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The Kīlauea Volcano: Be a Volcanologist

Monitoring Hawai'i Volcanoes

Learning IN MOTION®

1 Monitoring Hawai‘i Volcanoes

Students take on the role of volcanologists working to keep the public safe on the island of Hawai‘i. They begin by analyzing geologic data from the days leading up to the May 2018 eruption of Kīlauea. Students use the data to make predictions and recommendations about mitigating the effects of volcanic hazards on the island. Students will continue this process in the next lesson. They will also refer to this information as they create a Hazard Response Plan in the final lesson.

This lesson requires some familiarity with basic terms and concepts related to volcanoes. If your class has limited prior knowledge of volcanoes, it is recommended that you complete Lesson 0 before doing this lesson.

GUIDING QUESTION

How do scientists monitor volcanoes in order to predict hazards and keep the public safe?

Lesson 1: Monitoring Hawai‘i Volcanoes

MATERIALS

Teacher Materials

- **Monitoring Hawai‘i Volcanoes** visuals
  - **Hawai‘i Volcanoes** slideshow
  - **Deformation Model Demonstration** video (optional)
  - **Hawai‘i Lava Flow Hazard Map** visual
- Optional: Materials for deformation model demonstration
  - Cardboard or Styrofoam box
  - Plastic tubing
  - Baking flour
  - Tape
  - Balloon
  - Optional: Trash bag

Student Materials

- **Hawai‘i Volcanoes Data** handout (online or print) (1 per pair or team of 4)
- **Volcanology** handout (1 per student)
- **Observation Journal** handout (1 per student)
- Optional: Computer or tablet with Internet access (1 device per pair)
- Optional: Poster paper for class chart

RESOURCES

Websites

USGS Volcano Hazards Program

Optional: IRIS Measuring Deformation and Tilt with GPS

Lesson 1: Monitoring Hawai‘i Volcanoes

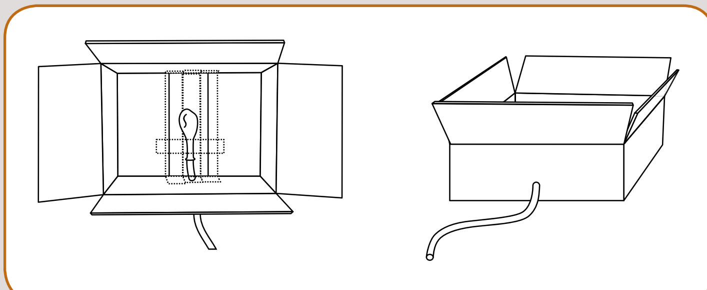
LESSON PREPARATION

Determine Lessons' Fit in Curriculum

1. If you have not done Lesson 0, read through that lesson and determine whether your class needs the introduction to different types of volcanoes and their characteristics. Lesson 1 and the subsequent lessons are designed to provide opportunities for students to analyze and interpret data from a recent hazardous event: the eruption of Kīlauea volcano. The lessons assume students' knowledge of the features of volcanoes.

Prepare Lesson Materials

1. Determine which lesson handouts you will need hard copies of, and print enough for your class. Note that the **Hawai‘i Volcanoes Data** handout can be accessed online. It is recommended that students work in groups of four if using hard copies and in pairs if using computers. If using hard copies, printing in color is highly recommended to support student analysis.
    - The **Volcanology** handout can be laminated for re-use.
    - Each student needs a copy of the **Observation Journal** handout; alternatively, you can create a model of the handout somewhere easily visible, such as on a white board.
2. Determine whether you will do a live demonstration of a deformation model or show students the **Deformation Model Demonstration** video to support student learning during the activity. If doing the live demonstration, set it up as follows:



    - Tape the bottom of the box, or line it with a trash bag to prevent leakage.
    - Make a hole on the side of the box near the bottom (to feed the tubing through).
    - Insert one end of the tubing into the balloon and tape it in place. Place the balloon on the bottom of the box and feed the other end of the tubing out through the hole in the side of the box.
    - Tape the tubing down on the bottom of the box.
    - Fill the box with 6–8 inches of flour and press and smooth it down.

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- Test out your deformation model by blowing into the tubing to inflate the balloon, causing deformation, and then letting the air out rapidly to create a caldera. Ensure that you can inflate the balloon and that it has the proper effects. After testing, ensure the balloon is deflated and press down and smooth out the flour again before doing the demonstration.

3. Prepare a class chart based on the table in the **Observation Journal** handout for use in the discussion part of the lesson (see page 26).

Prepare the Activity Approach

1. Determine how you would like to structure the Activity section of this lesson. For example:
   - Have teams self-direct their pacing and decide for themselves which data to analyze first.
   - Give students more structured guidance. Encourage the class to start with the reports from the five volcanoes on the island of Hawai‘i and then progress to the earthquake data.
   - You might also assign team roles and/or designate different students within the teams to lead the team’s analysis of different pieces of data.

2. Part of the activity involves plotting coordinate points on a map. If students have not plotted coordinate points on a map before, demonstrate the process. This map shows latitude and longitude lines to the tenth of a degree; students should estimate the placement of points between those lines. Be sure that students understand how to plot points to the hundredth of a degree and recognize that the values of the *x*-axis decrease from left to right (because they represent coordinates west of the prime meridian; these can also be considered negative coordinates). Note that the coordinates on both axes of the map do not start at 0 because the map shows only the area around the island of Hawai‘i.

Hawai‘i Volcanoes Online Data interactive map

Lesson 1: Monitoring Hawaiʻi Volcanoes

- If students have access to a computer or tablet, they can use the interactive map in the **Hawaiʻi Volcanoes Online Data**. Demonstrate how to find and mark a point on the map. Students can check off each earthquake from the list as they plot it.
- If computer access is not available, students can plot the points by hand on the paper map provided in the **Hawaiʻi Volcanoes Data** handout.

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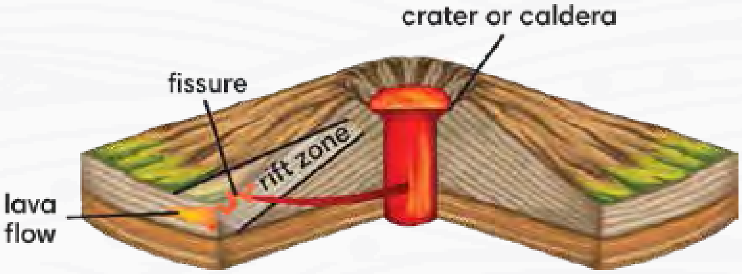
OPENING

Elicit Prior Knowledge

1. If your class completed Lesson 0, remind them that they prepared for their role as volcanologists by exploring important concepts about volcanoes and classifying them into different categories.
2. If your class did not complete Lesson 0, engage students' prior knowledge of volcanoes by asking questions such as:
   - *Has anyone ever visited a volcano? What did you observe?*
   - *Why do you think it is important to study volcanoes?*
   - *How might volcanoes affect humans?*

Introduce the Hawaiian Volcanoes

1. Show students the **Hawaiʻi Volcanoes** slideshow. The first image is a map that names some of the volcanoes in the chain of the Hawaiian islands.
   - Explain that some islands were formed by one volcano, while others are made up of two or more.
   - Point out the five volcanoes on the "Big Island" of Hawaiʻi—Kohala, Mauna Loa, Mauna Kea, Hualālai, and Kīlauea—and explain that these are all shield volcanoes.
2. Then go over the diagram showing the structure and features of a shield volcano. If the class completed Lesson 0, this diagram will be familiar from that lesson.
3. Next, show the profiles of each volcano in the slideshow. After showing the volcanoes, ask students:
   - *Which volcanoes should be closely monitored, and why?*



Hawaiʻi Volcanoes slideshow

Students might say:

- **Mauna Loa, Hualālai, and Kīlauea because they are all active volcanoes.**
- **I think Mauna Kea should also be monitored because it is dormant and it might erupt again.**
- **Kīlauea should be monitored very closely because it has been continuously erupting.**

Lesson 1: Monitoring Hawai‘i Volcanoes

Kohala

Mauna Loa

Mauna Kea

Hualālai

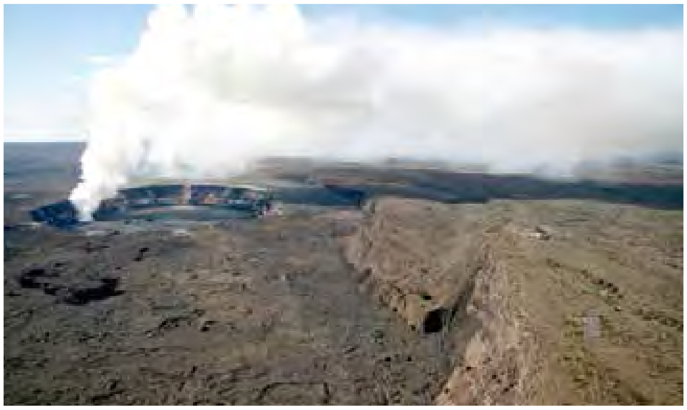


Image Credit: U.S. Geological Survey

Kīlauea

Lesson 1: Monitoring Hawai‘i Volcanoes

Introduce Working as Volcanologists

1. Introduce or review the unit Guiding Question:

   How do scientists monitor volcanoes in order to predict hazards and keep the public safe?

2. Introduce students to their role for this lesson and the following lessons: They will work as volcanologists (scientists who study volcanoes) on the island of Hawai‘i. As volcanologists, students will interpret scientific information and use it to keep the public safe from volcanic hazards. Set the scene for students as beginning in late April 2018. Give each student a copy of the **Observation Journal** handout.


