The Kīlauea Volcano: Be a Volcanologist

Grades 6-8

Learning in Motion®

Public attention was captured in May 2018, when the Hawaiian volcano Kīlauea erupted with rivers of lava that flowed through Leilani Estates and other nearby neighborhoods. Your students may have seen videos of hot lava covering roads, destroying homes, or reaching the ocean with clouds of hot steam. You can capitalize on their interest by using data from this real-world event.

In these middle school lessons, students take on the role of volcanologists in order to analyze geologic data about the May 2018 eruption of Kīlauea and provide recommendations for mitigating its harmful effects.

ANCHORING PHENOMENON

A new eruption of Hawai'i's Kīlauea volcano began in early May 2018 following changes in geologic activity. The eruption produced volcanic hazards that affected residents of the area and changed the landscape of the island.

GUIDING QUESTION

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

OBJECTIVES

- **Lesson 0**
  - Identify different types of volcanoes and describe their characteristics.
- **Lesson 1**
  - Analyze and interpret geologic data in order to predict changes in volcanic activity and make safety recommendations.
  - Map the hazards of volcanic activity on the island of Hawaiʻi.
  - Construct oral and written arguments, supported by empirical evidence and scientific reasoning, to support an explanation for predictions about volcanic activity.
- **Lesson 2**
  - Analyze data from maps, graphs, and photos of the May 2018 Kīlauea volcano eruption to describe patterns, determine which areas are at risk, and make safety recommendations.
  - Use cause and effect relationships to predict the phenomena associated with volcanic eruptions.
  - Construct oral and written arguments, supported by empirical evidence and scientific reasoning, to support an explanation for volcanic activities, and provide recommendations for mitigating the harmful effects of an eruption.
- **Final Project: Hazard Response Plan**
  - Produce a Hazard Response Plan that addresses the monitoring, predictions, and recommended responses to two hazards resulting from the May 2018 eruption of Kīlauea.

Image Credit: Tyler Lastovich / Unsplash

STANDARDS

Next Generation Science Standards	
MS-ESS3-2	**Earth and Human Activity** • Analyze and interpret data on natural hazards to forecast future catastrophic events and inform the development of technologies to mitigate their effects.
Science and Engineering Practice 4	**Analyzing and Interpreting Data** • Analyze and interpret data to determine similarities and differences in findings and to provide evidence for phenomena.
Science and Engineering Practice 7	**Engaging in Argument from Evidence** • Construct an oral and written argument supported by empirical evidence and scientific reasoning to support or refute an explanation or a model for a phenomenon or a solution to a problem.
Science and Engineering Practice 8	**Obtaining, Evaluating, and Communicating Information** • Integrate qualitative scientific and technical information in written text with that contained in media and visual displays to clarify claims and findings.
Disciplinary Core Idea ESS3.B	**Natural Hazards** • Mapping the history of natural hazards in a region, combined with an understanding of related geologic forces can help forecast the locations and likelihoods of future events.
Crosscutting Concept 1	**Patterns** • Graphs, charts, and images can be used to identify patterns in data.
Crosscutting Concept 2	**Cause and Effect** • Cause and effect relationships may be used to predict phenomena in natural or designed systems.
Connections to the Nature of Science	**Science Addresses Questions About the Natural and Material World** • Scientific knowledge can describe the consequences of actions but does not necessarily prescribe the decisions that society takes.

Texas Essential Knowledge and Skills	
Grade 6, Science, 6.2.E	**Scientific Investigation and Reasoning** • The student is expected to analyze data to formulate reasonable explanations, communicate valid conclusions supported by data, and predict trends.
Grade 6, Science, 6.3	**Scientific Investigation and Reasoning** • The student uses critical thinking, scientific reasoning, and problem solving to make informed decisions.
Grade 6, Science, 6.3.B	**Scientific Investigation and Reasoning** • The student is expected to use models to represent aspects of the natural world.
Grade 7, Science, 7.2.E	**Scientific Investigation and Reasoning** • The student is expected to analyze data to formulate reasonable explanations, communicate valid conclusions supported by the data, and predict trends.
Grade 7, Science, 7.3	**Scientific Investigation and Reasoning** • The student uses critical thinking, scientific reasoning, and problem solving to make informed decisions.
Grade 7, Science, 7.3.B	**Scientific Investigation and Reasoning** • The student is expected to use models to represent aspects of the natural world.
Grade 8, Science, 8.2.E	**Scientific Investigation and Reasoning** • The student is expected to analyze data to formulate reasonable explanations, communicate valid conclusions supported by the data, and predict trends.
Grade 8, Science, 8.3	**Scientific Investigation and Reasoning** • The student uses critical thinking, scientific reasoning, and problem solving to make informed decisions.
Grade 8, Science, 8.3.B	**Scientific Investigation and Reasoning** • The student is expected to use models to represent aspects of the natural world.

Florida Next Generation Sunshine State Standards for Science	
Grade 6, SC.6.E.7.4	Differentiate and show interactions among the geosphere, hydrosphere, cryosphere, atmosphere, and biosphere.
Grade 8, SC.8.N.4.1	Explain that science is one of the processes that can be used to inform decision making at the community, state, national, and international levels.
Grade 8, SC.8.E.5.10	Assess how technology is essential to science for such purposes as access to outer space and other remote locations, sample collection, measurement, data collection and storage, computation, and communication of information.
Grades 6–8, SC.68. CS-PC.2.7	Interpret writings and/or communications which use developmentally appropriate terminology.
Grade 6–8, SC.68. CS-PC.3.5	Identify resources such as city, state, and federal government websites and explain that these resources can be used for communication between citizens and government.

THE 5Es

In Lesson 0, students **engage** with the topic of volcanoes by sorting a set of volcanoes into categories and making observations to describe volcano characteristics. They then **explore** in Lesson 1 by analyzing scientific data from the days prior to the Kīlauea eruption in 2018. Students use this data to **explain** their predictions and safety recommendations to their partner or team and in class discussion. In Lesson 2, students **elaborate** on their understandings by analyzing additional data and continuing to make predictions and safety recommendations as the eruption progresses. As an **evaluation**, students work with their partner or team to devise a Hazard Response Plan in a format of their choosing that addresses the hazards of the 2018 Kīlauea eruption.

Image Credit: Nurhadi Cahyono / Unsplash

RESOURCES

Websites

USGS About Volcanoes

This page on the United States Geological Survey's Volcano Hazards Program website provides background information about volcanoes, including definitions, scientific explanations, and basic statistics.

USGS Volcano Hazards Program

The United States Geological Survey's Volcano Hazards Program monitors and studies volcanoes, conducts research, and communicates findings and alerts to authorities and the public. The website provides news, activity alerts, warnings, monitoring information, multimedia, and more. Focus is on volcanoes within the United States.

Smithsonian Institution Global Volcanism Program

This website provides a database of current and archived reports of global volcanic eruptions from the last 10,000 years. Features include a volcano search and a weekly volcanic activity report.

USGS Kīlauea Status Report

This page within the USGS Volcano Hazards Program website provides current alerts and updates about the Kīlauea volcano. During periods of heightened activity such as the May 2018 eruption, updates are added daily.

USGS Kīlauea Multimedia

This page within the USGS Volcano Hazards Program website provides photo and video chronology of the May 2018 eruption of Kīlauea volcano. The latest photos and videos are posted with explanations, and an archive search features provides access to previous media.

IRIS Measuring Deformation and Tilt with GPS

IRIS (Incorporated Research Institutions for Seismology) is a group of institutions that gathers, manages, and distributes data about earthquakes and related hazards such as volcanic activity. Its website offers a variety of educational resources, including this deformation animation that demonstrates how tiltmeters and GPS can be used to monitor deformation on a volcano.

Hawai'i County Civil Defense Alert Archive

The County of Hawai'i website hosts this archive of previous alerts posted to their Civil Defense Messages and Alerts page. The page also includes a link to current alerts.

FEMA.gov Kīlauea Eruption

FEMA (Federal Emergency Management Association) is a U.S. government agency that helps people before, during, and after disasters. This web page focuses on the eruption event at Kīlauea beginning on May 3, 2018. It provides information about federal assistance for affected residents as well as news releases, fact sheets, links to state resources, and more.

Image Credit: Iswanto Arif / Unsplash

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The Kīlauea Volcano: Be a Volcanologist

About Volcanoes

0 About Volcanoes

Students explore background information about volcanoes in order to ensure they have the understandings necessary to participate in the following series of lessons. Students work with a team to sort a set of volcanoes into categories of their own choosing based on images and data. They read about categories commonly used to classify volcanoes by type (composite, shield, and cinder cone) and status (active, dormant, and extinct), and classify the set of volcanoes into these categories.

GUIDING QUESTION

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

Lesson 0: About Volcanoes

MATERIALS

Teacher Materials

- **About Volcanoes** visual
  - **Volcano** photographs

Student Materials

- **Volcano Card Sort Data** handout (online or print) (1 per team of 4)
- **Volcanology** handout (1 per student)

LESSON PREPARATION

- Decide whether to use hard copies of the handouts or have students access the online version.
  - If students will use hard copies, prior to class, ask a student to cut apart the volcano profile cards in each **Volcano Card Sort Data** handout, so the teams can sort them. If desired, the cards can be laminated for re-use. Keep the graphic organizer from each handout to provide to the team.
- Print a copy of the **Volcanology** handout for each student. Students will use the pages in this handout throughout the unit. If desired, the pages can be laminated for re-use.
- Designate 4 stations around the classroom for students to read about their volcano topic:
  - Station 1: composite volcanoes (page 5)
  - Station 2: shield volcanoes (page 6)
  - Station 3: cinder cone volcanoes (page 7)
  - Station 4: active, dormant, and extinct volcanoes (page 8)

Image Credit: Gary Saldana / Unsplash

Lesson 0: About Volcanoes

OPENING

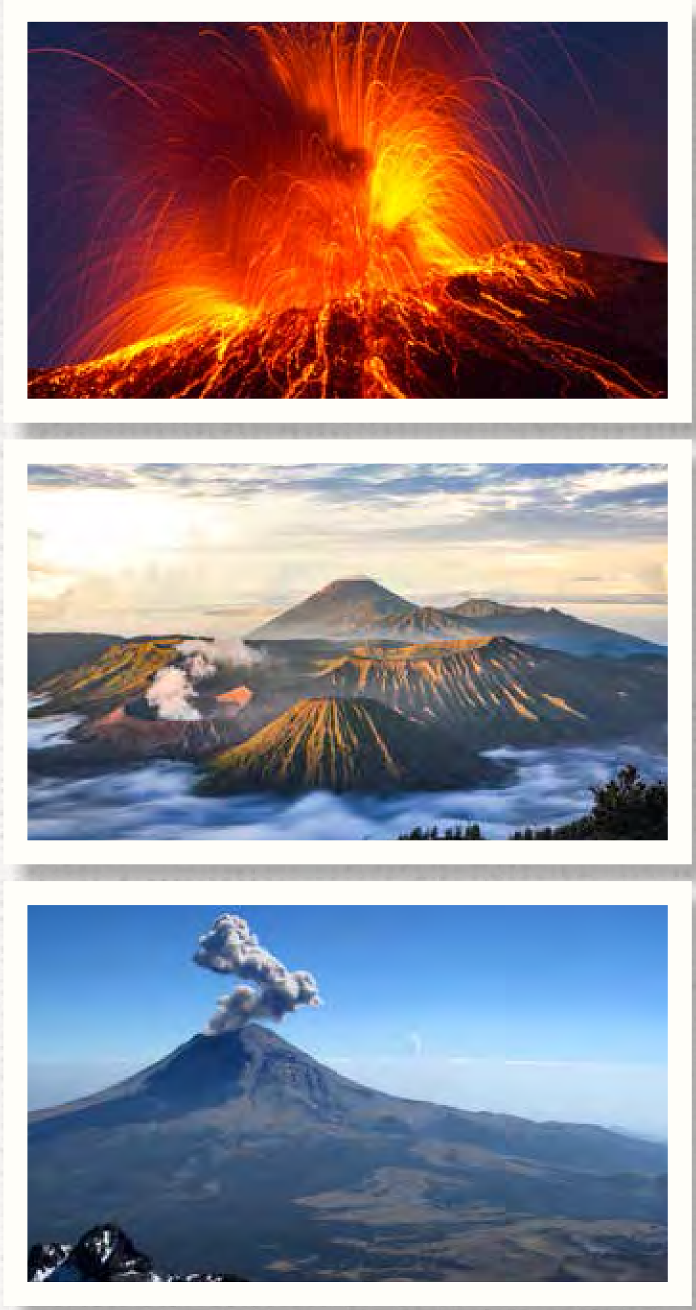
Elicit Prior Knowledge

1. Show students the **Volcano** photographs. Ask students questions such as the following to engage their prior knowledge of volcanoes:

   - *What is a volcano?*
   - *Have you ever visited a volcano? What did you observe?*
   - *Why do you think it is important to study volcanoes?*
   - *How might volcanoes affect humans?*

2. Ask students to consider the following set of statements and decide whether they think each statement is true or false. You can have students raise their hand to indicate their choice or raise one finger for "true" and two fingers for "false."

   - A volcano can grow or change shape over time. *(true)*
   - A volcano that hasn't erupted in thousands of years can still erupt again in the future. *(true)*
   - All volcanoes are shaped like tall, steep cones. *(false)*
   - All volcanoes have a crater at the top with a lake of hot lava inside. *(false)*
   - Any volcano in the world might erupt at any time, and there is no way to predict it. *(false)*
   - Not all volcanic eruptions are fast and explosive. Some happen very slowly. *(true)*



Volcano photographs

Lesson 0: About Volcanoes

Introduce the Guiding Question

1. Introduce the unit Guiding Question:

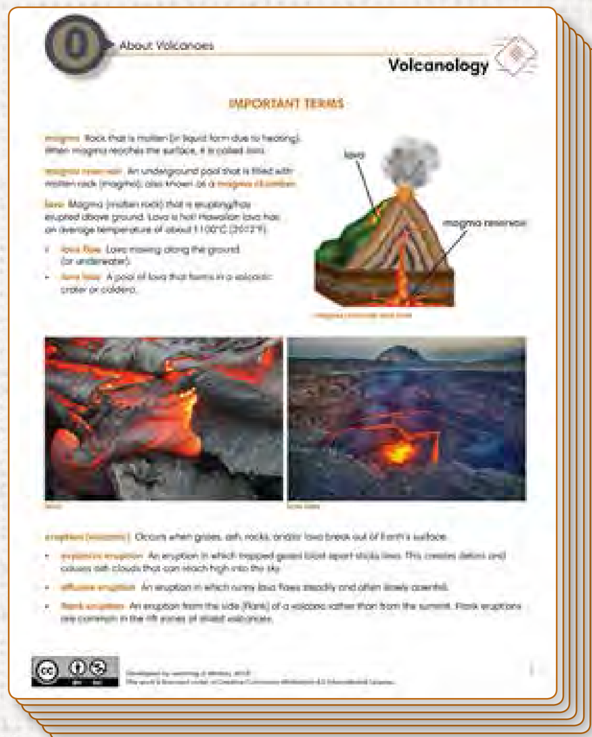
   How do scientists monitor volcanoes in order to predict hazards and keep the public safe?

2. Let students know that over the next series of lessons, they will work as volcanologists, or scientists who study volcanoes. Explain:
   - Their task will be to analyze data about volcanic activity in order to keep the public safe.
   - Before they start analyzing data (in the next lesson), it is important that they understand the basics about volcanoes and volcanic eruptions. Today they will prepare for their role as volcanologists by exploring different types of volcanoes and their characteristics.

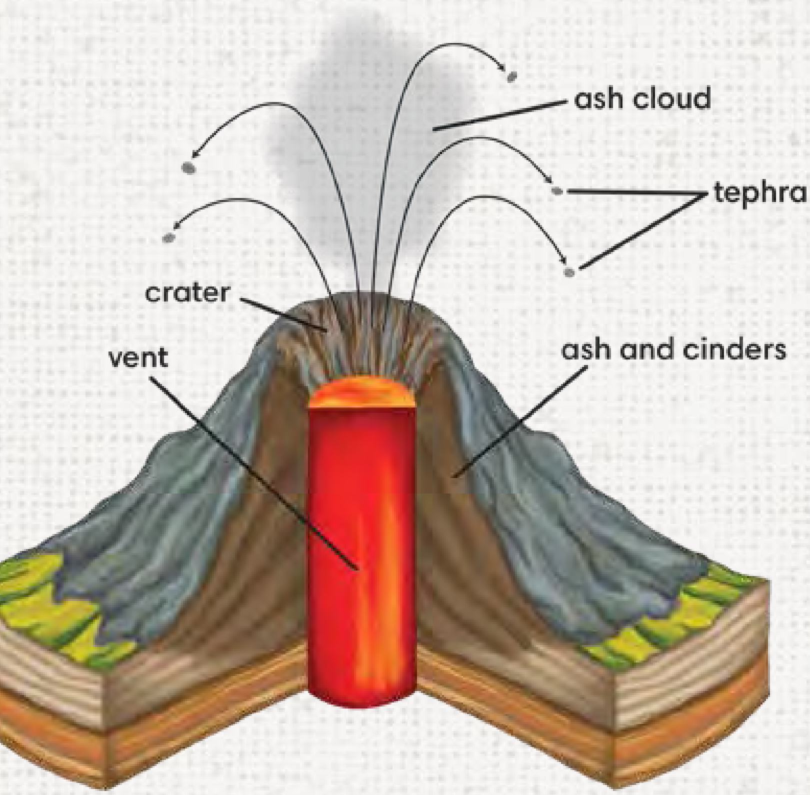
ACTIVITY

Try Sorting Volcanoes

1. Provide each student with a **Volcanology** handout, and explain that it contains information that they can reference throughout the unit as they work as volcanologists. Point out the sections that they will need today on pages 1–8.



