptions;

teach that precursors let scientists forecast that an eruption is becoming more likely, and that unrest can last weeks to years or fade without an eruption (the 2009 swarm illustrates this). Keep Part C at the level of community planning; this sheet does not give personal emergency instructions.

Scaffold offered to students: Building the argument

Claim frame: 'The data show that an eruption of Mount Corva is becoming (more / less) likely, so the alert level should be ____.' Evidence frame: 'From week 4 to week 12, ____ rose from ____ to ____.' Reasoning frames: 'Rising earthquakes and shallower depths suggest ____.' 'Unlike in 2009, ____.' 'Because Corva's magma is thick and its past flows reached 15 km, ____.' 'The data cannot tell us the day because ____.'

Extension: When scientists got it right, and what it cost to wait

In 1991, scientists watching Mount Pinatubo in the Philippines used rising earthquakes, gas and ground swelling to forecast a large eruption, and tens of thousands of people were evacuated before it erupted on June 15. Read the USGS fact sheet about the eruption. Write a paragraph comparing their evidence with Corva's, and explain one problem officials face if they evacuate too early (people may go home before the eruption) or too late.