Observation Journal

Observation Journal handout

3. Explain that students should use the **Observation Journal** to:
   - Predict changes in volcanic hazards on the island.
   - Make safety recommendations to the public.

4. You may want to record these tasks on the board or somewhere else easily visible to students for reference.

ACTIVITY

Introduce the Activity

1. Organize students into teams of four.

2. Give each team a copy of the **Volcanology** handout, which contains important information they can use to help them analyze the volcano data they will receive. If the class completed Lesson 0, they will have already read pages 1–8. If not, they can refer to these pages as needed. Point out the following sections on pages 9–11 that pertain to today's lesson, and read the topic questions as a class:
   - *How and why do scientists monitor deformation at volcanoes?*
   - *How and why do scientists monitor earthquakes around volcanoes?*
   - *How and why do scientists monitor sulfur dioxide concentrations around volcanoes?*


1
Monitoring Hawai‘i Volcanoes
Volcanology
The ground is swelling!
How and why do scientists monitor deformation at volcanoes?

Volcanology handout

Lesson 1: Monitoring Hawaiʻi Volcanoes

3. Also provide each team with access to the **Hawaiʻi Volcanoes Data** handout (either the print or online version), which includes:
   - A recent report from each of the five volcanoes on Hawaiʻi, including a graph of deformation at Kīlauea
   - A list of the date, time, and location of recent earthquakes on and near the island
   - A map of the island with latitude and longitude lines
   - A map of sulfur dioxide concentration on and near the island

4. Emphasize that if students run into unfamiliar vocabulary or aren't sure how to interpret the data in their **Hawaiʻi Volcanoes Data** handout, they can refer to the **Volcanology** handout for assistance.

5. You may want to conduct a quick class brainstorm regarding possible ways to organize the data in the **Observation Journal**—for example:
   - By date
   - By type of observation (earthquakes, deformation, etc.)
   - By location/area

   Alternatively, suggest one of these methods for all students to use.

Hawaiʻi Volcanoes Data handout

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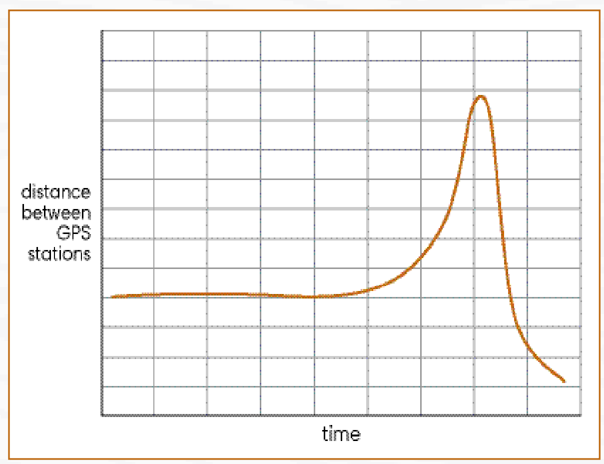
Demonstrate Deformation

1. As teams get started, do the deformation model demonstration (see Lesson Preparation) or show students the [Deformation Model Demonstration] video in a location where small groups can view it. Call the teams of students, one by one, to observe the demonstration while the rest of the class continues working.

Deformation Model Demonstration video

Source: U.S. Geological Survey

   - Before starting the demonstration, ask students to draw a “Before” picture of the setup.
   - Then blow up the balloon or show that portion of the video. Cover the tubing so that the balloon does not deflate, or pause the video before the deflation is shown. Ask students to draw a “During” picture and share their observations.
   - Finally, allow the balloon to deflate rapidly. (It may help to suck the air out of the balloon through the tubing.) This process should form a caldera in the flour. Ask students to draw a “Final” picture and share their observations.
   - Engage the team in briefly talking about what happened to the land and why.
   - Then ask students to consider how GPS stations (described in their **Volcanology** handout) can monitor the types of changes they observed. Tell them to imagine two GPS stations set up on opposite sides of the volcano. Ask:
     - *How would the distance between the stations change as the volcano inflates? How would it change after the eruption?*
   - Briefly create a graph like the example shown to show changes in deformation leading up to and after an eruption. The increase in distance between the stations occurs as inflation pushes the ground outward. After an eruption, the distance rapidly decreases again as the ground sinks back down.



   - You may also opt to show students the **Volcano Monitoring: Measuring Deformation and Tilt with GPS** animation from IRIS (Incorporated Research Institutions for Seismology).
   - Reset the demonstration before calling up the next team.

Lesson 1: Monitoring Hawai‘i Volcanoes

Observe, Organize, and Analyze Data

1. After doing the deformation model demonstration or showing the video, circulate to provide support as teams work together to analyze all of the information in the **Hawai‘i Volcanoes Data** handout. Prompt them to refer to the **Volcanology** handout to help them make sense of new terms and concepts. Also remind students to record their observations, analyses, and recommendations in the **Observation Journal**.

2. As students discuss ideas with their teams, remind them to focus on determining whether they anticipate any changes in volcanic activity, and, if so, where. If a team struggles with the process, consider asking questions such as:
   - *What patterns do you notice about the earthquake data?*
   - *What do you notice about the sulfur dioxide data?*
   - *What do you notice about the deformation data? How does it compare to the deformation demonstration that you observed?*
   - *How does that information help you make a prediction about volcanic activity on Hawai‘i?*
   - *How does the data your team looked at help you identify areas at risk for new volcanic hazards or eruptions?*

   As students view the deformation data from Kīlauea, they should notice that the graph shows a sharp increase prior to May 2018. This increase can be interpreted as inflation of the magma reservoir, which often occurs prior to eruption and/or movement of magma.

   Students' plotted earthquake data should look like the example shown here:

3. Note that students using the **Hawai‘i Volcanoes Data** handout online can use the Print Map button to generate an image file of their map that they can then print or save to their computer. Students may want to use this image later as part of their final project.

Lesson 1: Monitoring Hawai‘i Volcanoes

Discuss Data Analysis and Recommendations

1. Gather the class for discussion.
2. Have each team take turns sharing a finding they found important, and then ask for input from the rest of the teams: do they agree or disagree?
3. Begin a chart to keep track of ideas and recommendations from the teams. A completed class chart might resemble the following (note that your class may have chosen to organize their **Observation Journal** in a different way, such as by date):

Our Observations	Our Analysis	Our Recommendations
Earthquakes • A couple of earthquakes occurred on Mauna Loa in March. • At the beginning of May there were lots of earthquakes around Kīlauea. • Earthquake locations were mostly south and east of the Kīlauea summit.	• The increase in earthquakes in the Kīlauea area might mean Kīlauea is about to erupt.	• Scientists should watch Kīlauea closely. • Scientists should monitor the area southeast of the Kīlauea summit. • People who live near Kīlauea should make emergency plans. • Scientists should also continue monitoring Mauna Loa.
Deformation • Inflation has been happening at Mauna Loa, but it seems to be slowing down recently. • Starting around March 2018, a sharp increase in inflation happened near Pu‘u‘ Ō‘ō at Kīlauea.	• The sharp increase in inflation might mean Kīlauea is about to erupt. • The eruption could happen at Pu‘u‘ Ō‘ō or somewhere nearby in the rift zone.	• Scientists should watch Kīlauea closely. • People who live near Kīlauea—and especially in the rift zone—should make emergency plans.
Sulfur dioxide • The concentration of sulfur dioxide around Kīlauea increased between April 3 and May 3.	• Magma is probably getting near the surface. • The increase in sulfur dioxide might mean Kīlauea is about to erupt.	• Scientists should watch Kīlauea closely. • Anyone who has problems with breathing should leave the area.

Keep the chart for review and reference in the following lessons.

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Decide on a Plan

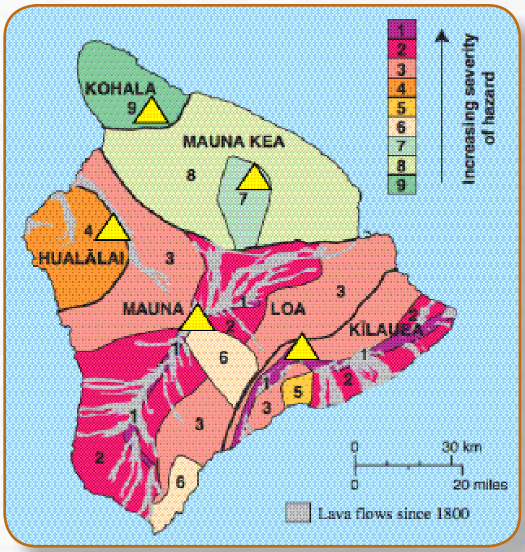
1. Review the teams' recommendations on the class chart.
2. Show students the following options, and have them vote on what they think is the best course of action at this point. Students may select more than one option.
   - Evacuate the entire island.
   - Closely monitor the area around Mauna Loa.
   - Closely monitor the area around Kīlauea.
   - Evacuate the area around Kīlauea.
   - Issue an alert for the area around Kīlauea.
3. After each vote, call on students to provide reasoning for their selection. If students disagree, allow them to respectfully challenge each other's reasoning. For example, students might say:
   - **I think scientists should closely monitor the area around Kīlauea and issue an alert for that area. The warning signs were all happening there, but not around the other volcanoes.**
   - **I think scientists should also monitor the area around Mauna Loa. Even though there weren't as many warning signs there, it is still an active volcano.**
   - **I think the entire island should be evacuated, just to be safe.**
   - **I don't think the entire island should be evacuated because it would be difficult, and it would affect a lot of people. I think they should just evacuate the area around Kīlauea.**
   - **I don't think people should be evacuated yet. Kīlauea has already been erupting for a long time, and they didn't need to evacuate the whole area. They just closed areas where the lava was flowing. They should just issue an alert and watch the area closely.**

Lesson 1: Monitoring Hawai‘i Volcanoes

REFLECTION

Summarize

1. After completing the class chart, review some of the main points that students made. For example, you might say:
    - Our class noticed a lot of earthquakes in the area near Kīlauea to the south and east. We also observed sudden inflation of the land around Pu‘u‘ Ō‘ō and an increase in sulfur dioxide around Kīlauea. Based on these observations, we recommended that the Kīlauea area should be monitored closely and residents should be prepared to leave the area, because these warning signs all indicate that a new eruption could happen soon.
2. Explain that volcanologists can use a volcano’s past eruptive history to document zones where hazards might be the greatest in a future eruption.
    - Display the **Hawai‘i Lava Flow Hazard Map** visual, which illustrates areas of increasing relative severity of lava-flow hazards, designated “9” through “1.”
    - Note that the gray shaded areas show land covered by flows erupted in the past two centuries from three of Hawai‘i’s five volcanoes.
    - Call on students to point out where Kīlauea’s past flows have been and where the highest severity of hazard is near that volcano.