Volcanology handout



Lesson 0: About Volcanoes

2. Have students meet with teams of four. Provide each team with a **Volcano Card Sort Data** handout (either the **Volcano Card Sort Online Data** handout or the printed **Volcano Card Sort Data** handout with the cards cut out).

3. Point out that the **Volcano Card Sort Data** handout contains information about 11 different volcanoes. Explain that students will work with their team to take a few moments to sort the volcanoes into groups based on the photos and information provided. Students can use any criteria of their choosing to sort the volcanoes.
   - **Print version:** Students should sort the cards into piles. They can create labels for their piles using pieces of scrap paper.
   - **Online version:** Students should access the Sort tab of Lesson 0. They can drag and drop the volcanoes to sort them into groups and add labels for their categories using text boxes.
   - As students sort the volcanoes, they should refer to the **Volcanology** handout for help understanding unfamiliar terms.

Volcano Card Sort Data handout

4. Allow a few teams to share the criteria they sorted their volcanoes by. For example, they might sort them based on shape, size, appearance, date of last eruption, or any other characteristic that they notice.

Gather Information

1. Explain that as volcanologists, students will learn a few categories commonly used to classify volcanoes. Each student in a team will be assigned a different topic. They will read an information sheet about their topic and be responsible for helping their team sort the volcanoes based on that information.

2. Review the four topics in the **Volcanology** handout (pages 5–8) with the class:
   - *What is a composite volcano?*
   - *What is a shield volcano?*
   - *What is a cinder cone volcano?*
   - *How can you tell if a volcano is active, dormant, or extinct?*

3. Have teams determine which student will read each of the four topics. Instruct students to find their assigned topic in the **Volcanology** handout (pages 5–8).

4. Have each team member go to their designated reading station and find a partner who has the same topic (see Lesson Preparation). Allow students time to read their assigned info sheet with their partner.

Lesson 0: About Volcanoes

Classify Volcanoes

1. Signal for students to meet back with their home team. Tell students that they need to work together with their team to classify each volcano as a composite volcano, shield volcano, or cinder cone volcano, and as active, dormant, or extinct.
   - As the team looks at each volcano together, each student should consider the information that they read in their info sheet and share any key ideas with their team that will help the team classify the volcano.
   - Students can also ask other team members questions about their topics.
   - **Print version:** Students should record the name of each volcano in the appropriate space in the graphic organizer.
   - **Online version:** Students should select the appropriate categories from the two drop-down menus next to each volcano profile in the Classify tab. You may also choose to provide the printed graphic organizer for students working online.
   - Emphasize that students should be prepared to justify their decisions about volcano classifications to the class during discussion.
   - Students should classify as many of the volcanoes as they can within the time limits of the activity.

Discuss

1. After students have classified the volcanoes, bring the class together for discussion.
2. Draw a copy of the graphic organizer on the board. Ask for student input about how they classified the volcanoes. Ensure that students provide reasoning for each classification. A completed graphic organizer and example student responses are shown below. Students might say:
   - **We classified Stromboli as an active composite volcano because it has a tall mountainous shape with a summit crater, and it has been explosively erupting recently.**

Stromboli

Lesson 0: About Volcanoes


Gunung Agung

- We classified Ngauruhoe as an active composite volcano because is really tall and mountainous like most composite volcanoes, and it has erupted recently. Some of the eruptions were explosive.
- We classified Gunung Agung as an active composite volcano because it has the size, shape, and appearance of a composite volcano, and it has erupted explosively recently.
- We classified Erta Ale as an active volcano because it has erupted recently, and it has continuous lava lakes. It is a shield volcano because it has a broad shape and because it has eruptions from fissures on its flanks, which are common in shield volcanoes.
- We classified La Cumbre as an active shield volcano because effusive eruptions occur from fissures on the flanks, and they have been happening since 2009. It also has a broad shape and isn't steep like a composite volcano.
- We classified Cerro Negro as an active cinder cone volcano because it is a young volcano so it has erupted recently, and it erupts a lot of ash and volcanic debris.
- We classified Mount Edgecumbe as a dormant composite volcano because it hasn't erupted in thousands of years, but some of the eruptions were less than 10,000 years ago.
- We classified Mauna Kea as a dormant shield volcano because it has effusive eruptions, was built up by lava flows, and may erupt again.


Mauna Kea

Lesson 0: About Volcanoes

- We classified Lava Butte as dormant because it hasn't erupted in a long time, but it was still less than 10,000 years ago. It is a cinder cone because the cone shape was formed by hot ash and cinders, and it formed on a larger volcano.
- We classified Mount Shari as an extinct composite volcano because it hasn't erupted in hundreds of thousands of years, and it's made of layers of hardened lava and ash, which is how composite volcanoes are formed.
- We classified Kīlauea as an active shield volcano because it has been erupting effusively and because it has rift zones, which shield volcanoes often have.

	Composite	Shield	Cinder Cone
Active	Stromboli Ngauruhoe Gunung Agung	Erta Ale La Cumbre Kīlauea	Cerro Negro
Dormant	Mount Edgecumbe	Mauna Kea	Lava Butte
Extinct	Mount Shari		

3. Ask students to share any other interesting observations or questions from the activity. For example, students might notice:

- Some of the active volcanoes have ash or gas clouds in the pictures, but not all of them. You can't always tell by looking at the volcano whether it is active or not.
- I noticed that a volcano can have snow around the top.
- Some of the volcanoes look different than I expected. I didn't know that they could be flat-looking like Erta Ale or Kīlauea.

Image Credit: David Wollschlegel / Unsplash

Lesson 0: About Volcanoes

REFLECTION

Summarize

1. Summarize that today students discovered patterns in the features and eruption histories of different volcanoes. They used these patterns to sort and classify the volcanoes. Classifications such as these can provide useful information to scientists and make it easy to communicate. For example, the classification "active shield volcano" can tell a scientist a lot about a volcano.
2. Remind students that they will continue to apply their understandings about volcanoes in the lessons that follow, when they will analyze data in order to make predictions about volcanoes and keep the public safe.

Reflect

1. Ask students to write the following:
   - *1 way that volcanoes interact with Earth's water or air*
   - *1 way that volcanoes can change landscapes*
   - *1 thing they still want to know about volcanoes*
2. You may ask students to record their reflections on a separate piece of paper to turn in or in another location, such as a science journal, according to your class routines.

Image Credit: ibrahim kusuma / Unsplash

About Volcanoes

Volcanology

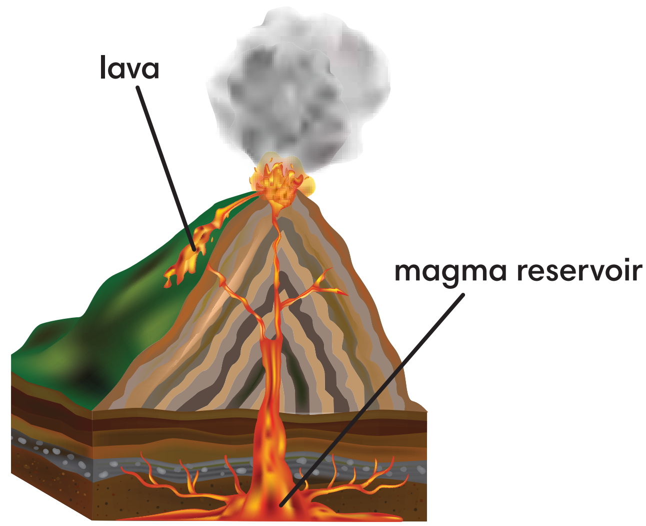
IMPORTANT TERMS

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

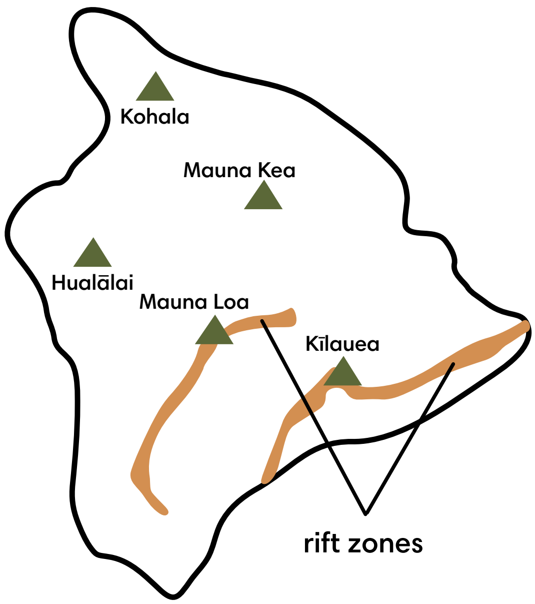
effusive eruption

flank eruption (effusive)

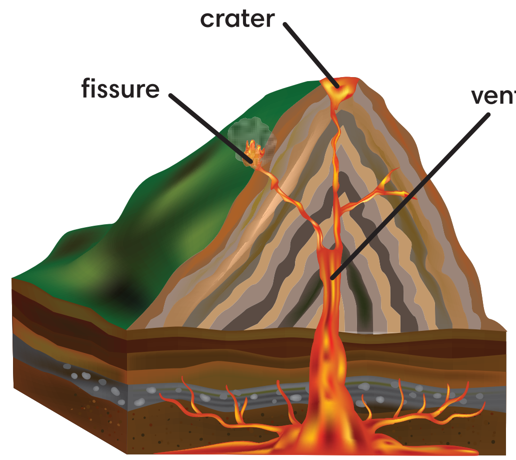
fissure A long crack or break in the ground from which volcanic gases, ash, rocks, and/or lava erupts.

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.



rift zones



vent, fissure, and crater

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

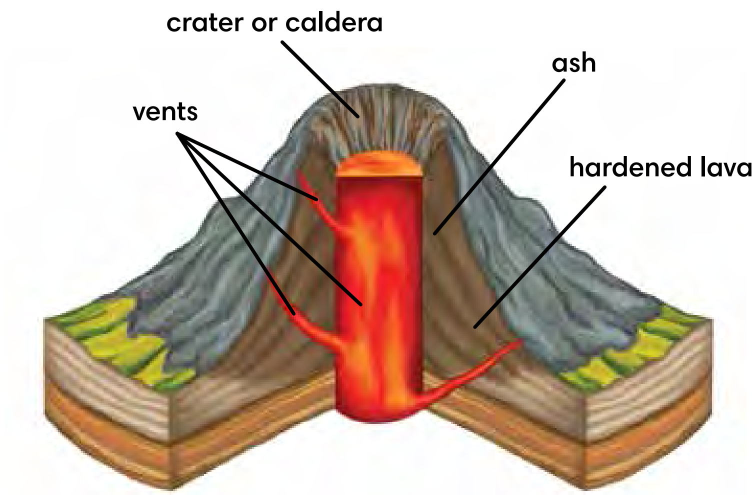
WHAT IS A COMPOSITE VOLCANO?

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

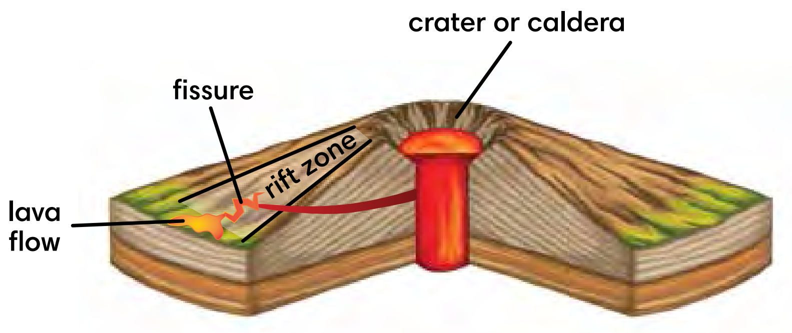
WHAT IS A SHIELD VOLCANO?

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.

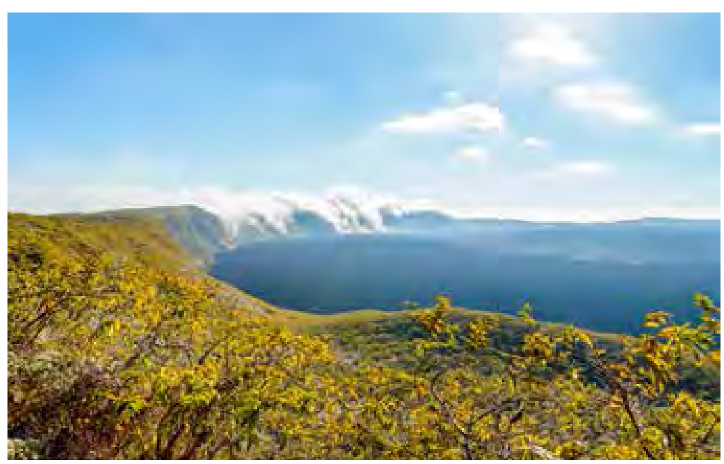
A shield volcano often has effusive eruptions of runny lava. However, explosive eruptions can also occur. Eruptions often occur from fissures in rift zones.

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

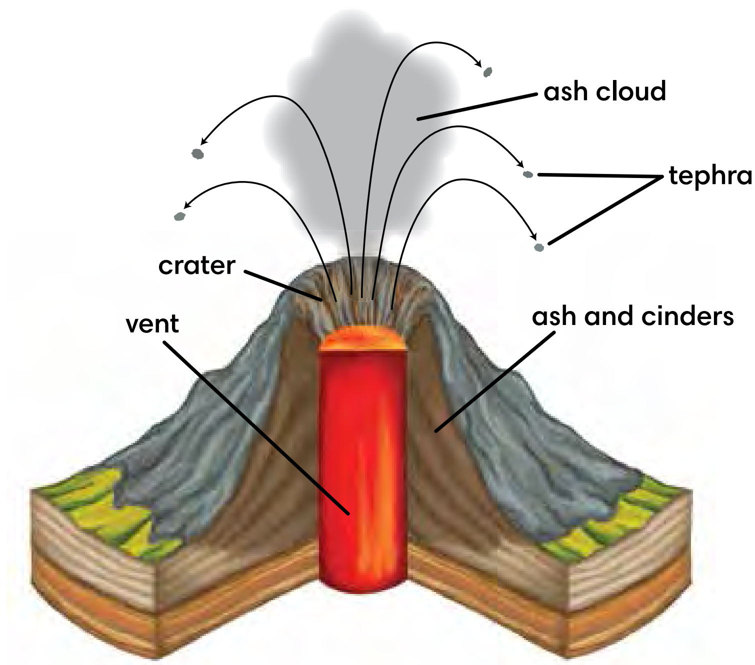
WHAT IS A CINDER CONE VOLCANO?

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

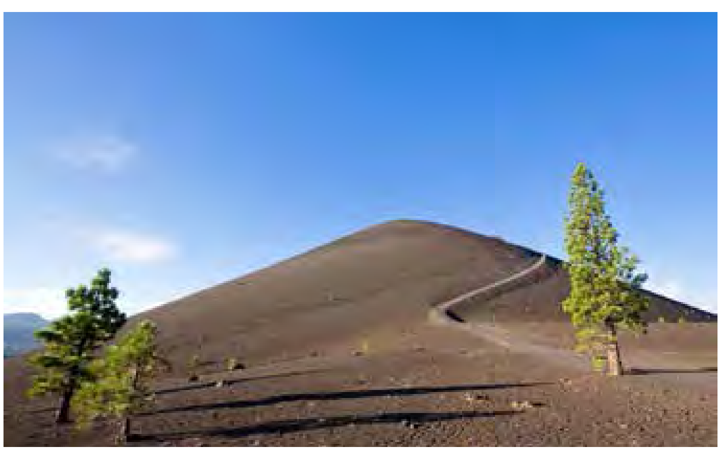
Cinder cones are relatively small. They rarely rise more than 300 m above their surroundings.

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

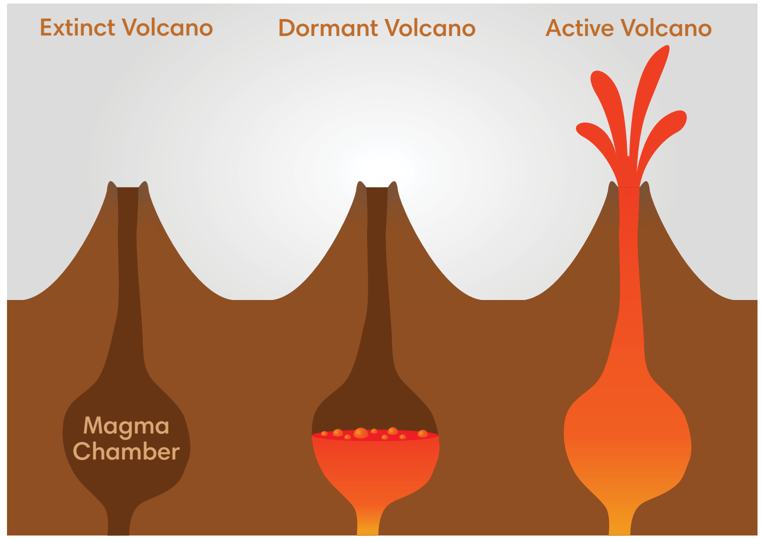
cinder cones within Haleakalā National Park, Hawai‘i

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

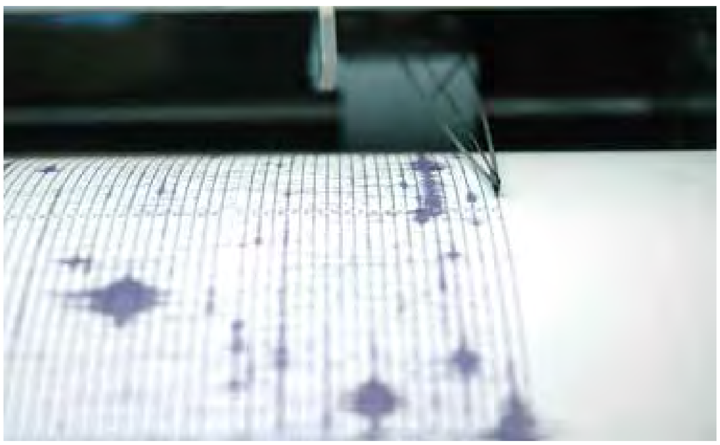
setting up a portable GPS receiver on a Hawaiian volcano

GPS receiver at North Rim Station, Newberry Volcano, Oregon

The ground is shaking!

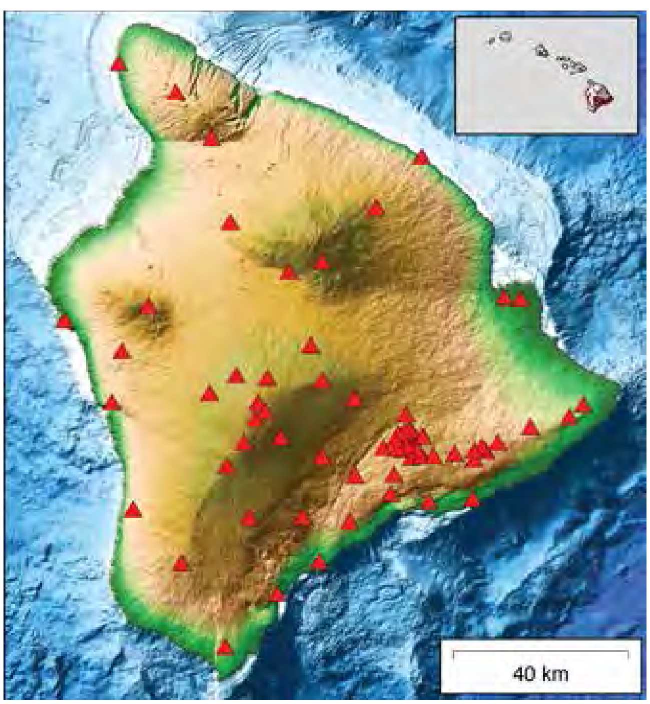
How and why do scientists monitor earthquakes around volcanoes?

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.



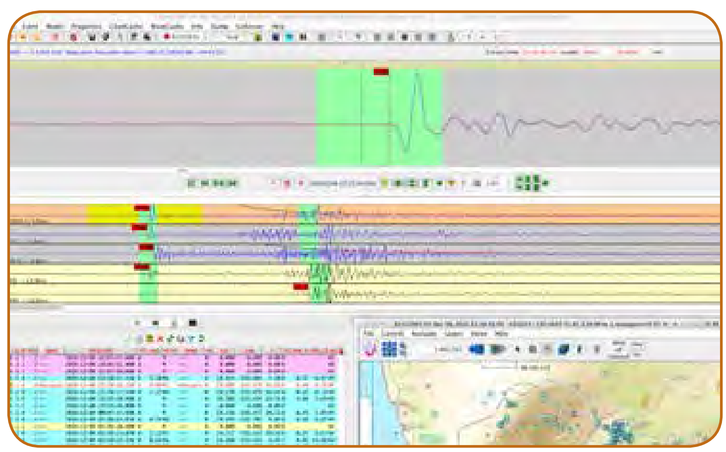
seismograph recording

earthquake monitoring station on Vesuvius



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

Source: U.S. Geological Survey



screenshot from Hawai‘i 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

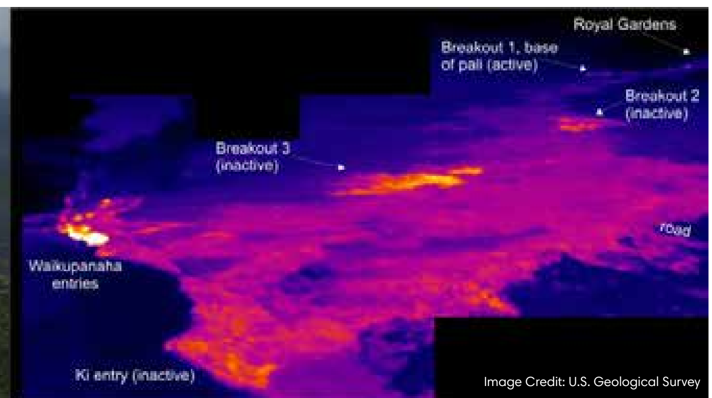
sampling gases at Augustine Volcano, Alaska

It's hot down there!

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

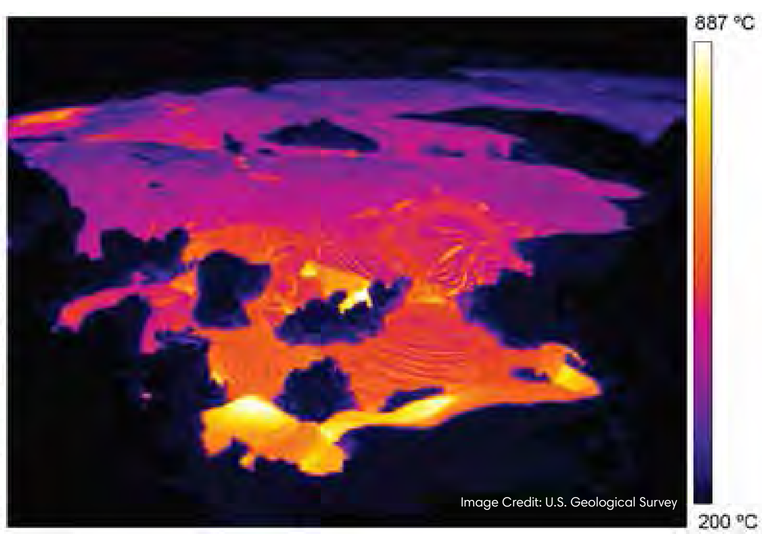
Anyone who lives near an active volcano will want to know if they are in the path of an eruption. Scientists use a method called **thermal imaging** to locate volcanic hazards. Thermal imaging uses special cameras or sensors that allow scientists to measure temperatures from a distance. The cameras/sensors 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

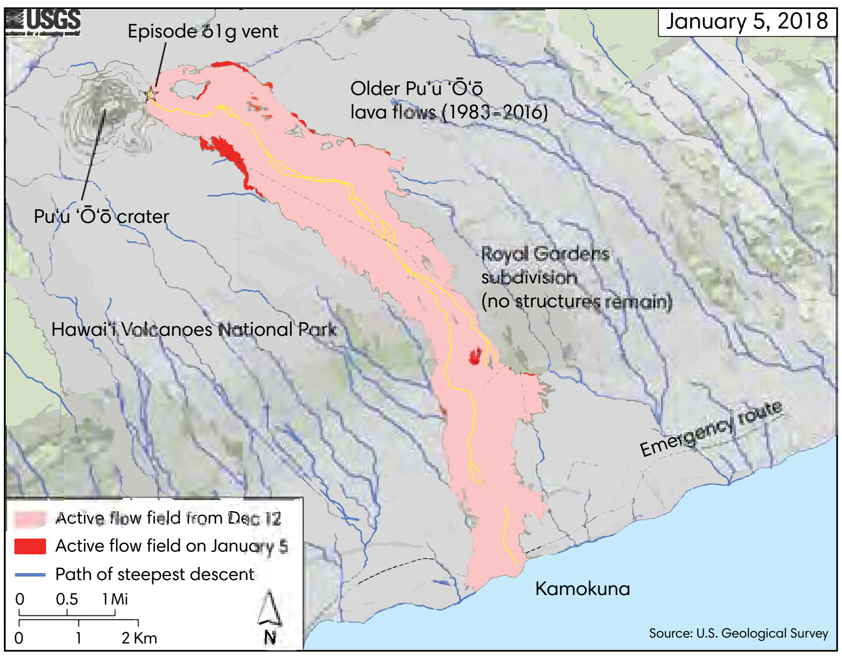
Get out of the way!

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.

Volcano Card Sort Data

Name: Erta Ale

Location: Afar Region, Ethiopia

Data:

- The name means "smoking mountain" in the local Afar language.
- It has almost continuously had a **lava lake**, which sometimes overflows on the south side of the volcano.
- A major **eruption** in 2005 killed 250 livestock and caused many people to flee.
- Another eruption occurred in 2017.
- **Fissure** eruptions have occurred recently on the volcano's flanks.
- It has a very broad shape—it is about 600 m tall and 50 km wide.

Name: Stromboli

Location: Mediterranean Sea north of Sicily, Italy

Data:

- It has been in almost continuous **eruption** for the past 2,000 years. The most recent eruption was in 2013–2014.
- **Explosive eruptions** occur at the summit **crater**.
- It forms an island 2 km wide. Its base begins over 1,000 m below the sea and rises over 900 m above sea level.
- The name of the volcano comes from the term *Strombolian eruptions*, which are short, quick blasts of lava.

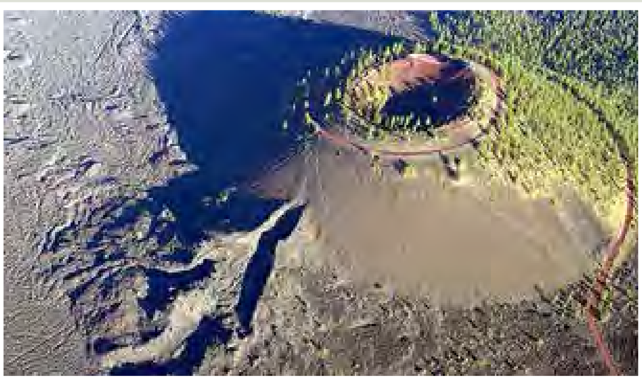
Volcano Card Sort Data

Name: La Cumbre (Fernandina Island)

Location: Galápagos Islands, Ecuador

Data:

- It has been erupting since 2009.
- **Effusive eruptions** occur from the summit **caldera** area and from **fissures** along the flanks. Lava flows reach the ocean.
- **Explosive eruptions** have also occurred, causing the **caldera** floor to collapse.
- It forms an island 6.5 km wide and rises nearly 1,500 m from the ocean surface.



Name: Lava Butte

Location: Oregon, United States

Data:

- It has erupted only once, about 7,000 years ago.
- The eruption spewed hot ash and cinder to form the cone shape.
- It is part of the larger Newberry Volcano (a shield volcano).
- It stands about 155 m tall, with a summit **crater** from 20 m to 50 m deep.

Volcano Card Sort Data

Name: Ngauruhoe

Location: North Island, New Zealand

Data:

- It is the highest peak in a group of volcanoes called Tongariro volcanic complex.
- It first erupted about 2,500 years ago.
- **Explosive eruptions** and lava flows have occurred several dozen times since the 1800s. The most recent eruption was in 1977.
- Fun fact: It was used to portray Mount Doom in the *Lord of the Rings* movies.

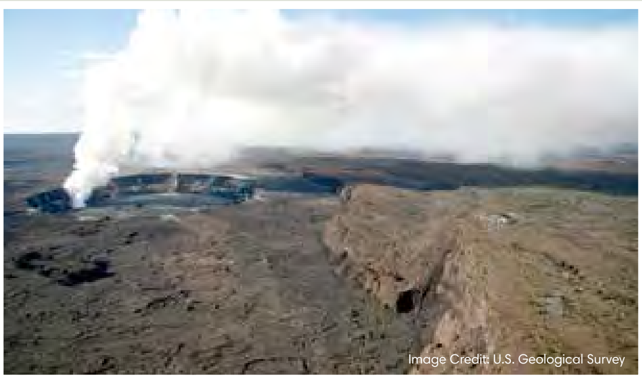


Image Credit: U.S. Geological Survey

Name: Kīlauea

Location: Island of Hawai'i, United States

Data:

- It has had ongoing **effusive eruptions** since 1983.
- **Lava flows** have covered hundreds of square kilometers and added new land to the coastline of Hawai'i.
- It has a **summit caldera** that contains a **crater** with a **lava lake**.
- It has two **rift zones** (East Rift Zone and Southwest Rift Zone) between the summit and the ocean.
- It is considered to be the home of the goddess Pele from Hawaiian legends.

Volcano Card Sort Data

Name: **Mount Edgecumbe**

Location: Alaska, United States

Data:

- It last erupted around 2200 BC.
- A series of **explosive eruptions** occurred about 9,000–13,000 years ago.
- It stands 970 m tall, with a well-defined **crater**.

Name: **Mount Shari**

Location: Hokkaido, Japan

Data:

- It was last active about 300,000 years ago.
- It is formed of alternate layers of hardened lava and ash.
- It stands 1,070 m tall.
- It is one of Japan's 100 most famous mountains.

Volcano Card Sort Data

Name: Mauna Kea

Location: Island of Hawai'i, United States

Data:

- The last **eruption** was around 4,500 years ago.
- **Effusive eruptions** from this and nearby volcanoes have built up the island of Hawai'i over many years.
- It rises 4,207 m and spreads broadly at its base.
- It may reawaken; its history shows long breaks in activity between past eruptions.
- Scientists built an observatory at the summit.

Name: Gunung Agung

Location: Bali, Indonesia

Data:

- It **erupted** in 2017 and was still erupting as of August, 2018. Thousands of people fled the area and flights were suspended.
- **Explosive eruptions** send up huge ash clouds.
- It rises over 3,000 m high and forms the tallest peak on the island of Bali.
- It is the site of an important temple for the Balinese people.

Volcano Card Sort Data

Name: Cerro Negro

Location: León, Nicaragua

Data:

- It is one of the youngest volcanoes in Central America.
- It first appeared in 1850.
- **Explosive eruptions** of ash and volcanic debris have occurred every few years to every few decades.
- Falling ash sometimes damages towns and crop fields nearby.
- Frequent eruptions have changed the volcano's shape and size.

	Composite	Shield	Cinder Cone
Active			
Dormant			
Extinct			

1

The Kīlauea Volcano: Be a Volcanologist

Monitoring Hawai‘i Volcanoes

1 Monitoring Hawaiʻi Volcanoes

Students take on the role of volcanologists working to keep the public safe on the island of Hawaiʻi. 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

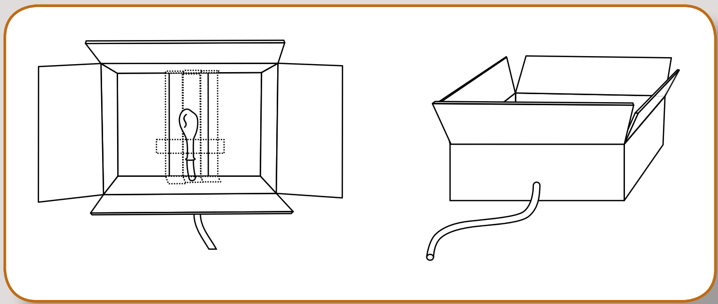
LESSON PREPARATION

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.

Lesson 1: Monitoring Hawaiʻi Volcanoes

- 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 Hawaiʻi 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 Hawaiʻi.

Hawaiʻi 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.

Lesson 1: Monitoring Hawaiʻi Volcanoes

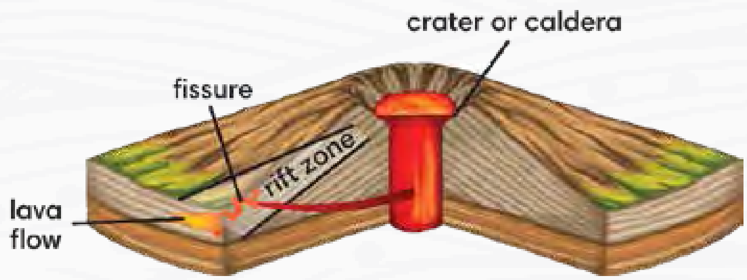
OPENING

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.



Hawaiʻi Volcanoes slideshow

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?*

   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 Hawaiʻi Volcanoes

Kohala

Mauna Loa

Mauna Kea

Hualālai

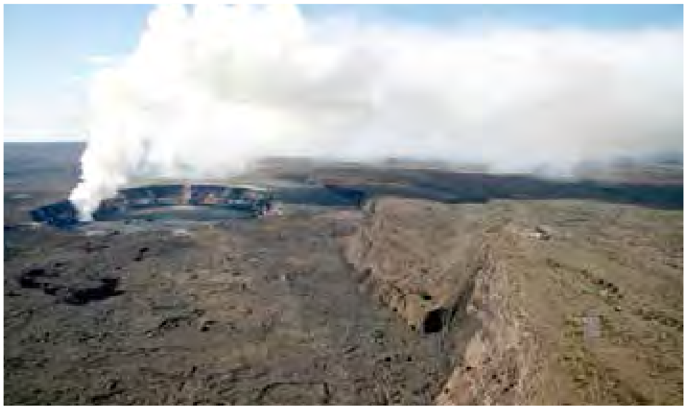


Image Credit: U.S. Geological Survey

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.

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.

Observation Journal

Observation Journal handout

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?*

Monitoring Hawai‘i Volcanoes

Volcanology

The ground is swelling!

How and why do scientists monitor deformation at volcanoes?