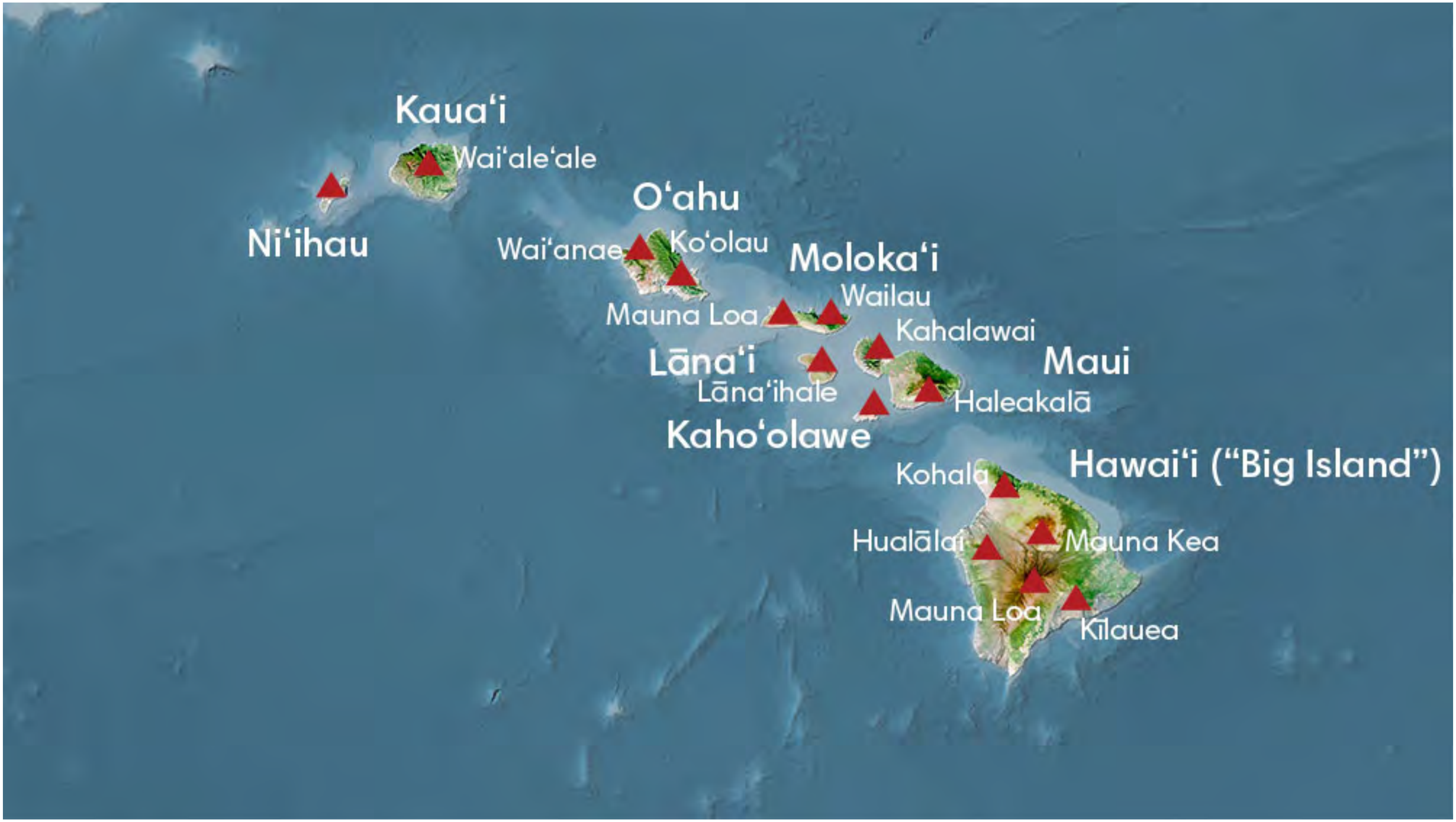


Hawai‘i Lava Flow Hazard Map visual

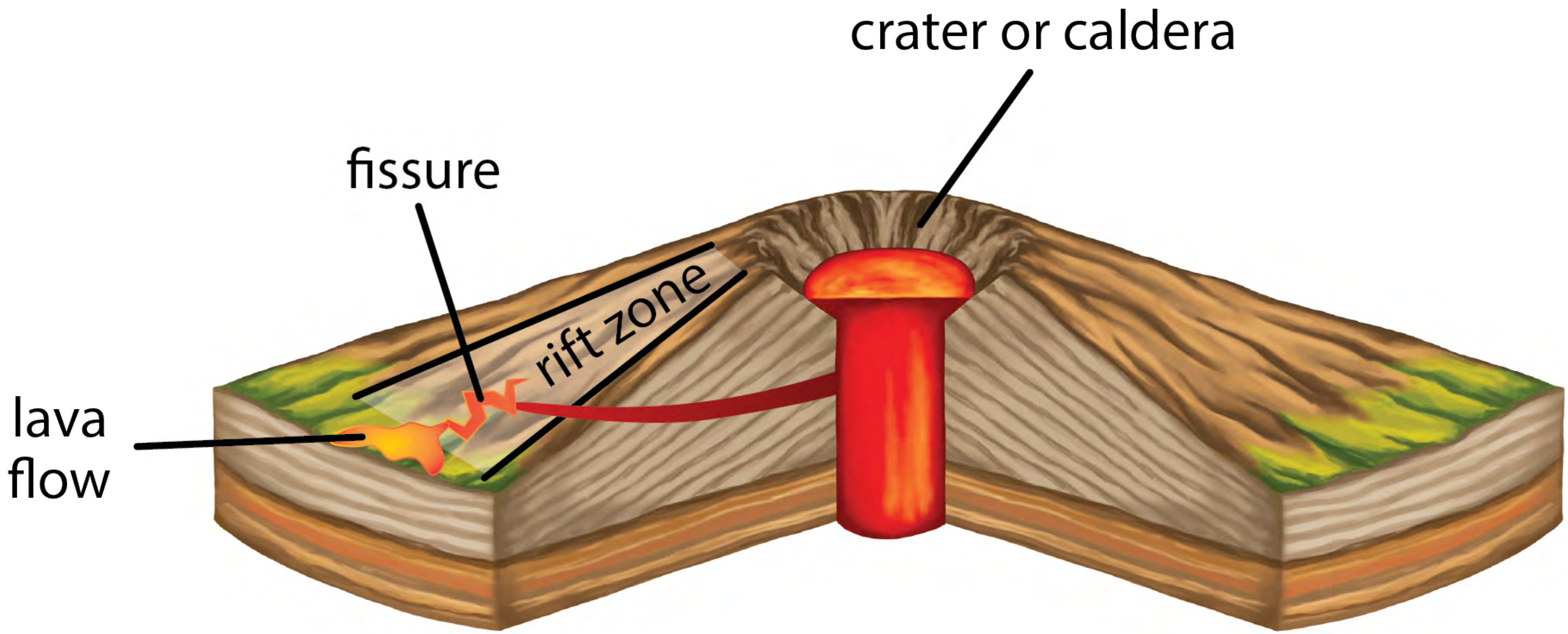
Source: U.S. Geological Survey

3. Explain that scientists work with emergency management organizations at the national, state, and local level to issue warnings and alerts about natural hazards such as volcanic eruptions. Point out that analyzing scientific data, as students did in today’s lesson, does not necessarily tell us exactly how people should act or respond. However, it does help us make informed decisions.
4. Show students the United States Geological Survey (USGS) Volcano Hazards Program website. Explain that this government website provides citizens with information about how scientists help keep the public safe.
5. Congratulate students for their work interpreting geologic data in order to keep the public safe.

Hawai‘i Volcanoes



Shield Volcano



Kohala

20.09º N, 155.72º W, Summit Elevation 1,670 m (5,479 ft.)
Kohala is an ***extinct volcano*** that last erupted about 60,000 years ago.

Mauna Loa

19.48º N, 155.60º W, Summit Elevation 4,170 m (13,681 ft.)
Mauna Loa is an ***active volcano*** that is not currently erupting.

Mauna Kea

19.82º N, 155.47º W, Summit Elevation 4,205 m (13,796 ft.)
Mauna Kea is a ***dormant volcano***. It was last active about 4,600 years ago.

Hualālai

19.69º N, 155.87º W, Summit Elevation 2,523 m (8,278 ft.)

Hualālai is an ***active volcano*** that typically erupts two to three times per 1,000 years. It last erupted in 1801.

Kīlauea

19.42º N, 155.29º W, Summit Elevation 1,247 m (4,091 ft.)
Kīlauea is an ***active volcano*** that has been erupting continuously since 1983.

Observation Journal

Date(s)	Observations	Analysis (What are the hazards? What do you predict next?)	Recommendations

Observation Journal

Date(s)	Observations	Analysis (What are the hazards? What do you predict next?)	Recommendations

Hawaiʻi Volcanoes Data

Here are reports from the end of April, 2018 about each of the five volcanoes on the island of Hawaiʻi.

Kohala

- 20.09° N, 155.72° W
- Summit elevation 5,479 ft (1,670 m)
- Kohala is an **extinct volcano** that last erupted about 60,000 years ago.

Mauna Loa

- 19.48° N, 155.60° W
- Summit elevation 13,681 ft (4,170 m)
- Mauna Loa is an **active volcano** that is not currently erupting.
- **Deformation** beneath the summit and upper Southwest Rift Zone has been slowing down.

Mauna Kea

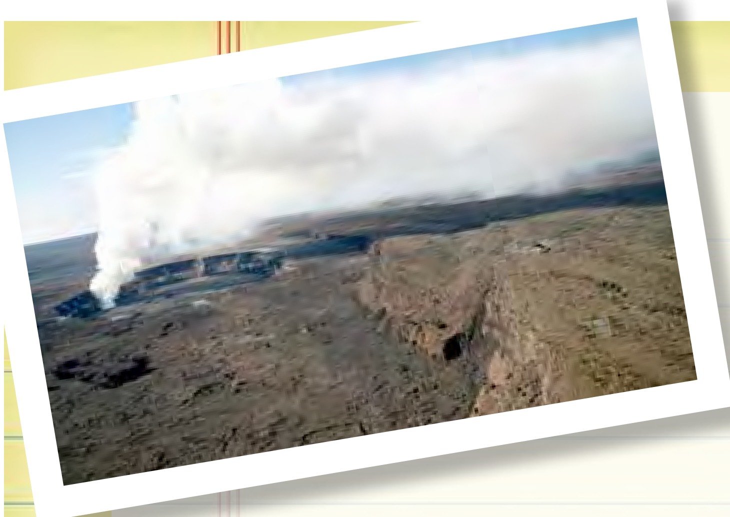
- 19.82° N, 155.47° W
- Summit elevation 13,796 ft (4,205 m)
- Mauna Kea is a **dormant volcano**. It was last active about 4,600 years ago.

Image Credit: J. Kauahikaua

Hualālai

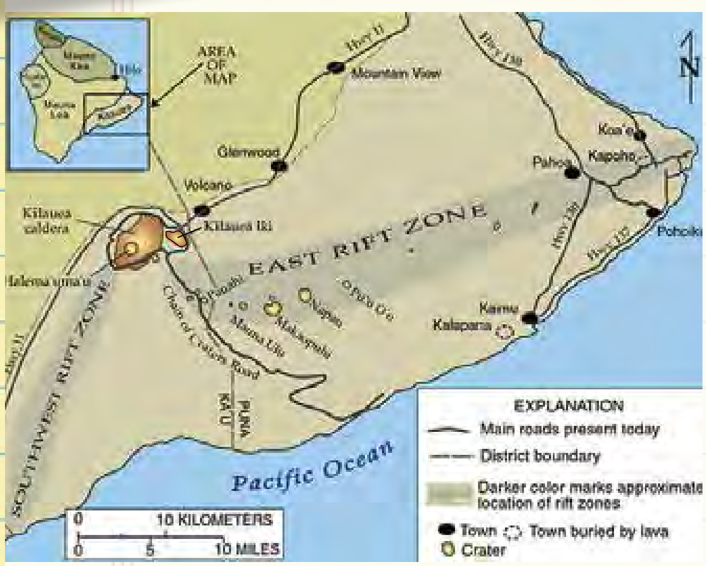
- 19.69° N, 155.87° W
- Summit Elevation 8,278 ft (2,523 m)
- Hualālai is an **active volcano** that typically erupts two to three times per 1,000 years. It last erupted in 1801.
- No significant **deformation** around Hualālai has been reported during the past five years.

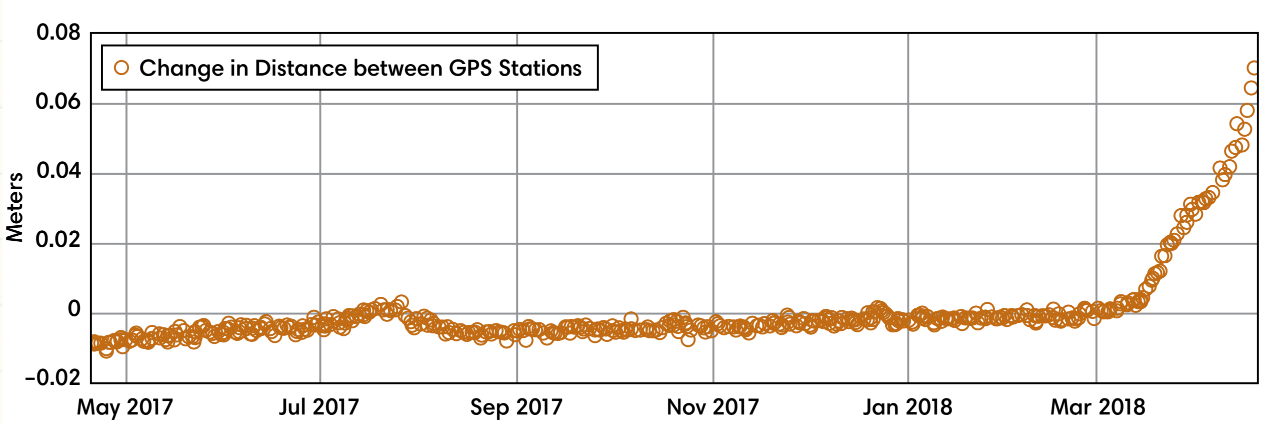
Hawaiʻi Volcanoes Data



Kīlauea

- 19.42° N, 155.29° W
- Summit elevation 4,091 ft (1,247 m)
- Kīlauea is an **active volcano** that has been erupting continuously since 1983. **Lava flows** have occurred from the East Rift Zone (see map) and entered the ocean. New **fissures** erupted near Puʻu ʻŌʻō (see map) in June 2014 and May 2016. There is an active lava flow from Puʻu ʻŌʻō within an area that is closed to the public. There is no lava entering the ocean at this time.
- **Deformation** from the past year is shown in the graph below.





Change in distance between two GPS stations near Puʻu ʻŌʻō

Source: Adapted from U.S. Geographical Survey
Image credit: U.S. Geographical Survey

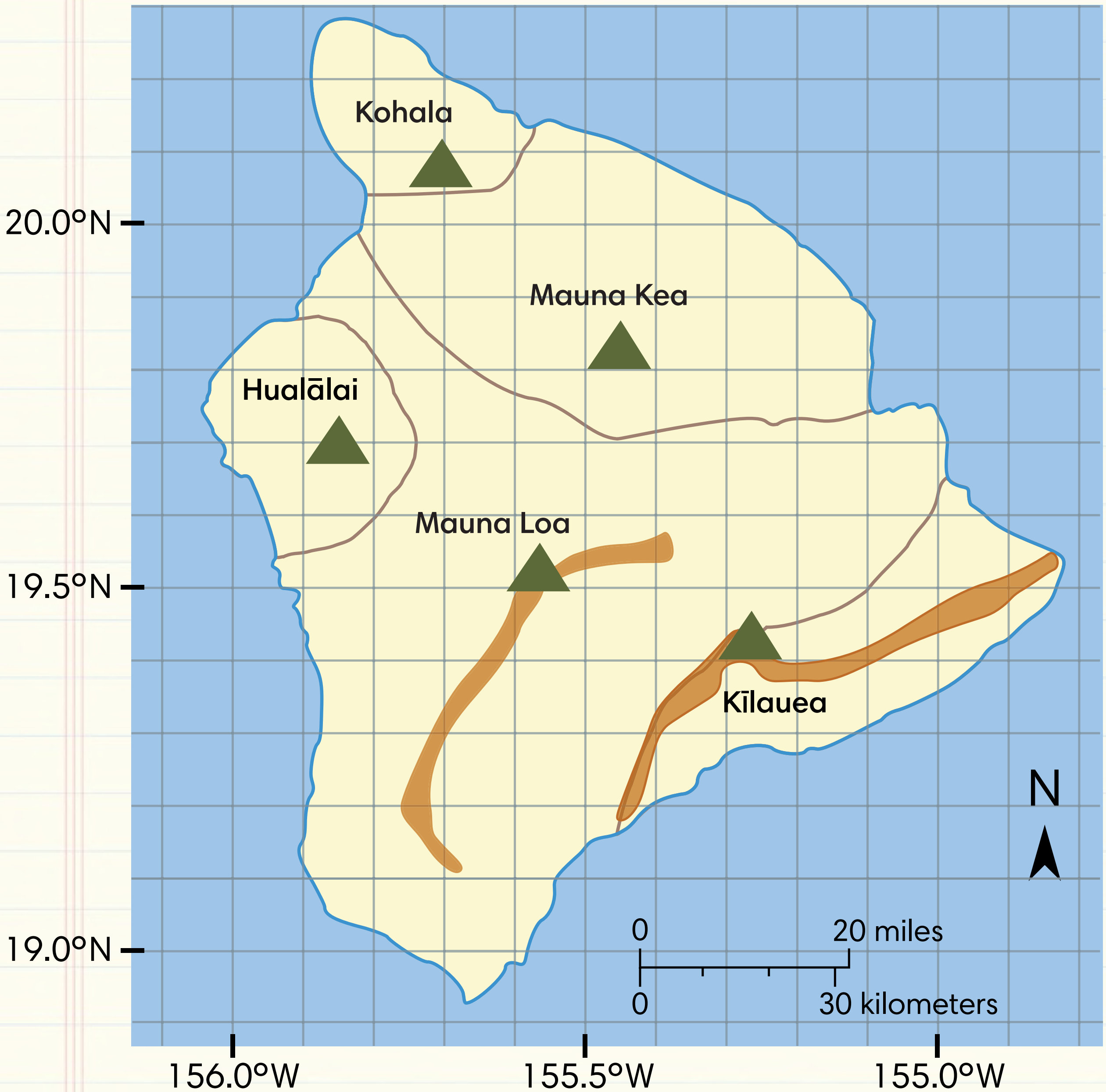
EARTHQUAKES

- The list below shows the earthquakes that occurred in the area shown on the map on the next page during the dates of March 3, 2018 to May 3, 2018*.
- Use the coordinates of the locations to plot the earthquakes on the map.