Volcanology handout

Lesson 1: Monitoring Hawai‘i Volcanoes

3. Also provide each team with access to the **Hawai‘i Volcanoes Data** handout (either the print or online version), which includes:
    - A recent report from each of the five volcanoes on Hawai‘i, 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 **Hawai‘i 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.

Hawai‘i Volcanoes Data handout

Lesson 1: Monitoring Hawai‘i Volcanoes

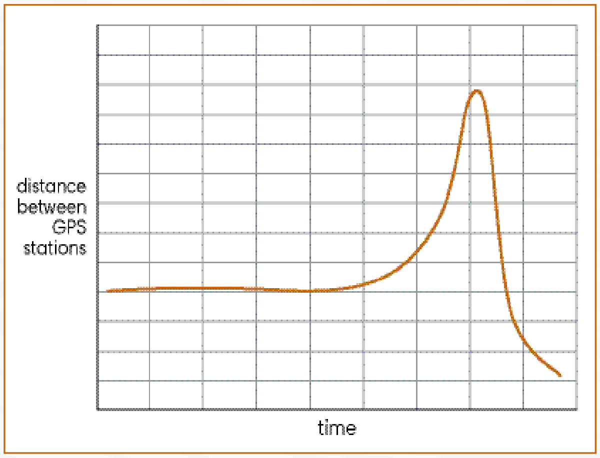
Demonstrate Deformation

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.

Lesson 1: Monitoring Hawai‘i Volcanoes

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

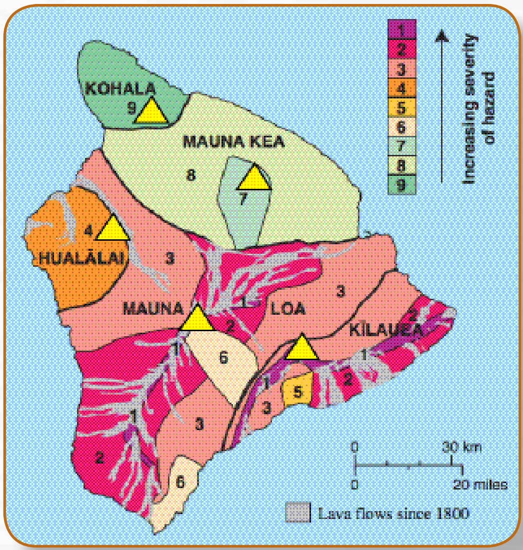
Summarize

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

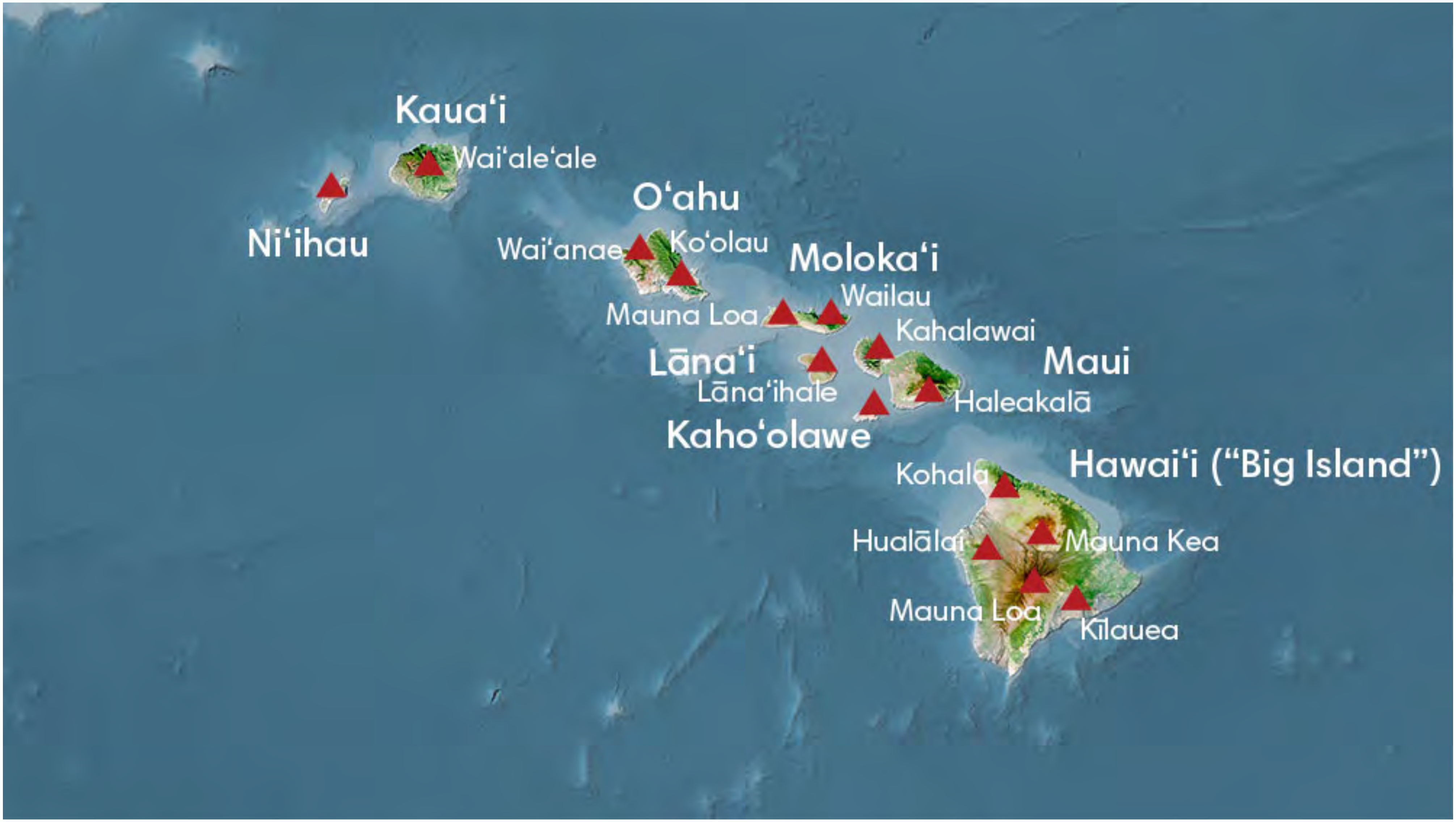
Source: U.S. Geological Survey

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.

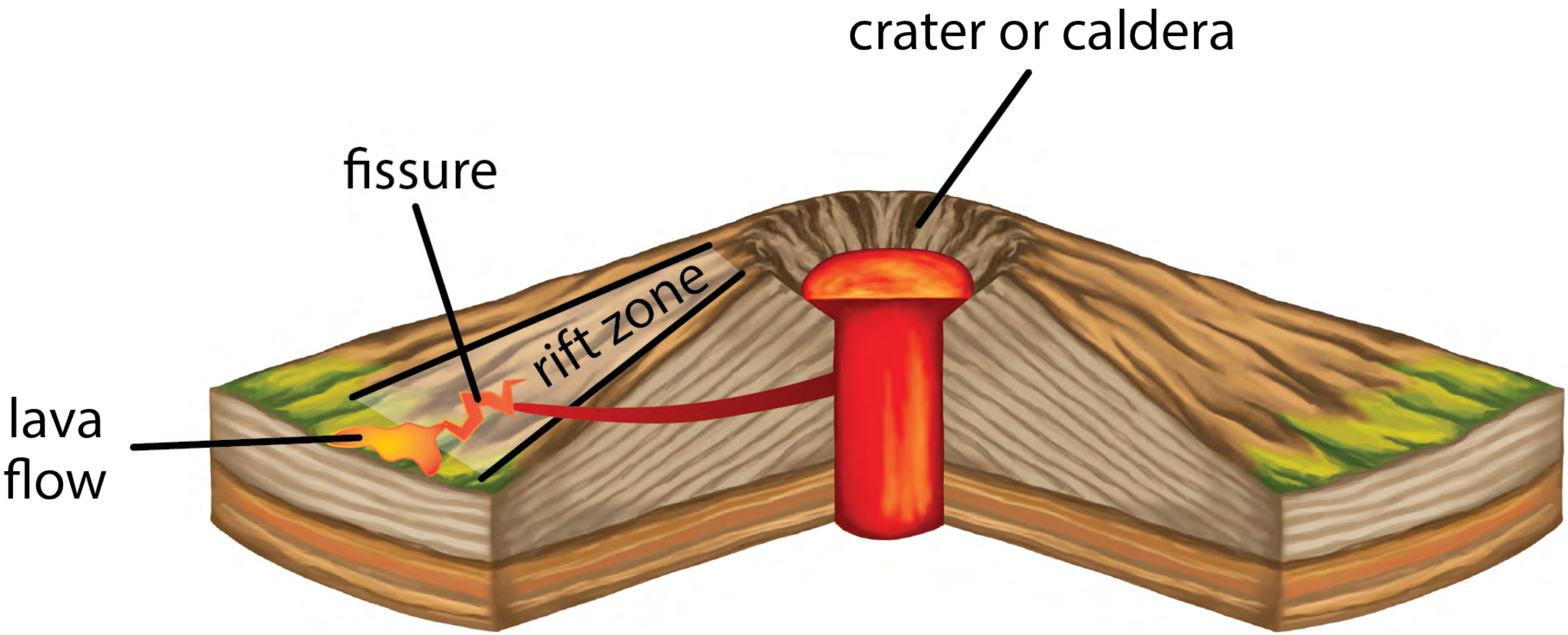
4. Show students the [United States Geological Survey (USGS) Volcano Hazards Program] website. Explain that this government website provides citizens with information about how scientists help keep the public safe.

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

Hawai'i Volcanoes Data

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

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

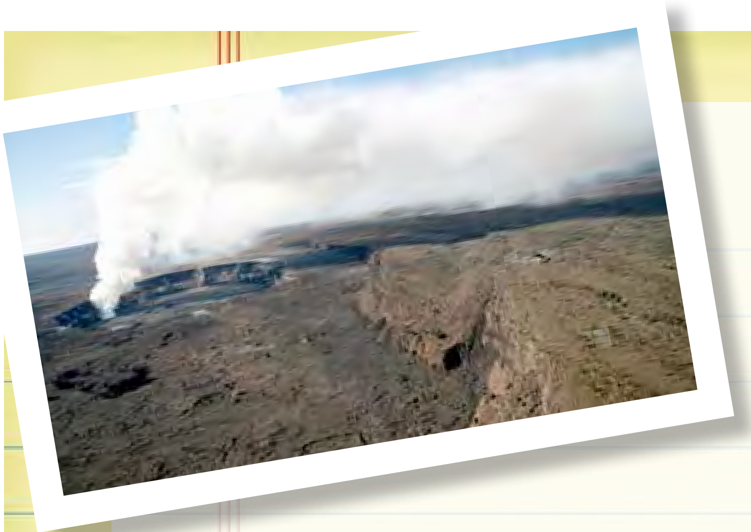
- 19.82° N, 155.47° W
- Summit elevation 13,796 ft (4,205 m)
- Mauna Kea is a **dormant volcano**. It was last active about 4,600 years ago.

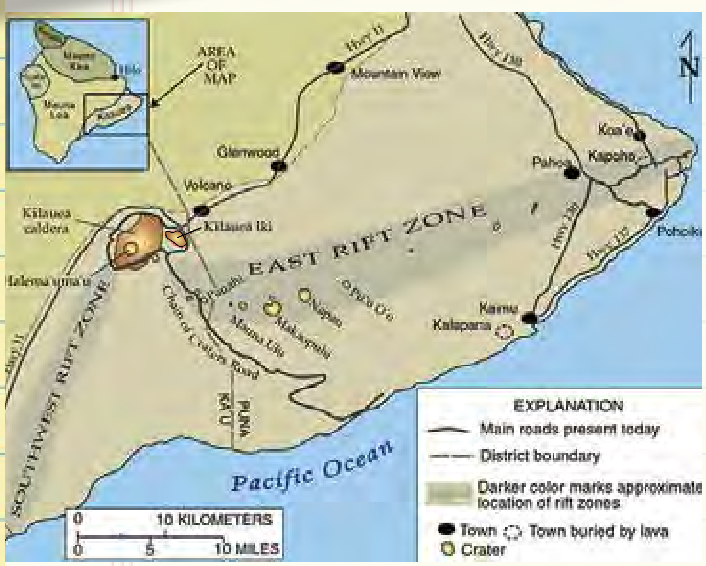
Image Credit: J. Kauahikaua

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.

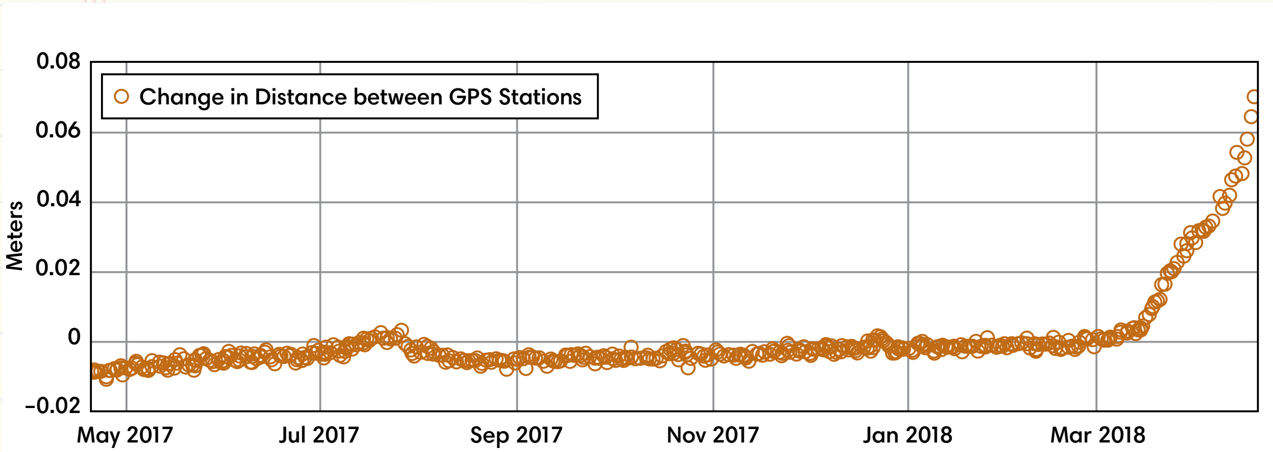
Hawaiʻi Volcanoes Data





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

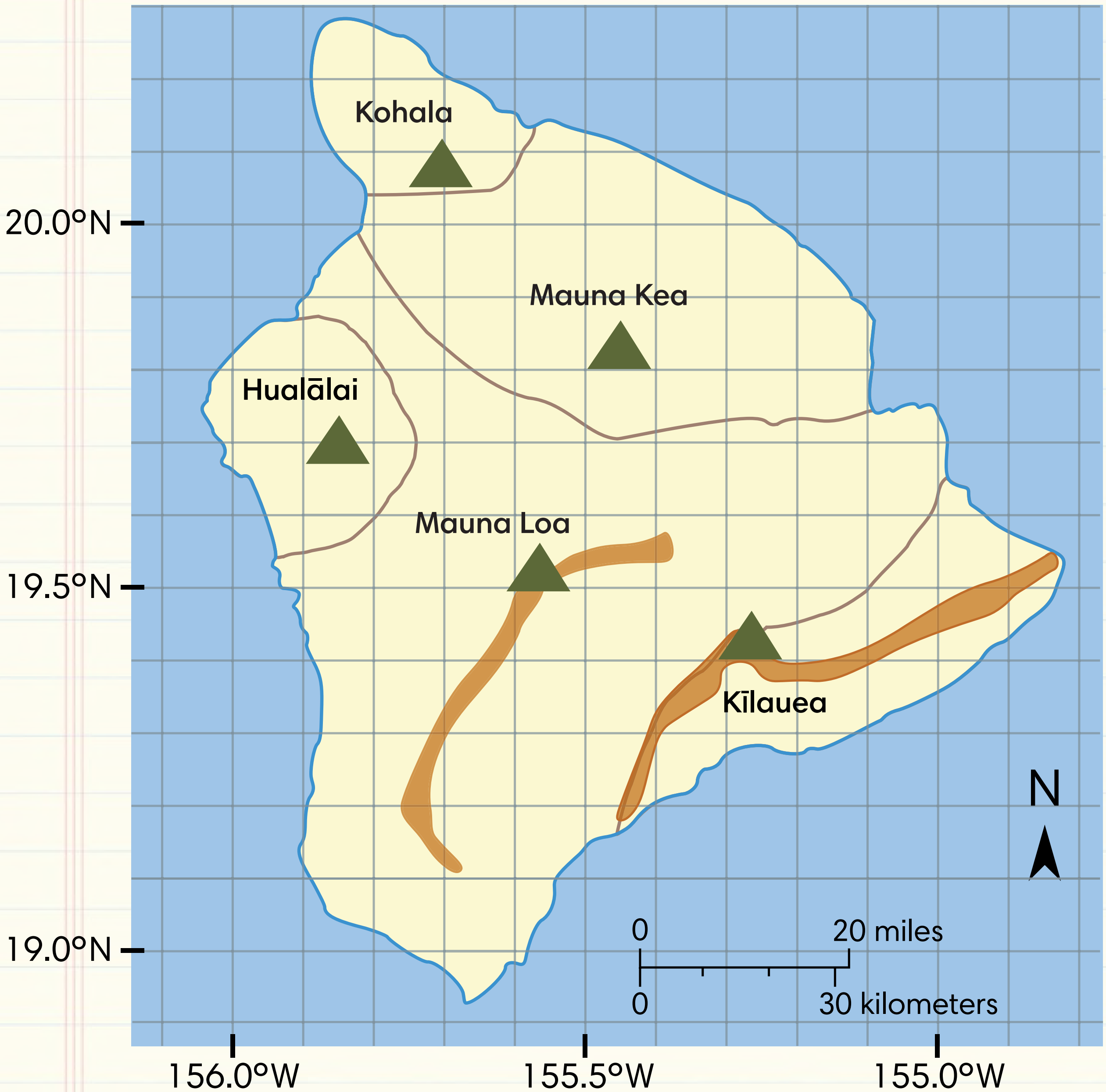
EARTHQUAKES

- 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.