*Earthquakes shown are of magnitude 3.0 or greater.

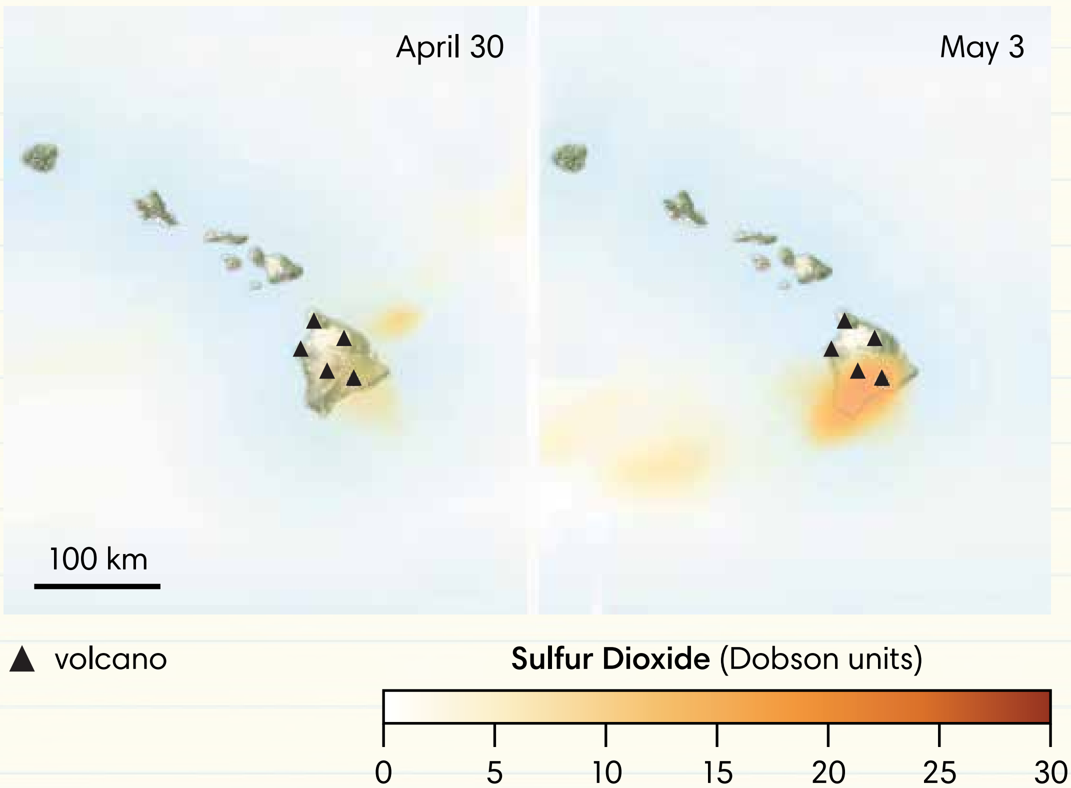
Date	Time	Location
3/3/18	6:10 PM	19.42 N, 155.61 W
3/4/18	9:31 PM	19.43 N, 155.61 W
3/21/18	3:49 AM	19.21 N, 155.41 W
3/28/18	1:43 AM	18.91 N, 155.37 W
4/4/18	8:24 AM	18.90 N, 155.36 W
4/26/18	11:08 PM	19.38 N, 155.24 W
5/1/18	4:40 AM	19.34 N, 155.06 W
5/1/18	5:49 AM	19.33 N, 155.06 W
5/1/18	12:39 PM	19.27 N, 155.10 W
5/1/18	1:12 PM	19.34 N, 155.02 W
5/1/18	3:52 PM	19.34 N, 155.02 W
5/1/18	10:07 PM	19.34 N, 154.99 W
5/2/18	4:00 AM	19.31 N, 154.97 W
5/2/18	6:47 AM	19.33 N, 154.98 W
5/2/18	9:31 AM	19.31 N, 154.96 W
5/3/18	9:22 AM	19.38 N, 154.86 W
5/3/18	9:22 AM	19.38 N, 155.22 W
5/3/18	8:30 PM	19.38 N, 155.22 W

ISLAND OF HAWAI‘I



SULFUR DIOXIDE

The map below shows the amount of sulfur dioxide that was present in the atmosphere around Hawaiʻi on April 30 and May 3, 2018.



Source: Base map and data: NASA

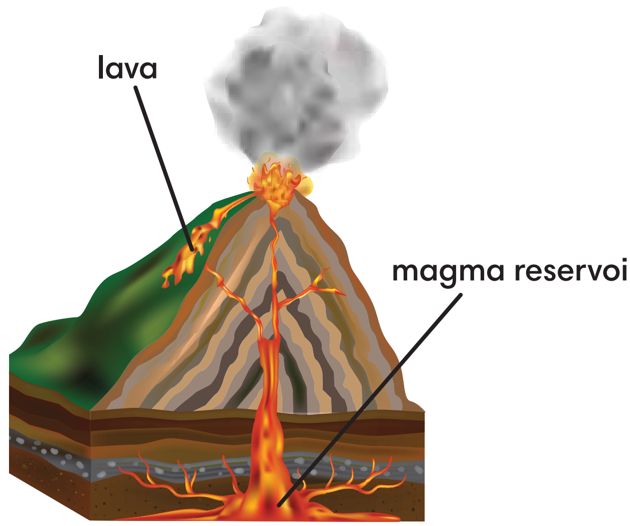
IMPORTANT TERMS

magma Rock that is molten (in liquid form due to heating). When magma reaches the surface, it is called *lava*.

magma reservoir An underground pool that is filled with molten rock (magma); also known as a **magma chamber**.

lava Magma (molten rock) that is erupting/has erupted above ground. Lava is hot! Hawaiian lava has an average temperature of about 1100°C (2012°F).

- **lava flow** Lava moving along the ground (or underwater).
- **lava lake** A pool of lava that forms in a volcanic crater or caldera.



magma reservoir and lava


lava


lava lake

eruption (volcanic) Occurs when gases, ash, rocks, and/or lava break out of Earth's surface.

- **explosive eruption** An eruption in which trapped gases blast apart sticky lava. This creates debris and causes ash clouds that can reach high into the sky.
- **effusive eruption** An eruption in which runny lava flows steadily and often slowly downhill.
- **flank eruption** An eruption from the side (flank) of a volcano rather than from the summit. Flank eruptions are common in the rift zones of shield volcanoes.

explosive eruptions

effusive eruption

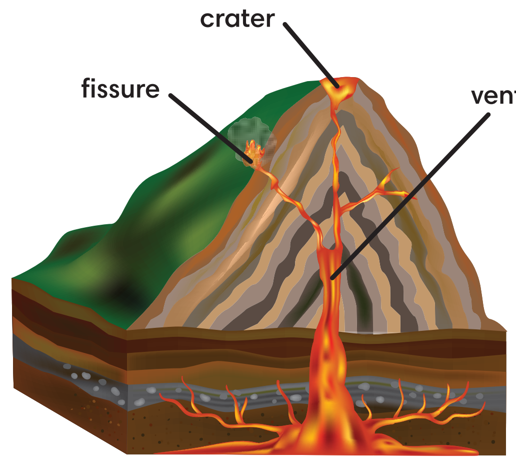
flank eruption (effusive)

Volcanology

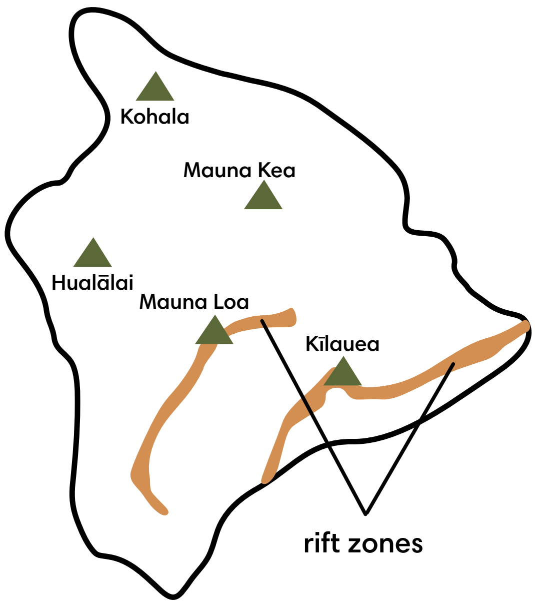
fissure A long crack or break in the ground from which volcanic gases, ash, rocks, and/or lava erupts.

rift zone An area along the side of a volcano where the land is splitting apart. Fissures often form in these areas. Rift zones are common in shield volcanoes.

vent An opening in a volcano that carries magma up to the summit crater or to a fissure.



vent, fissure, and crater



rift zones

fissure

caldera A large, steep-sided pit on a volcano. It is formed when the summit (highest point) collapses because magma has drained away or lava has erupted from it. Calderas are found on many dormant volcanoes. Sometimes, however, a caldera can have an active crater inside it.

crater A pit with openings for volcanic activities like lava flow and eruption of ashes. Craters are smaller than calderas and are generally circular.

caldera

crater within a caldera

tephra Ash and lava fragments that are thrown into the air during a volcanic eruption.

- **volcanic bomb** (or **projectile**) A piece of tephra that measures over 64 mm.
- **volcanic ash** A piece of tephra that measures less than 2 mm.


eruption of tephra

volcanic bomb

volcanic ash

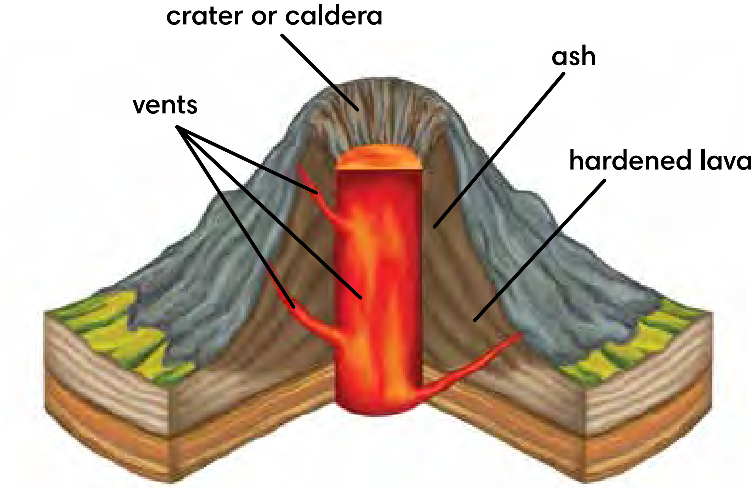
WHAT IS A COMPOSITE VOLCANO?

A **composite volcano** is the tallest and steepest type of volcano. It has the shape and size of a mountain.

On a composite volcano, thick and sticky lava erupts from a central vent. The eruptions are often explosive. Flank eruptions can also occur.

Composite volcanoes are formed of layers of hardened lava and ash. Most have a summit crater, which can become a caldera after a large explosion and collapse.

Another word for a composite volcano is **stratovolcano**.



structure of a composite volcano

Mount Fuji, Japan

Volcán Arenal, Costa Rica

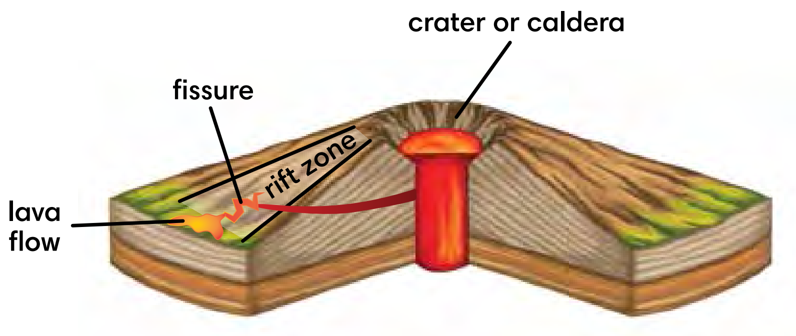
WHAT IS A SHIELD VOLCANO?

A **shield volcano** is the largest and widest type of volcano. It is less steep than other volcanoes. The name "shield" comes from the broad shape, which looks like a warrior's shield.

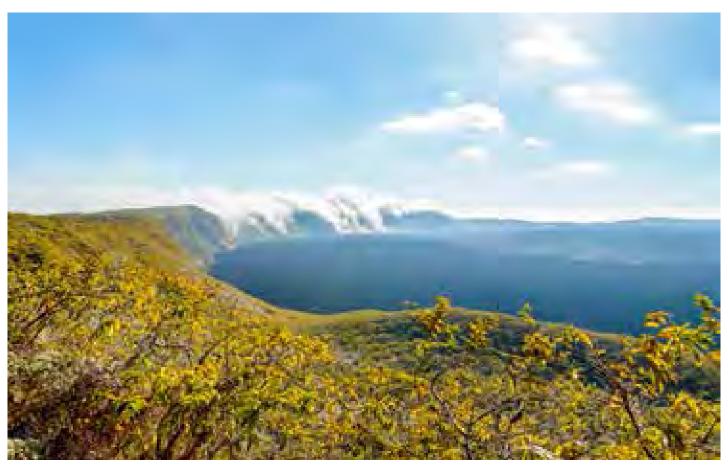
A shield volcano often has effusive eruptions of runny lava. However, explosive eruptions can also occur. Eruptions often occur from fissures in rift zones.

Shield volcanoes build up over time from lava flows that pour in all directions. When this occurs in the ocean, the hardened lava can form an island.

A large eruption on a shield volcano can form a caldera.



structure of a shield volcano



Galápagos Islands, Ecuador

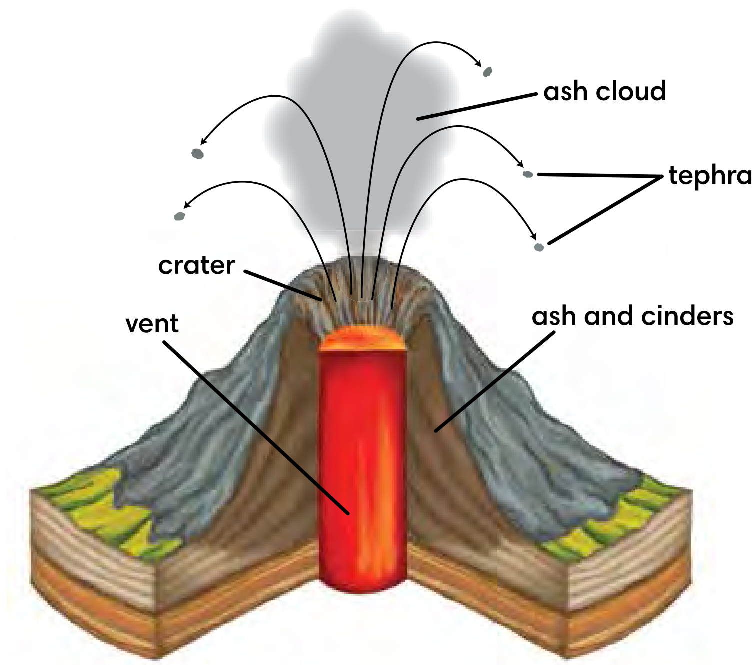
WHAT IS A CINDER CONE VOLCANO?

A **cinder cone volcano** is the simplest form of volcano.

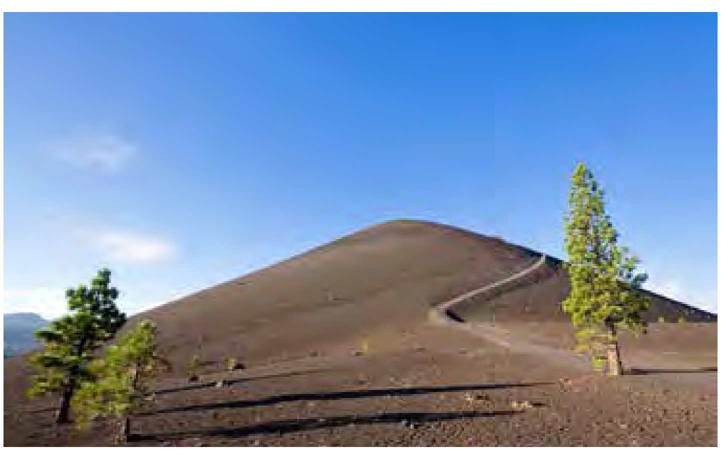
Cinder cones are relatively small. They rarely rise more than 300 m above their surroundings.

Cinder cones have explosive eruptions of gas, lava, and ash from a single vent. These lumps of lava cool into cinders and pile up with ash to create a cone shape with a crater at the top.

Cinder cones often form on or near larger volcanoes (shield or composite volcanoes).



structure of a cinder cone volcano



cinder cone, Lassen Volcanic National Park, CA

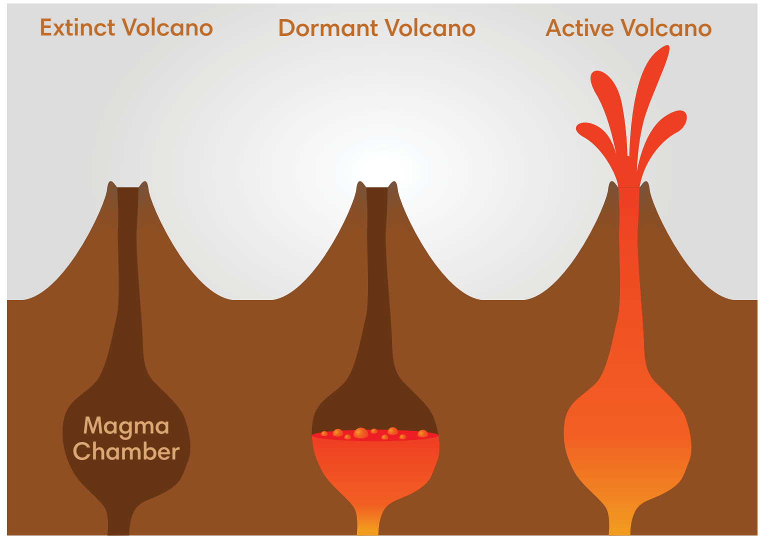
cinder cones within Haleakalā National Park, Hawai'i

HOW CAN YOU TELL WHETHER A VOLCANO IS ACTIVE, DORMANT, OR EXTINCT?