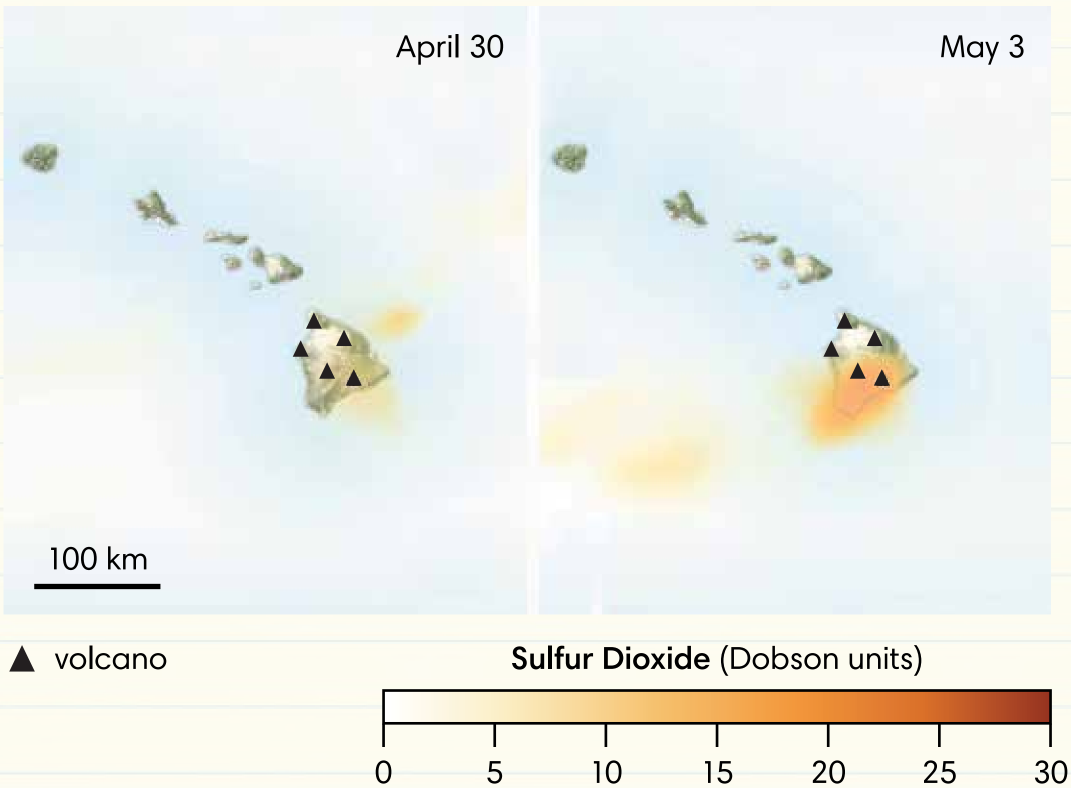
Date	Time	Location
3/3/18	6:10 PM	19.42 N, 155.61 W
3/4/18	9:31 PM	19.43 N, 155.61 W
3/21/18	3:49 AM	19.21 N, 155.41 W
3/28/18	1:43 AM	18.91 N, 155.37 W
4/4/18	8:24 AM	18.90 N, 155.36 W
4/26/18	11:08 PM	19.38 N, 155.24 W
5/1/18	4:40 AM	19.34 N, 155.06 W
5/1/18	5:49 AM	19.33 N, 155.06 W
5/1/18	12:39 PM	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 HAWAIʻI



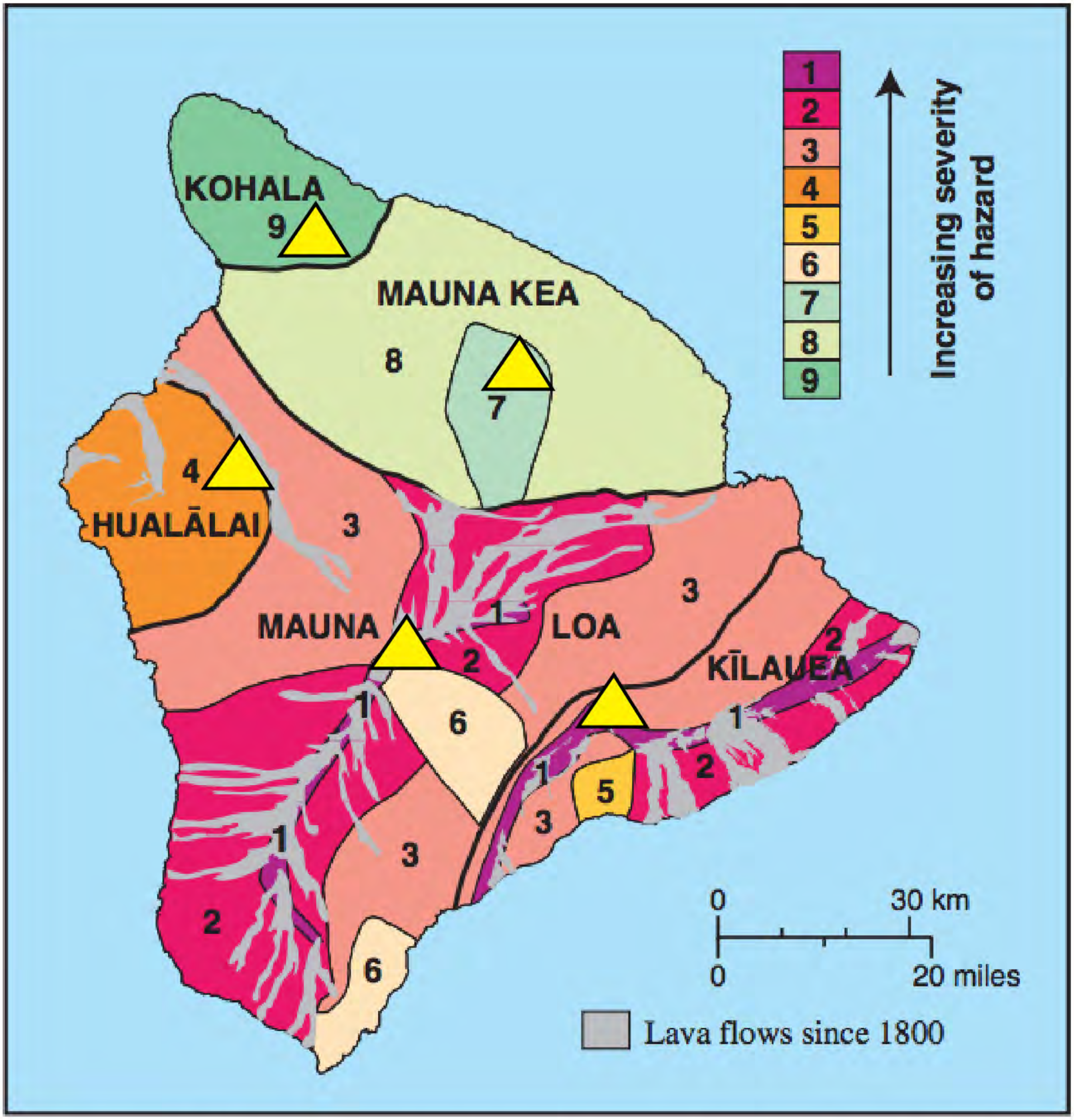
SULFUR DIOXIDE

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

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).

2

The Kīlauea Volcano: Be a Volcanologist

Monitoring Kīlauea

Learning IN MOTION®

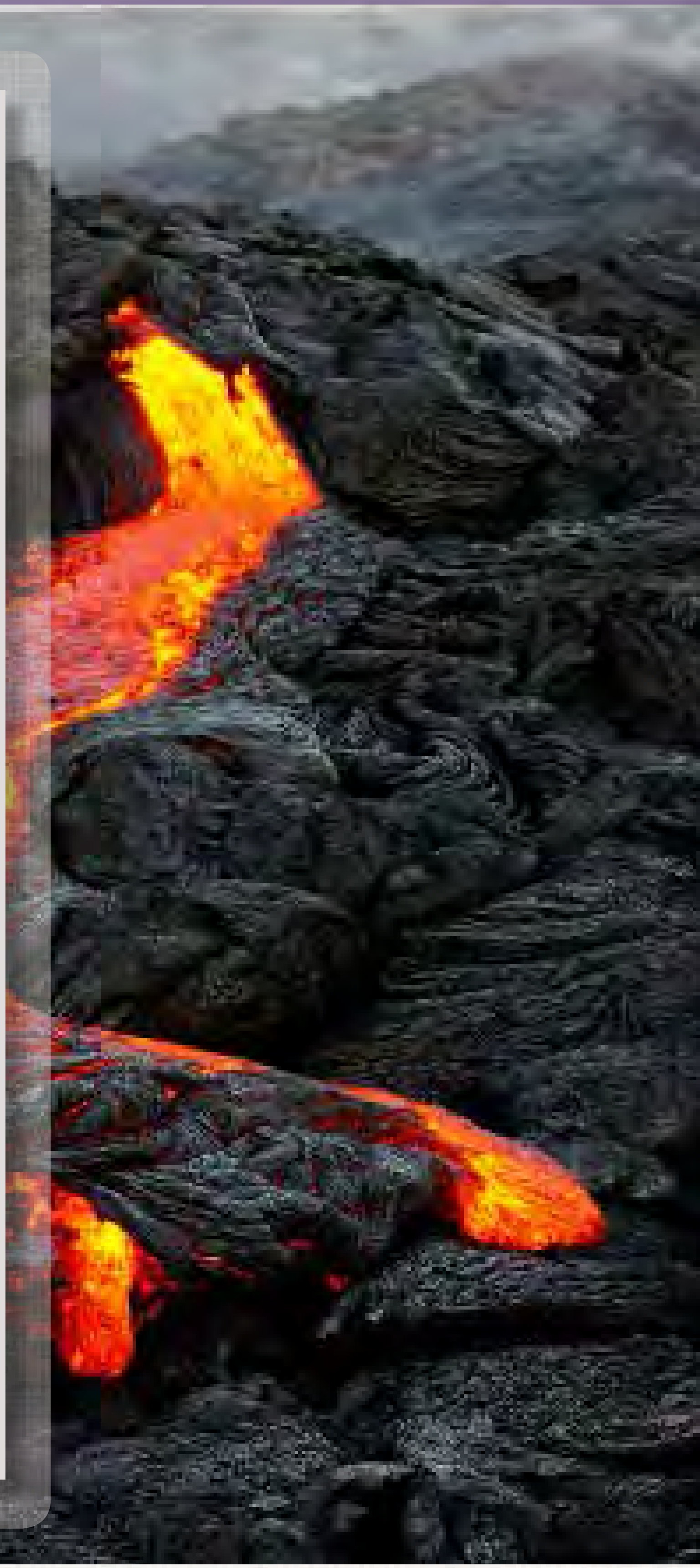
2 Monitoring Kīlauea

Students continue playing the role of volcanologists on the island of Hawai‘i. They analyze new geologic data (including maps, photos, and graphs) from the first few days of the May 2018 eruption of Kīlauea in order to predict the occurrence and effects of volcanic hazards and make safety recommendations to the public.

GUIDING QUESTION

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

Lesson 2: Monitoring Kīlauea



MATERIALS

Teacher Materials

- **Monitoring Kīlauea** visuals
  - **May 2, 2018 Map** visual
  - **Eruption in Leilani Estates** photograph
  - **Hawai‘i Volcano Hazard Update** visual
  - **Evacuation and Road Closure Map** visual

Student Materials

- **Monitoring Kīlauea Data** handout (online or print) (1 per pair or team of 4)
- **Volcanology** handout (from previous lessons) (1 per student)
- **Observation Journal** handout (1 per student)
- Optional: Computer or tablet with Internet access (1 device per team)

RESOURCES

Websites

Hawai‘i County Civil Defense Alert Archive website (for Extension)

FEMA.gov Kīlauea Eruption web page (for Extension)

PREPARATION

Prepare Lesson Materials

1. Determine which lesson handouts you will need hard copies of, and print enough for your class. Note that the **Monitoring Kīlauea 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 of data represented in maps and photos.

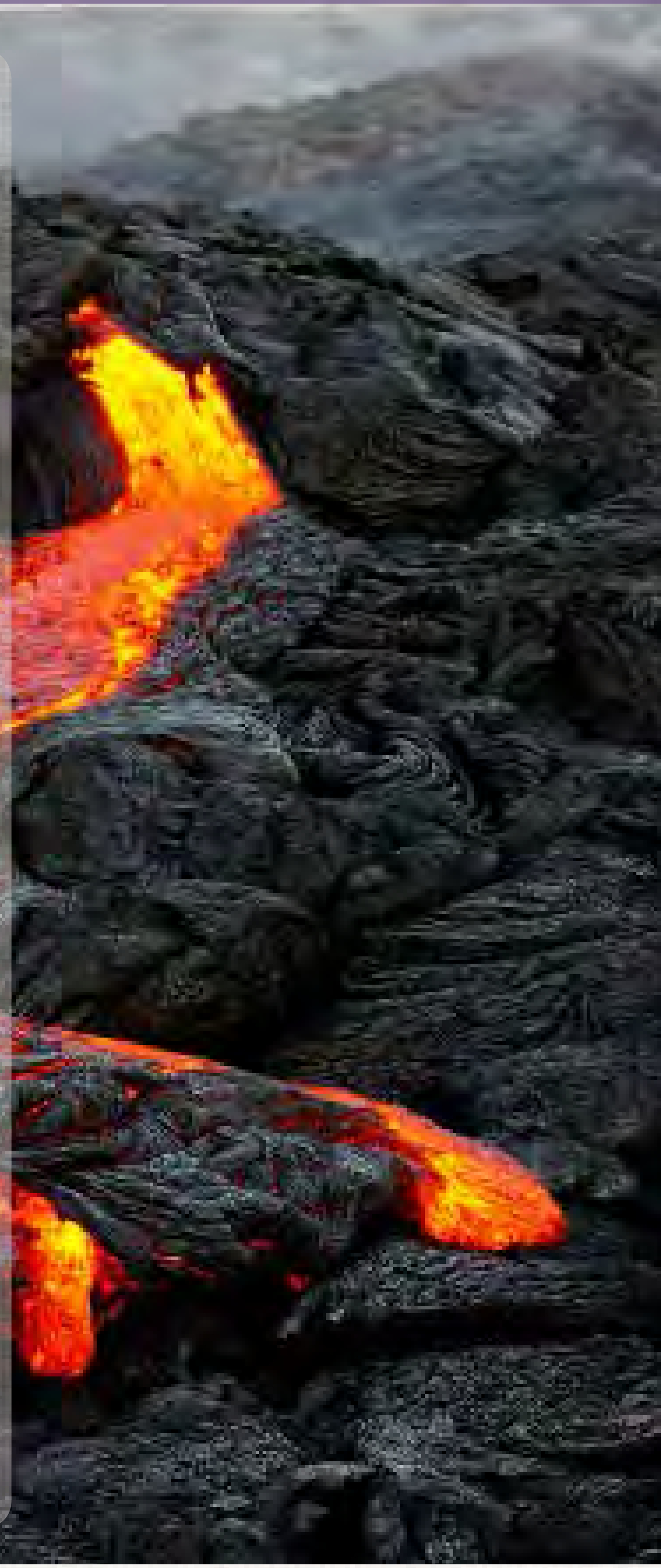
Lesson 2: Monitoring Kīlauea

- The **Volcanology** and **Monitoring Kīlauea Data** handouts can be laminated for re-use.

2. Students should continue using the **Observation Journal** that they started in Lesson 1. Prepare a class chart based on the table in the **Observation Journal** handout for use in the discussion part of the lesson (see page 41).

Prepare the Activity Approach

1. Determine how you will structure the Activity section of the lesson. Depending on the needs of your class, you may opt to conduct the activity with an open-ended approach or with more structured guidance. 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 maps and images and then progress to the graph.
   - 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. For a self-directed approach, be prepared to monitor teams as they determine their own allocation of tasks, pacing, and process for recording data.