Most scientists call a volcano **active** if it has erupted in the last 10,000 years.

If a volcano has not erupted very recently but is expected to erupt again, then it is called **dormant**. A dormant volcano is a kind of active volcano. It still holds magma beneath it.

A volcano is called **extinct** if scientists think it will never erupt again. Most extinct volcanoes show no evidence of an eruption within the last 10,000 years. An extinct volcano is cut off from any supply of magma.



extinct, dormant, and active volcanoes

Glass House Mountains, Australia: extinct volcanoes

Kibo peak, Kilimanjaro, Tanzania: a dormant volcano

Mayon, Philippines: an active volcano

The ground is swelling!

How and why do scientists monitor deformation at volcanoes?

Deformation refers to changes to the ground surface on a volcano. These changes are caused by magma moving underground. The changes may appear as swelling (inflation) or sinking (deflation).

Inflation occurs when a magma reservoir fills. The reservoir swells and pushes the ground above it up and out, tilting the ground away. This often happens before an eruption. **Deflation** happens after magma erupts or as it moves away underground. This causes the ground to sink down.

These changes can usually only be measured with sensitive instruments. A Global Positioning System (GPS) receiver is an instrument that uses satellite signals to determine its location. Scientists set up GPS stations with receivers on volcanoes and measure the changes in their locations. They also measure changes in the distances between stations. An increase in distance between these GPS stations can mean that inflation is occurring.

Scientists monitor deformation because these changes can offer signs that a volcano may erupt soon.

inflation on Mount Saint Helens prior to an eruption in 1980

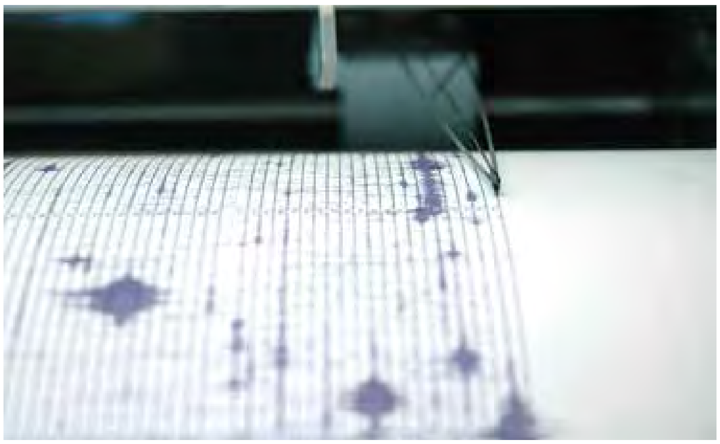
setting up a portable GPS receiver on a Hawaiian volcano

GPS receiver at North Rim Station, Newberry Volcano, Oregon

The ground is shaking!

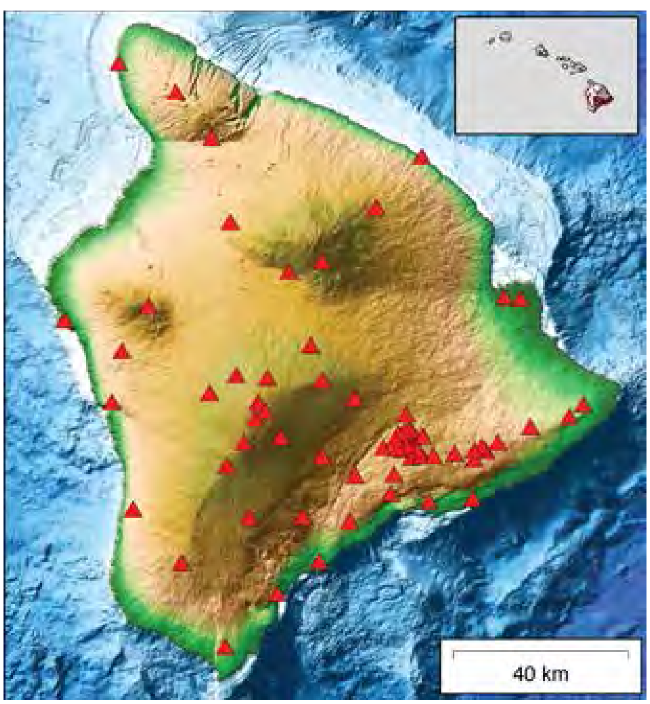
How and why do scientists monitor earthquakes around volcanoes?

Volcanic activity can sometimes cause earthquakes. Most of these earthquakes are too small for people to feel directly. However, scientists can use instruments called **seismographs** to detect them. Lots of small earthquakes near a volcano can provide warning signs that magma is cracking rocks and rising up through the cracks. When the magma is closer to the ground surface, the volcano may erupt soon.



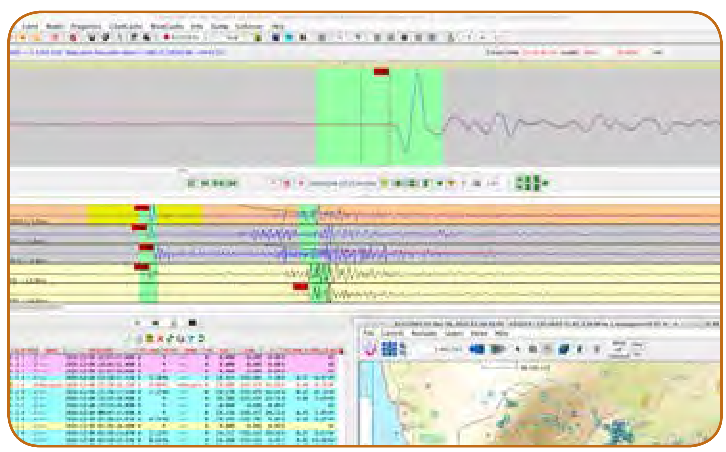
seismograph recording

earthquake monitoring station on Vesuvius



earthquake monitoring stations (red triangles) on the island of Hawaiʻi and across the state of Hawaii (inset)

Source: U.S. Geological Survey



screenshot from Hawaiʻi Volcano Observatory's earthquake monitoring software

Source: U.S. Geological Survey

Eew, that smell!

How and why do scientists measure sulfur dioxide concentrations around volcanoes?

Sulfur dioxide is a colorless gas with a nasty, sharp smell. It is produced by active volcanoes. Scientists use instruments called **spectrometers** to measure and monitor the amount of sulfur dioxide released by a volcano.

Changes in the amount of gases released can help scientists predict an upcoming eruption. These changes can also give clues about the amount of magma supplying an eruption. Volcanoes release more sulfur dioxide when magma comes near the surface.

Sulfur dioxide is toxic if it is inhaled. It can cause irritation of the nose and throat, as well as coughing and shortness of breath. Wind can carry the gas from its source to other areas nearby.

Scientists and public health officials recommend that people stay indoors and avoid exercise when levels of sulfur dioxide are high. Anyone with breathing or heart problems should leave the area.

measuring volcanic gases with a spectrometer at Kīlauea Volcano, Hawaiʻi

sampling gases at Augustine Volcano, Alaska

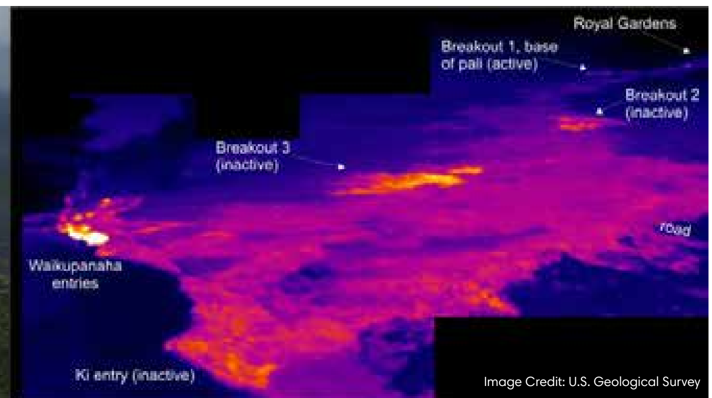
Volcanology

It's hot down there!

How does surface temperature help scientists predict changes in volcanic activity?