Lesson 2: Monitoring Kīlauea

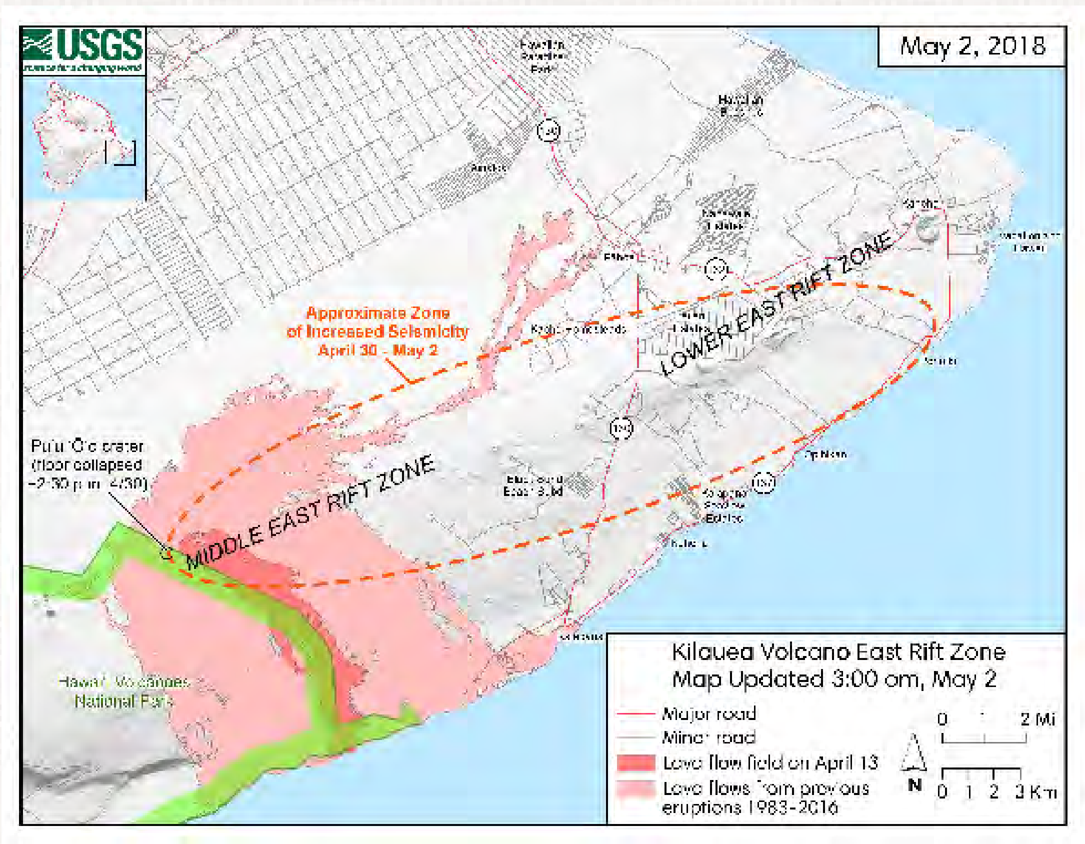
OPENING

Review Lesson 1 Key Ideas

1. Remind students that in the previous lesson they began working as volcanologists on the island of Hawai‘i to help determine ways to keep the public safe from volcanic hazards. Have a few students share the predictions that they made and the course(s) of action that the class recommended (monitoring, issuing an alert, and/or evacuating areas around one or more of the island's volcanoes).
2. Next, reveal that United States Geological Survey (USGS) scientists working on the island of Hawai‘i responded by closely monitoring the Kīlauea area. As a result, an alert was issued in anticipation of a possible eruption. Areas of Hawai‘i Volcanoes National Park around Kīlauea were closed due to potential volcanic hazards. Point out that the scientists also continued to monitor the other active volcanoes on the island, although less closely than Kīlauea.

Discuss Interpreting Data from Photos and Maps

1. Show the first image in the **Monitoring Kīlauea** visuals, which is the **May 2, 2018 Map** visual. This is a USGS map of the southeastern portion of the island of Hawai‘i.



May 2, 2018 Map visual

Source: U.S. Geological Survey

Lesson 2: Monitoring Kīlauea

2. Have a couple students point out something they notice. For example, you may have students locate:
   - The area of increased earthquake activity recorded from April 30 to May 2, 2018 (marked by a dotted oval and the label "Approximate Zone of Increased Seismicity April 30 - May 2")
   - Middle East and Lower East Rift Zones (the elevated ridge of land that runs along the southeastern coast, a few kilometers inland from the ocean)
   - Neighborhoods where people live, such as Black Sand Beach Subd., Leilani Estates, and Kaohe Homesteads
   - Puʻuʻ Ōʻō crater (at the edge of Hawaiʻi Volcanoes National Park on the west end of the Middle East Rift Zone)
   - Areas marked in light pink and in dark pink, which represent previous lava flows (in the Middle East Rift Zone, starting near Puʻuʻ Ōʻō crater)
3. Review that the class's previous observations were of activity that took place during March, April, and early May 2018.
4. Display the **Eruption in Leilani Estates** photograph, which shows the Kīlauea Volcano eruption on May 3, 2018. While displaying the image, read aloud the description, which provides an overview from the U.S. Geological Survey of news about the eruption:

   On May 3, 2018, a new eruption of Kīlauea Volcano began in the Leilani Estates neighborhood located in the lower East Rift Zone. Lava, hot water vapor, and gas fumes started spewing into the air from a newly-opened crack in the earth, and lava flowed slowly outward about 10 meters from this fissure.

Eruption in Leilani Estates photograph Source: U.S. Geological Survey

Introduce Today's Goal

1. Remind students of the unit Guiding Question:

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

2. Explain that students will work in their teams from the previous lesson to investigate and interpret data from maps, photos, and a graph. As in Lesson 1, they will organize their notes in their **Observation Journal**.
3. Explain that students should use the **Observation Journal** to:
   - Describe and predict volcanic hazards.
   - Make recommendations to keep the public safe.
4. You may want to record these tasks on the board or somewhere else easily visible to students for reference.


Observation Journal

Observation Journal handout

Lesson 2: Monitoring Kīlauea

ACTIVITY

Introduce the Activity

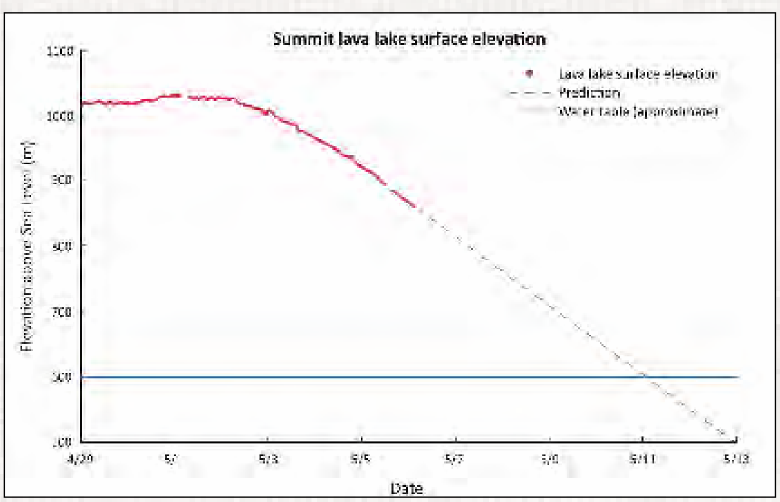
1. Ensure students have their **Observation Journal** handout from the previous lesson. Tell students to gather in their pairs or teams of four.

2. Ensure that each team has a copy of the **Volcanology** handout (from Lessons 0 and 1). These handouts provide information that teams can reference as needed to help them make sense of and analyze the volcano data. Point out the Lesson 2 section and review the topic question on each page:

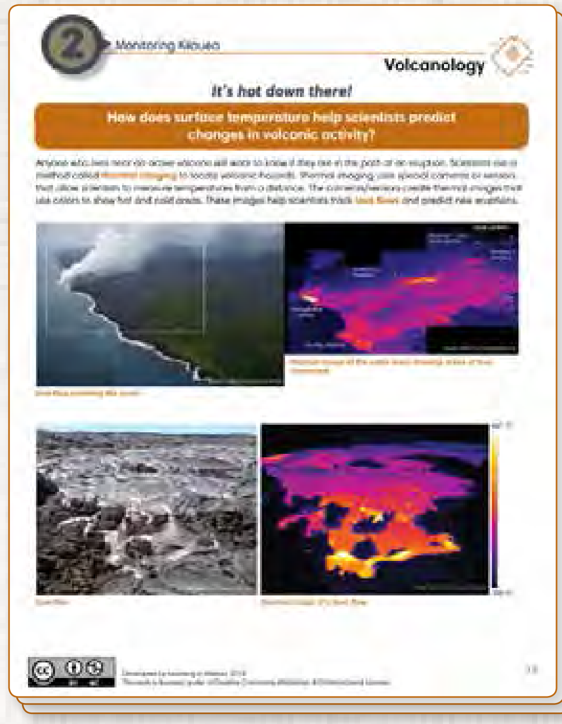
   - *How does surface temperature help scientists predict changes in volcanic activity?*
   - *How can scientists predict where lava will flow?*
   - *How can the lava lake provide clues about an eruption?*

3. Provide each team with a copy of the **Monitoring Kīlauea Data** handout (print or online), which includes:

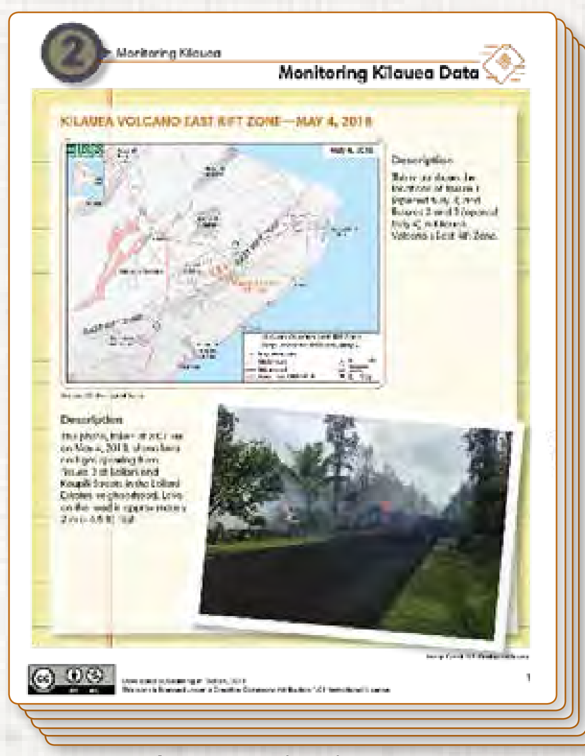
   - Photos and maps (including thermal maps) of the Lower East Rift Zone of Kīlauea Volcano from May 4–9, 2018
   - Graph of Kīlauea Volcano summit lava lake levels, with data from April 29–May 6, 2018, and predictions through May 13, 2018



Source: U.S. Geological Survey



Volcanology handout



Monitoring Kīlauea Data handout

Lesson 2: Monitoring Kīlauea

4. Remind students that if they come across unfamiliar concepts or vocabulary terms, they can refer to the **Volcanology** handout.
5. You may want to conduct a quick class brainstorm regarding possible ways to organize the data in students' **Observation Journal**—for example, by:
    - Date
    - Type of hazard (e.g., fissures, lava flows, toxic gases, explosions)
    - Location/area (e.g., volcano summit, East Rift Zone)
6. Encourage students to work together with their team to share information and discuss their ideas. Remind students to record their observations, analysis, and recommendations in the table in their **Observation Journal**.
7. If you feel that students need additional guidance, provide some guiding questions such as the following to help teams analyze the data:
    - *What can you understand from looking at each map, graph, or image? What information can help you interpret the data?*
    - *What hazards are currently present? What types of damage are they causing?*
    - *Where are the hazards located?*
    - *How would you describe the severity of the hazards you observed?*
    - *How do the locations or severity of the hazards change over time?*
    - *What patterns do you notice in the data?*
    - *What new or future hazards do you predict, and why?*

Organize, Analyze, and Interpret Data

1. As teams work, circulate to monitor progress and support students in interpreting the data. As necessary, remind them to refer to the **Volcanology** handout to help them make sense of new terms and concepts; also remind them to record their observations, analysis, and recommendations in their **Observation Journal**.
2. Engage with teams and monitor their understanding by posing further probing questions, such as:
    - *What are some volcano hazards that you notice in this [map, photo]?*
    - *What do you notice about the progression of fissures from May 4 to later dates?*
    - *What information have you found that can help you predict what might happen next with this Kīlauea volcano eruption?*
    - *What can you understand from looking at the graph of the lava lake level? Where can you find information to help you interpret the graph?*
    - *Based on the data your team has looked at, what areas do you think are at risk for volcanic hazards or eruptions? Why?*

Lesson 2: Monitoring Kīlauea

3. As you monitor the investigation, take notes about students' work in order to prepare for class discussion. For example, make note of unique and/or pervasive:
   - Ways teams organize their data
   - Observations about the maps, photos, or graph
   - Insights about the meaning of the data
   - Recommendations for keeping the public safe

Discuss Data Analysis and Recommendations

1. Have students reconvene for a whole-class discussion. As students share ideas that they recorded in their **Observation Journal**, encourage other teams to ask clarifying questions. If audience members disagree with some aspect of the presenters' interpretation, have them provide an argument explaining their alternate explanation.
2. Complete a class chart to record students' ideas. A completed class chart might resemble the following.

Our Observations	Our Analysis	Our Recommendations
Lava flow • New fissures are appearing in the Leilani Estates area of the East Rift Zone. • Thermal maps show hot areas spreading from around Fissure 8 on May 6 and around Fissure 15 on May 9. • The lava is covering and burning the areas near the fissures. • There are cracks in some of the roads such as Pohoiki Road. • The fissures are spreading in a line toward the northeast and southwest.	• Lava flows are a hazard to people living nearby and downhill. • More fissures might continue to appear in the same directions. • New fissures or lava flows might happen near the cracks.	• People who live in Leilani Estates and areas downhill should evacuate. • Roads in Leilani Estates should be closed. • People who live in areas to the northeast and southwest should be alerted. • Areas in the East Rift Zone and down the lines of steepest descent should be monitored or closed in those directions.
Summit lava lake • The lava lake level is dropping.	• The lava lake level might continue to drop. If it goes below the water table, there could be an explosive eruption. It is predicted to happen around May 11. • The drop in the lava lake level might mean more magma is moving down the rift zone.	• The area around the lava lake should be closed to the public.

Lesson 2: Monitoring Kīlauea

REFLECTION

Summarize

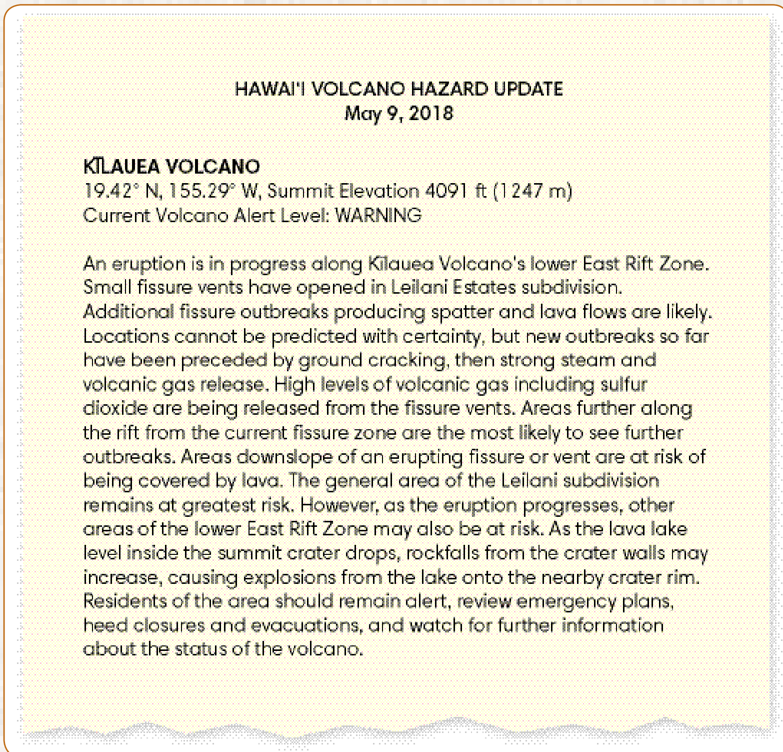
1. After completing the class chart, review some of the main points that students made. For example, you might say:
   - We noticed a series of fissures opening up in the Leilani Estates area and spreading in a line to the northeast and the southwest. The East Rift Zone area should continue to be monitored for new fissures. We recommended that the Leilani Estates area and other places downhill from that area be closed and evacuated because they are at risk of being burned and damaged by lava flows. We also noticed that the lava lake level at the summit is dropping and it might go below the water table. We predicted that this could cause an explosive eruption, so people should stay away from that area.
2. Review some of the technologies and methods—thermal imaging, seismographs, GPS stations—that scientists use to monitor volcanic activity. Discuss how this information helps them make predictions, based on which the public can be advised about how to stay safe. Explain that the class will now look at an alert and evacuation plan that scientists and officials created in response to the Kīlauea eruption.

Image Credit: U.S. Geological Survey

Lesson 2: Monitoring Kīlauea

View Hazard Documentation

1. Project the **Hawai'i Volcano Hazard Update** visual (adapted from the official daily updates produced by the USGS Hawaiian Volcano Observatory for May 4 to May 9, 2018). Read the update aloud, or have a student do so. As you read, have students consider how the information in the update compares to their own data analysis.



HAWAI'I VOLCANO HAZARD UPDATE
May 9, 2018

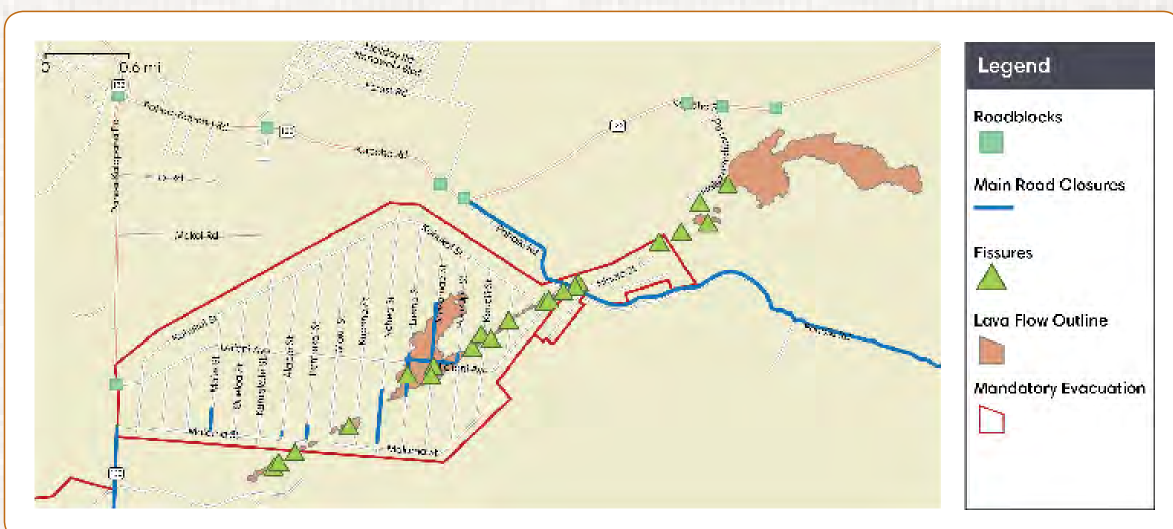
KĪLAUEA VOLCANO
19.42° N, 155.29° W, Summit Elevation 4091 ft (1247 m)
Current Volcano Alert Level: WARNING

An eruption is in progress along Kilauea Volcano's lower East Rift Zone. Small fissure vents have opened in Leilani Estates subdivision. Additional fissure outbreaks producing spatter and lava flows are likely. Locations cannot be predicted with certainty, but new outbreaks so far have been preceded by ground cracking, then strong steam and volcanic gas release. High levels of volcanic gas including sulfur dioxide are being released from the fissure vents. Areas further along the rift from the current fissure zone are the most likely to see further outbreaks. Areas downslope of an erupting fissure or vent are at risk of being covered by lava. The general area of the Leilani subdivision remains at greatest risk. However, as the eruption progresses, other areas of the lower East Rift Zone may also be at risk. As the lava lake level inside the summit crater drops, rockfalls from the crater walls may increase, causing explosions from the lake onto the nearby crater rim. Residents of the area should remain alert, review emergency plans, heed closures and evacuations, and watch for further information about the status of the volcano.

Hawai'i Volcano Hazard Update visual

Source: Adapted from U.S. Geological Survey

2. Then show the **Evacuation and Road Closure Map** visual.



Evacuation and Road Closure Map visual

Source: Adapted from County of Hawai'i

Lesson 2: Monitoring Kīlauea

Explain that the County of Hawaiʻi maintains an alert page on its website; information on this page includes civil defense messages and maps of hazards and evacuations. The website helps to provide important safety information to the public. The **Evacuation and Road Closure Map** is a reproduction of the 2018 Lava Information Map from the county website in mid May 2018. Have students identify the areas of mandatory evacuation, road closures, and other map features. Note that the pink areas represent all lava flows since the eruption began, including those that are no longer active.

Formative Assessment

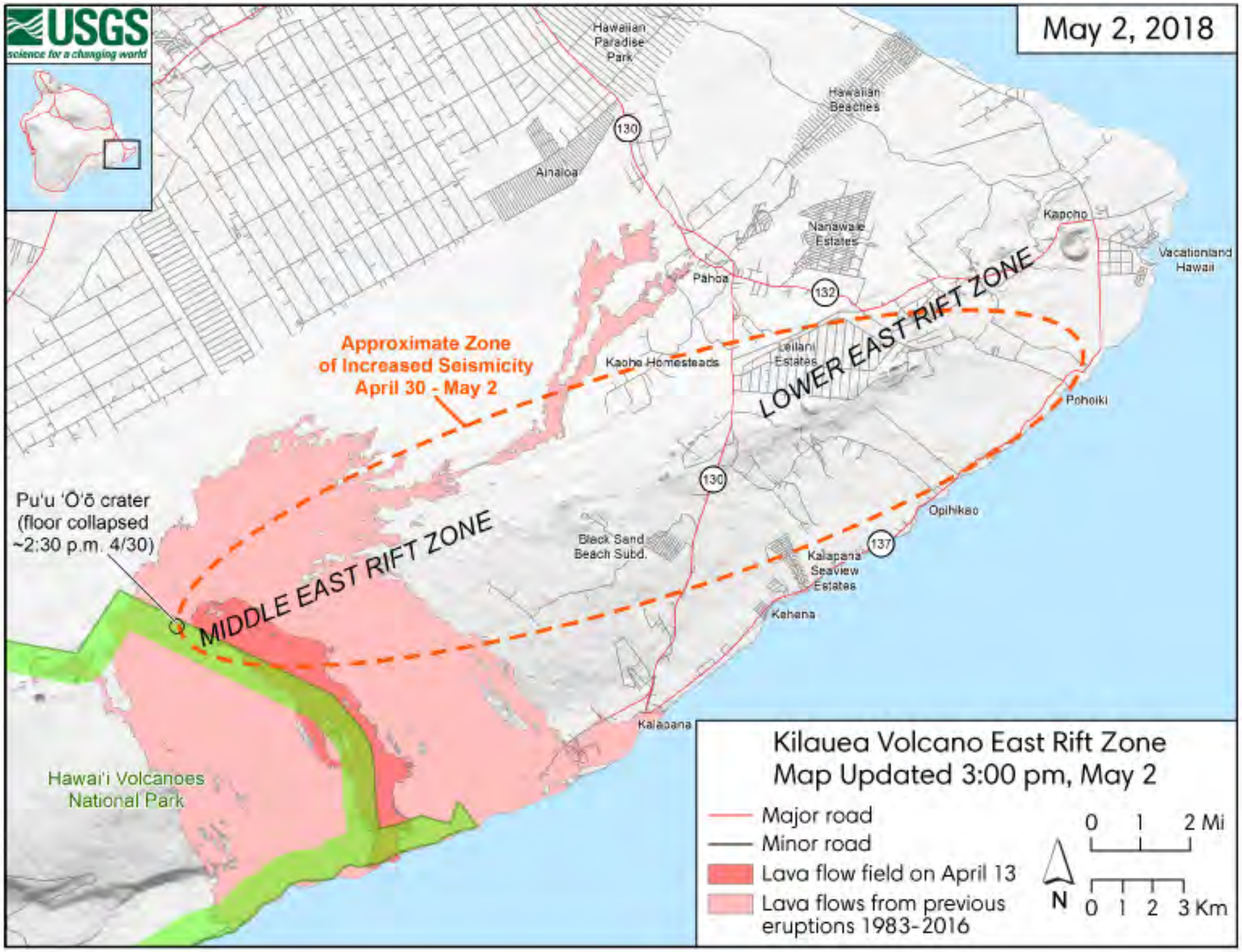
1. Ask students to record responses to the following:
   - ***How does technology help scientists keep the public safe and informed about hazards? Describe at least two ways.***
2. You may ask students to record their reflections on a separate piece of paper to turn in or in another location, such as a science journal, according to your class routines.

EXTENSION

Explore Additional Emergency Resources

1. Show students the **Hawaiʻi County Civil Defense Alert Archive** website. Choose an alert to read together and ask students to listen for:
   - Data and observations from scientific monitoring (such as sulfur dioxide levels, earthquake occurrences)
   - Decisions or advisories that were made based on the data (such as evacuations)
2. Show students the **FEMA.gov** web page about the Kīlauea eruption. Point out the features and services offered, such as:
   - Assistance for residents to access disaster recovery centers
   - News releases
   - Links to county alerts, healthcare resources, etc.

May 2, 2018 Map



This map shows the area of increased earthquake activity along the
East Rift Zone of the Kīlauea Volcano from April 30 to May 2, 2018.
Source: U.S. Geological Survey

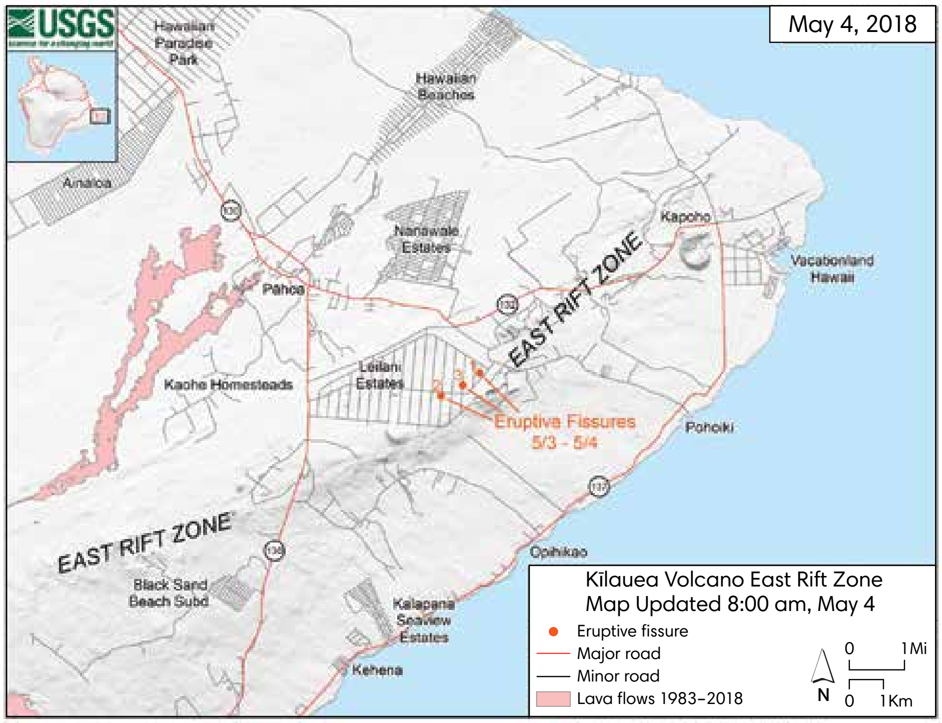
Eruption in Leilani Estates

On May 3, 2018, a new eruption of Kīlauea Volcano began in the Leilani Estates neighborhood located in the lower East Rift Zone. Lava, hot water vapor, and gas fumes started spewing into the air from a newly-opened crack in the earth, and lava flowed slowly outward about 10 m from this volcanic fissure.

Image Credit: U.S. Geological Survey

Monitoring Kīlauea Data

KĪLAUEA VOLCANO EAST RIFT ZONE—MAY 4, 2018



Source: U.S. Geological Survey

Description

This map shows the locations of fissure 1 (opened May 3) and fissures 2 and 3 (opened May 4) in Kīlauea Volcano's East Rift Zone.

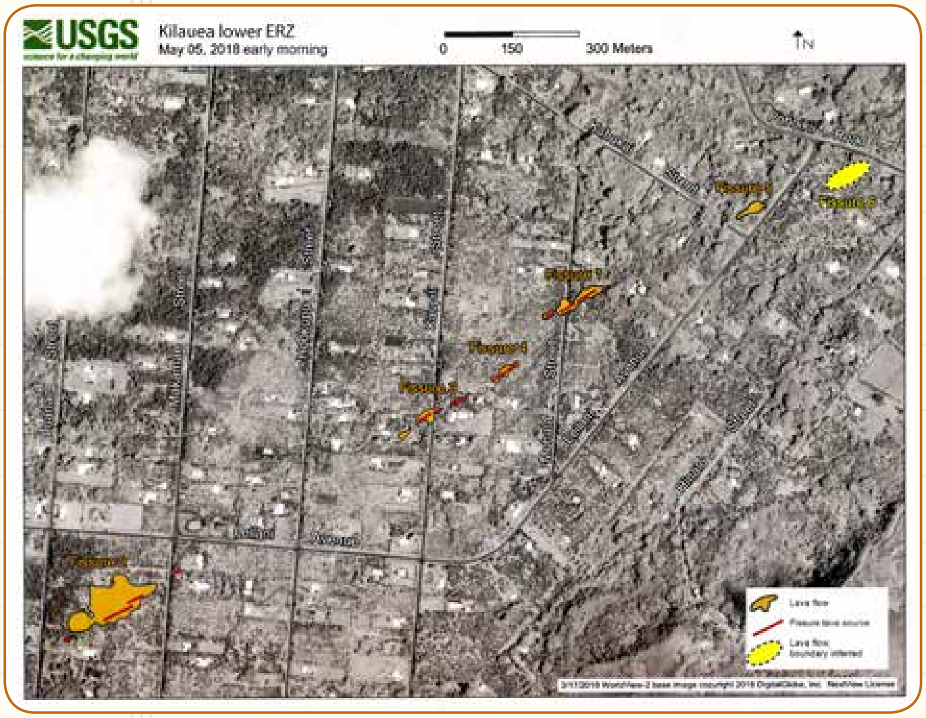
Description

This photo, taken at 8:07 AM on May 4, 2018, shows lava and gas spewing from fissure 3 at Leilani and Kaupili Streets in the Leilani Estates neighborhood. Lava on the road is approximately 2 m (~6.5 ft) high.

Image Credit: U.S. Geological Survey

Monitoring Kīlauea Data

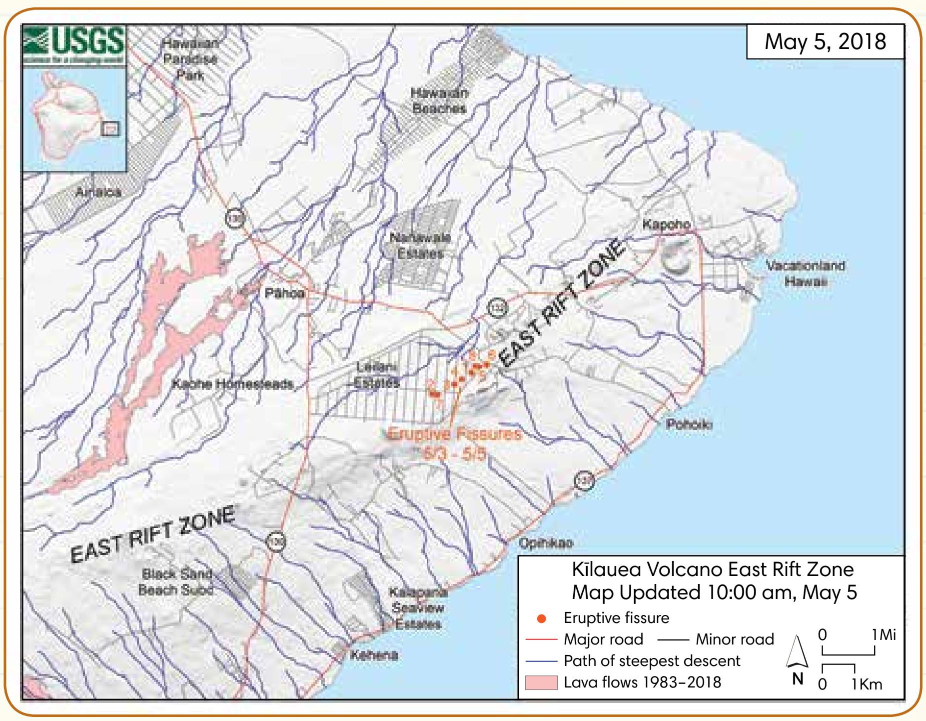
KĪLAUEA VOLCANO EAST RIFT ZONE—MAY 5, 2018



Source: U.S. Geological Survey
Satellite image ©2018 DigitalGlobe, a Maxar company

Description

This satellite image shows fissures 1–5 and lava-covered areas of Leilani Estates in Kīlauea Volcano's East Rift Zone on May 5, 2018.



Source: U.S. Geological Survey

Description

This map shows the locations of fissures 7–8 (opened May 5), along with previously-opened fissures 1–6. The blue lines show the paths of steepest descent.

Description

This photo shows a newly opened crack on Pohoiki road in Leilani Estates on May 5, 2018.

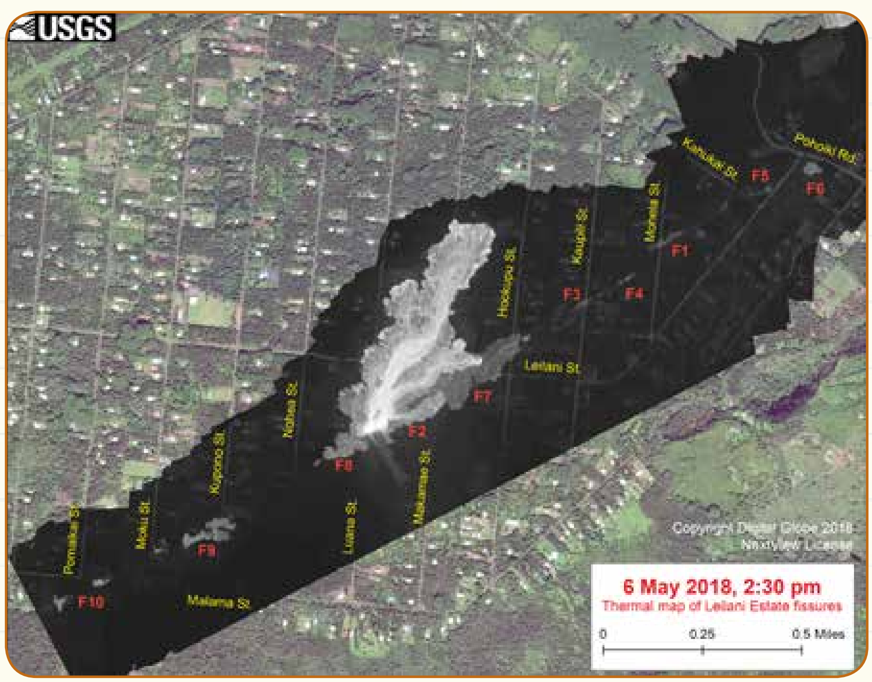
Image Credit: U.S. Geological Survey

KĪLAUEA VOLCANO EAST RIFT ZONE—MAY 6, 2018

Description

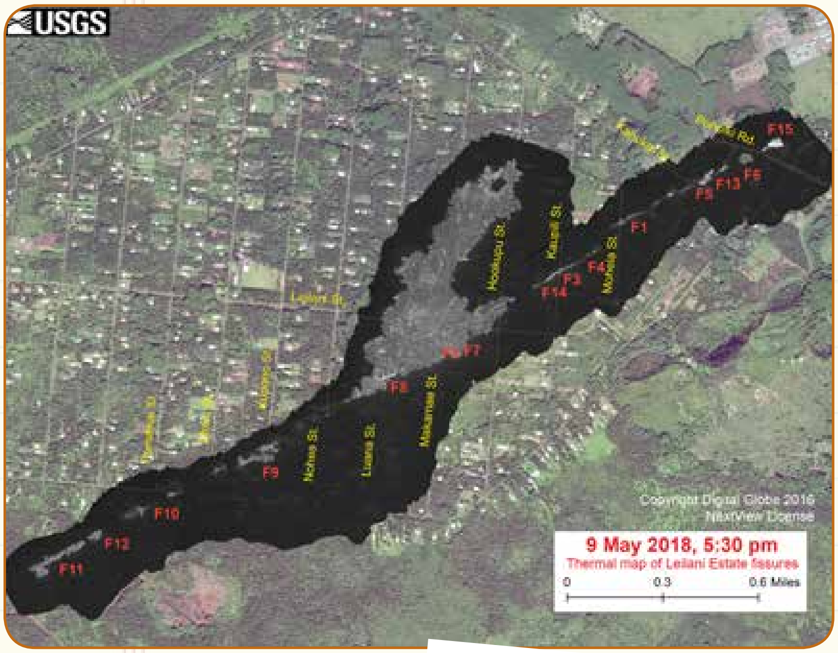
This thermal map, created at 2:30 PM on May 6, 2018, shows fissures 9–10 (opened May 6) along with previously-opened fissures 1–8 in Kīlauea Volcano's East Rift Zone.