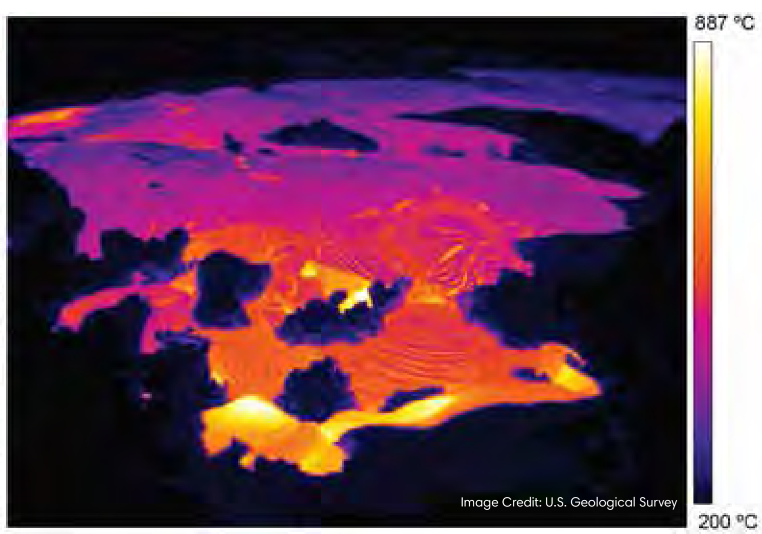
Anyone who lives near an active volcano will want to know if they are in the path of an eruption. Scientists use a method called **thermal imaging** to locate volcanic hazards. Thermal imaging uses special cameras or sensors that allow scientists to measure temperatures from a distance. The cameras/sensors create thermal images that use colors to show hot and cold areas. These images help scientists track **lava flows** and predict new eruptions.

lava flow reaching the coast



thermal image of the same area, showing areas of lava movement

lava flow



thermal image of a lava flow

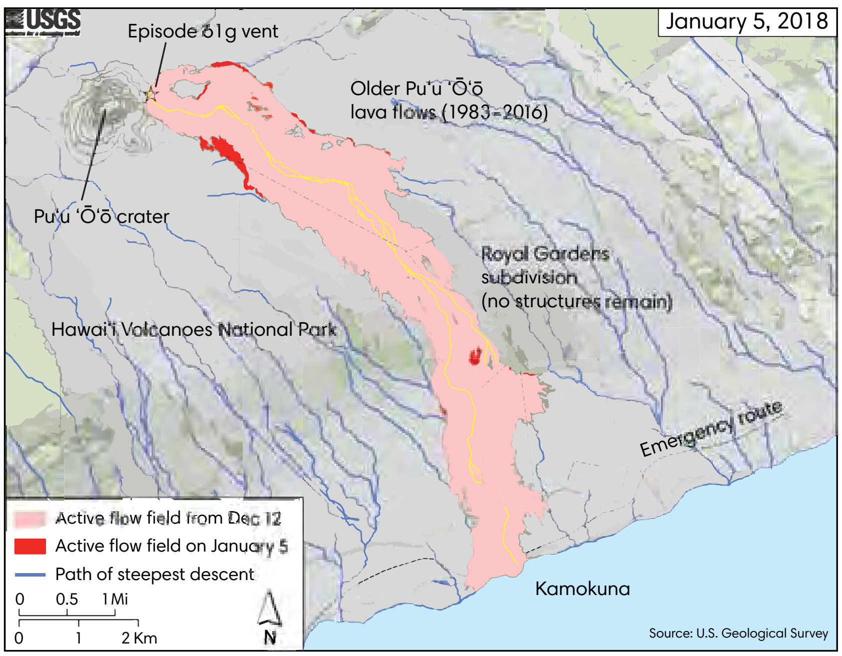
Get out of the way!

How can scientists predict where lava will flow?

When **magma** rises to the surface above a volcano, the hot, molten rock is called **lava**. In order to warn people where they might be in danger, scientists work to predict where the lava will flow.

Lava can sometimes flow from long **fissures**, or cracks in the ground, on a volcano's flanks. When lava erupts along a fissure, it may produce "curtains of fire." These rows of lava fountains often reach a few tens of meters in height and dwindle down after a few days.

Lava that spills from a **crater** or fissure will flow downhill. **Lava flows** are likely to follow the paths of steepest descent (where the ground slopes down the steepest). Once lava begins to flow, anyone living on the downhill side of its path will be alerted and evacuated. Roads, parks, and nearby areas at risk will be closed to the public.



map of lava flows and paths of steepest descent from Kīlauea's East Rift Zone in January 2018

area closure signs near a lava flow

a lava flow pours downhill from a fissure

It's gonna explode!

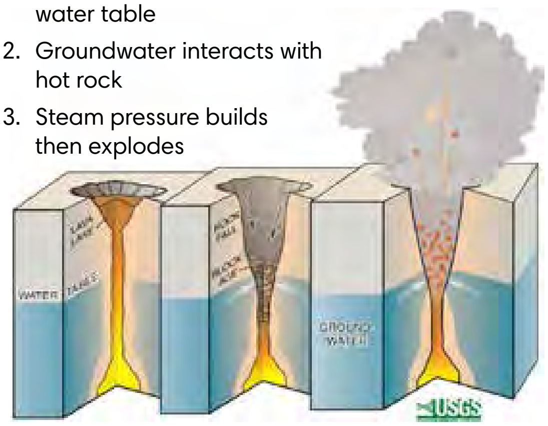
How can the lava lake provide clues about an eruption?

There are different types of volcanic eruptions. When a shield volcano erupts, the lava usually oozes slowly downhill. However, explosions can also occur. This can happen when a **lava lake** drops down below the water table underground. The water turns into steam, which builds up pressure until the rocks around it explode. Scientists monitor the levels of magma and groundwater in order to predict explosive eruptions.

Explosive eruptions blast **tephra**, or ash and lava fragments, into the air. Falling rocks called **volcanic bombs** can pose dangers to people close by. Ash can damage buildings, crops, and vehicles. It can endanger airplane flights and cause health problems when breathed in. Scientists try to predict eruptions to help people avoid these dangers.

Explosive eruptions can occur when:

1. Magma column drops below water table
2. Groundwater interacts with hot rock
3. Steam pressure builds then explodes



explosive eruption process

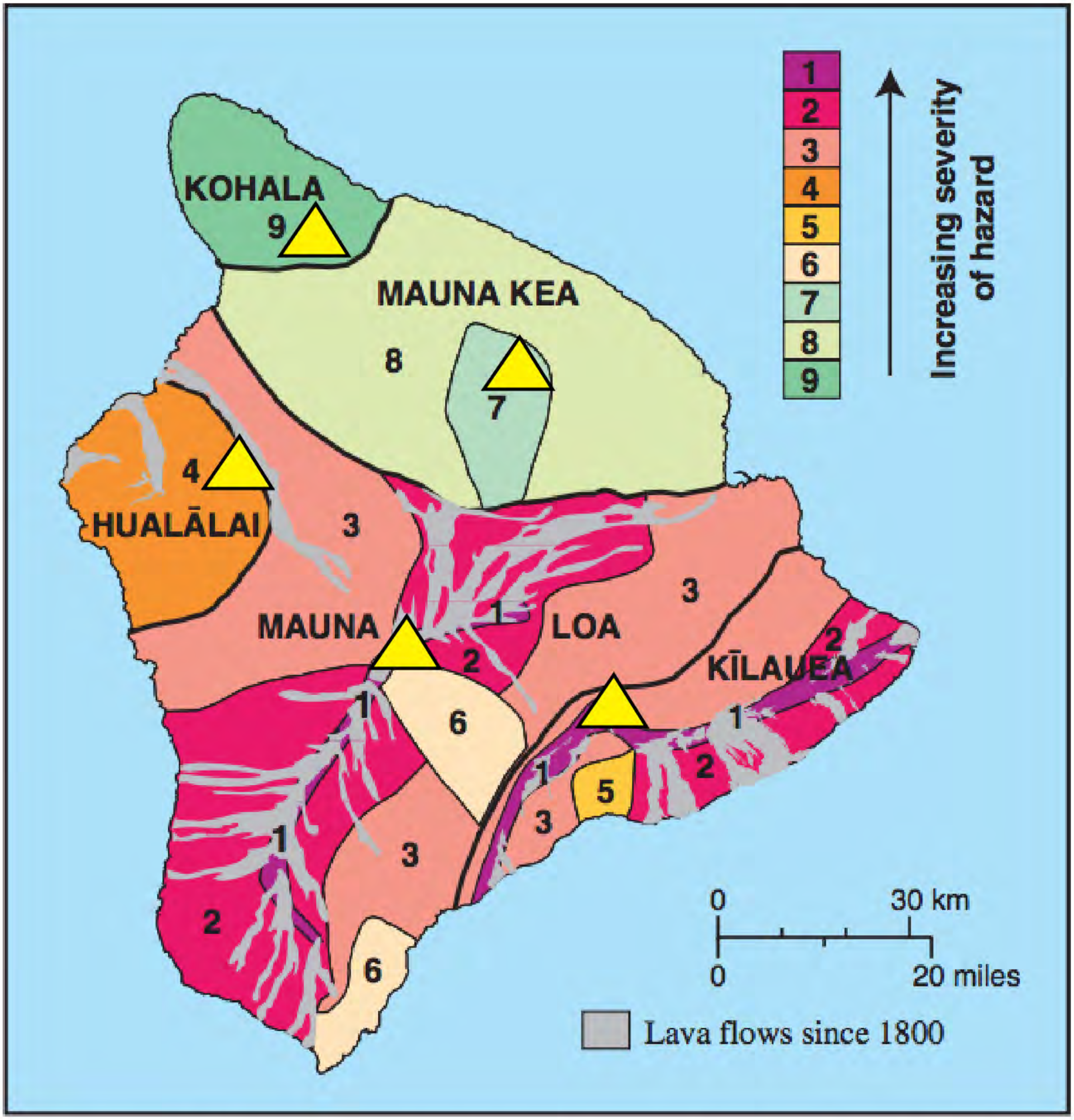
Source: U.S. Geological Survey

volcanic bombs from explosive eruptions littering the area near a volcanic crater

houses covered in ash from a volcanic eruption

A drop in the level of the lava lake can give scientists another clue. It may mean that magma is moving somewhere else underground. Another eruption might happen nearby.

Hawai'i Lava Flow Hazard Map



This map of the island of Hawai'i shows the volcanic hazards from lava flows. Severity of the hazard increases from zone 9 to zone 1. Shaded areas show land covered by flows erupted in the past two centuries from three of the five volcanoes on Hawai'i.
(Hualālai, Mauna Loa, and Kīlauea).