The thermal image is the black portion at the center. It is shown over a color satellite image of the area. Lava flow is shown in grey and white. The hottest temperatures appear as the brightest white areas.



Source: U.S. Geological Survey
Satellite image ©2018 DigitalGlobe, a Maxar company

KĪLAUEA VOLCANO EAST RIFT ZONE—MAY 9, 2018



Description

This thermal map, created at 5:30 PM on May 9, 2018, shows fissures 1-15 in Kīlauea Volcano's East Rift Zone. Fissures 11-12 opened May 7, fissures 13-14 opened May 8, and fissure 15 opened May 9.

The thermal image is the black portion at the center. It is shown over a color satellite image of the area. Lava flow is shown in grey and white. The hottest temperatures appear as the brightest white areas.

Source: U.S. Geological Survey
Satellite image ©2018 DigitalGlobe, a Maxar company

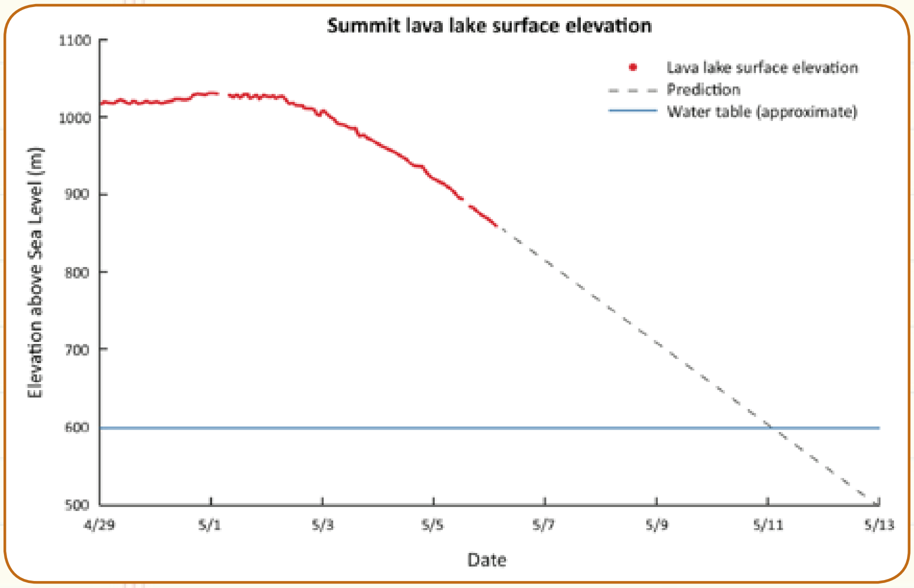
Description

This photo shows a geologist from the Hawaiian Volcano Observatory (HVO) measuring the temperature at cracks in Nohea Street in Leilani Estates at 11:47 AM on May 9, 2018. The temperature reading was 103°C (218° F).

This photo shows deep cracks, burned trees, and gas around fissure 14.

Image Credit: U.S. Geological Survey

KĪLAUEA VOLCANO SUMMIT CALDERA—MAY 6, 2018



Description

This is a graph of the lava lake level at the Kīlauea Volcano summit caldera. Data marked in red shows the lava lake level from April 29 to May 6, 2018. The dotted line shows predicted levels.

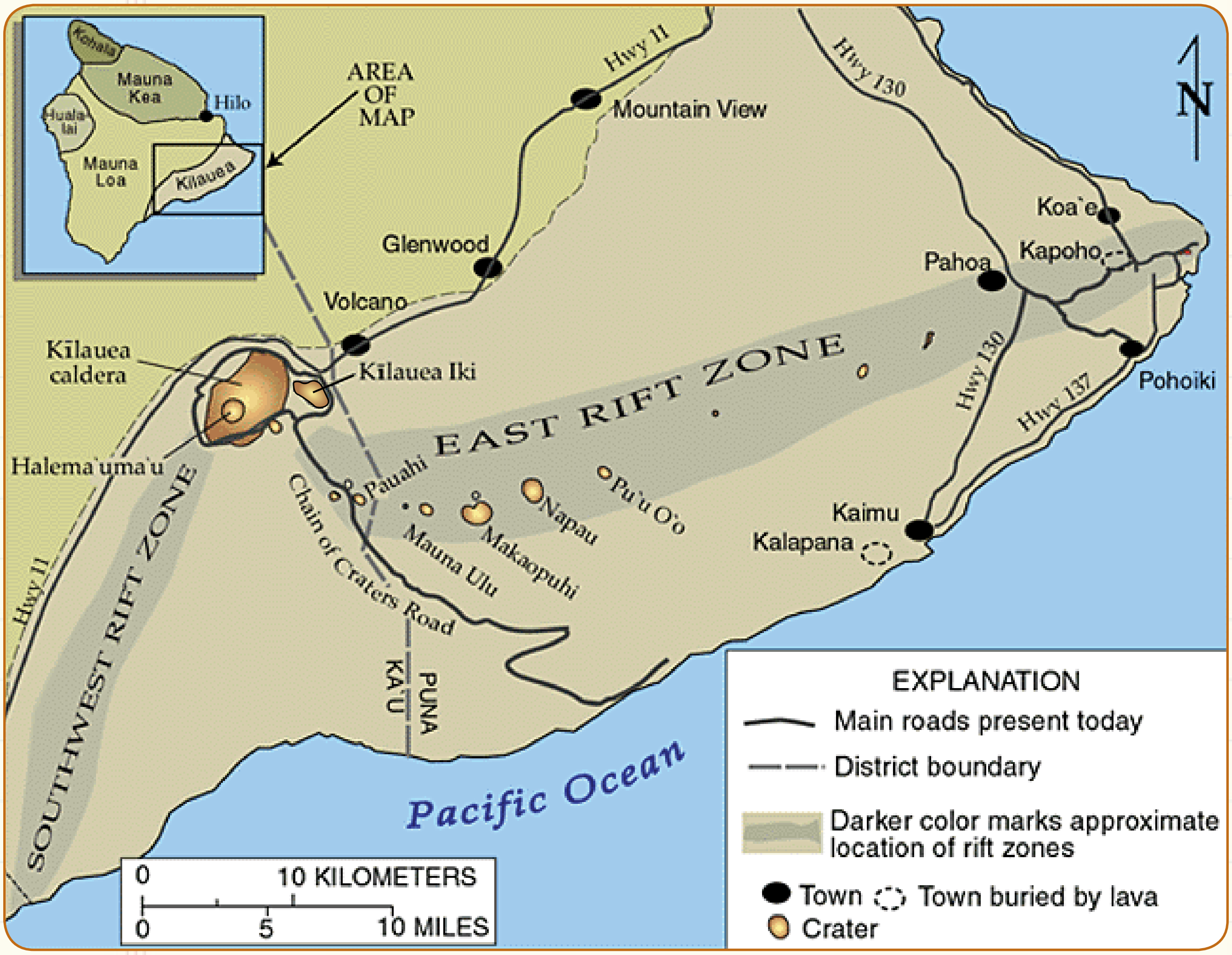
Source: Adapted from U.S. Geological Survey

Description

This photo shows the Kīlauea Volcano's summit crater. The level of the lava lake dropped significantly below the crater rim.

Source: U.S. Geological Survey

KĪLAUEA VOLCANO MAP



Source: U.S. Geological Survey

Description

This map of Kīlauea Volcano shows the summit caldera as well as rift zones and craters downhill from the summit.

Hawai‘i Volcano Hazard Update

HAWAI‘I VOLCANO HAZARD UPDATE
May 9, 2018

KĪLAUEA VOLCANO
19.42° N, 155.29° W, Summit Elevation 4091 ft (1247 m)
Current Volcano Alert Level: WARNING

An eruption is in progress along Kīlauea Volcano's lower East Rift Zone. Small fissure vents have opened in Leilani Estates subdivision. Additional fissure outbreaks producing spatter and lava flows are likely. Locations cannot be predicted with certainty, but new outbreaks so far have been preceded by ground cracking, then strong steam and volcanic gas release. High levels of volcanic gas including sulfur dioxide are being released from the fissure vents. Areas further along the rift from the current fissure zone are the most likely to see further outbreaks. Areas downslope of an erupting fissure or vent are at risk of being covered by lava. The general area of the Leilani subdivision remains at greatest risk. However, as the eruption progresses, other areas of the lower East Rift Zone may also be at risk. As the lava lake level inside the summit crater drops, rockfalls from the crater walls may increase, causing explosions from the lake onto the nearby crater rim. Residents of the area should remain alert, review emergency plans, heed closures and evacuations, and watch for further information about the status of the volcano.

Evacuation and Road Closure Map

This map shows roadblocks, road closures, and mandatory evacuation areas along Kīlauea Volcano's East Rift Zone in mid May, 2018.

Image Credit: Julien Millet / Unsplash

3

The Kīlauea Volcano: Be a Volcanologist

Final Project

Learning IN MOTION®

3 Final Project

In this two-day project, students apply their previous learning and data analysis about volcanic hazards. The class begins by reviewing a rubric for developing a Hazard Response Plan. Then, pairs or teams work together to each create their own plan for scientific monitoring and public response to two volcanic hazards they have selected. The class concludes with a brief summary of volcanic events that continued after the May 2018 eruption.

GUIDING QUESTION

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

Lesson 3: Final Project

MATERIALS

Teacher Materials

- **Final Project** visuals
  - **Kīlauea Eruption Continues** slideshow (for Extension)

Student Materials

- **Volcanology** handout (from previous lessons) (1 per student)
- **Observation Journal** handout (from previous lessons) (1 per student)
- **Hazard Response Plan Rubric** handout (1 per student)
- Optional: **Kīlauea Eruption Images** handout (online or print) (1 per pair or team)
- Optional: Data handouts from previous lessons (1 of each per pair or team):
  - **Hawai'i Volcanoes Data** handout
  - **Monitoring Kīlauea Data** handout
- Supplies and equipment for creating final project (see Lesson Preparation)

LESSON PREPARATION

Prepare the Project Approach

1. Prior to the lesson, decide how you will structure students' final projects. Depending on the needs of your class, you may opt to have students work in pairs or in their teams of four from previous lessons. In addition, decide the level of self-direction you will offer in terms of the format of students' Hazard Response Plans. You may opt to have students select from a set of options or leave the approach completely open-ended. Some potential formats include a poster, a brochure, or an announcement to be broadcast or distributed online.

Image Credit: Jens Johnsson / Unsplash

Lesson 3: Final Project

Prepare Lesson Materials

1. Print enough copies of the **Hazard Response Plan Rubric** handout for your class.

2. Determine how students will access images to use in their project.

    - **Print version:** If the **Volcanology**, **Hawai'i Volcanoes Data**, and **Monitoring Kīlauea Data** handouts were printed but not laminated, students can select and cut out appropriate images from these handouts. Alternatively, you can print a copy of the **Kīlauea Eruption Images** handout for each team, which contains select images from the **Volcanology** handout and data handouts without accompanying text.
    - **Online version:** If students will complete their project digitally, you can provide them with access to the online **Kīlauea Eruption Images**.
    - You may instruct students to illustrate their own visuals.

3. Prepare access to the supplies and equipment students will need for the project approach(es) chosen. These may include:

    - Poster board
    - Blank paper
    - Colored pens and pencils
    - Scissors
    - Computer access
    - Text and/or visual editing programs
    - Video camera
    - Printer

Image Credit: Jens Johnsson / Unsplash

Lesson 3: Final Project

OPENING

Review the Hazards from Kīlauea's Eruption

1. Briefly review with the class the volcanic events they have analyzed in past lessons. Write a list on the board:
    - Earthquakes
    - Deformation
    - Lava flows
    - Sulfur dioxide gas
    - Explosive eruptions and tephra

    Remind students that some of the events occur before an eruption, while others happen during an eruption.

Introduce the Project

1. Tell students that their goal today as volcanologists is to create a Hazard Response Plan for the May 2018 eruption of the Kīlauea Volcano.
2. Explain that they will work in pairs (or in their teams from the previous lessons) to design and produce a response plan to inform the public living on the Island of Hawaiʻi about what they should do to stay safe during the Kīlauea Volcano eruption.
3. Describe the option(s) for the format of students' Hazard Response Plan and the ways that the materials could be made available to the public; examples include:
    - A brochure (to be distributed in communities at risk or available online)
    - A poster (to be posted at public locations on the island)
    - A video (to be broadcast on TV or posted on an Internet news site)

    Tell students that they will base their Hazard Response Plan on the data they explored and recorded in their **Observation Journal**.

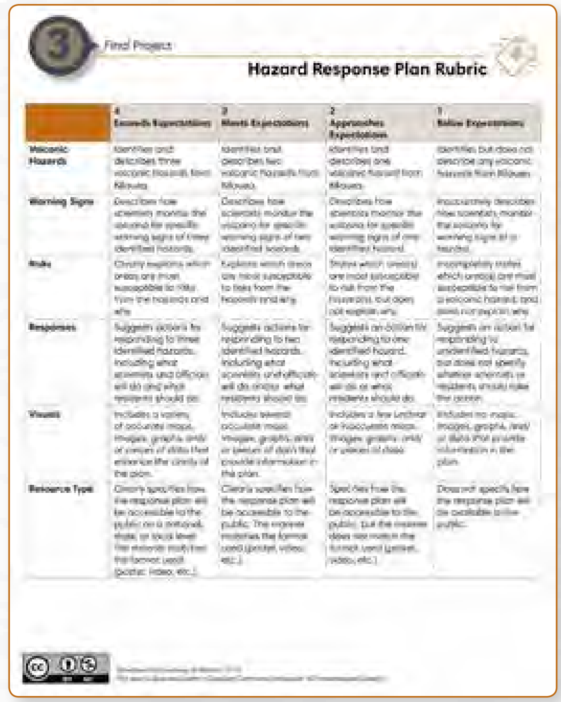
Image Credit: U.S. Geological Survey

Lesson 3: Final Project

Review the Project Rubric

1. Provide students with a copy of the **Hazard Response Plan Rubric** handout. Briefly review the requirements of the project. To meet expectations, students should:

- Identify and describe two volcanic hazards from Kīlauea.
- Describe how scientists monitor the volcano for specific warning signs of the two identified hazards.
- Explain which areas are most susceptible to risks from the hazards, and why.
- Suggest actions for responding to each identified hazard, including what scientists and officials will do and/or what residents should do.
- Include accurate images, maps, graphs, and/or data as appropriate to provide information in the plan. (Students can use images etc. from the **Volcanology**, **Hawai'i Volcanoes Data**, and **Monitoring Kīlauea Data** handouts, or the **Kīlauea Eruption Images** handout).
- Specify where/how their response plan should be accessible to the public (on a government website, TV broadcast, etc.).


Final Project

Hazard Response Plan Rubric

Hazard Response Plan Rubric handout

ACTIVITY

Create Response Plans

1. Show the class the supplies and equipment available to them. If students will be making brochures or posters, suggest that they design a layout before attaching text or visuals to the background paper or board. If students will be making digital recordings, introduce the functionality of the devices they will be using. Discuss norms for using video cameras, and set parameters around the video content and length.
2. Tell students to bring their completed **Observation Journal** handout with them as they gather in their pairs or teams. Remind them to work together in planning and developing their Hazard Response Plan. Suggest that they use the rubric as a means of defining what needs to be done and who might do which parts.
3. Allow students to work on their project for the remainder of the class period and the following class period, allowing some time at the end for final discussion and reflection. Depending on your class and the time available, you may opt to allow students additional days to work on their project.

Lesson 3: Final Project

Discuss

1. Call on multiple students and have each share one of the volcanic hazards they identified and their plan for scientific monitoring and public response. For example, students might say:
    - ***Lava flows*** are hazards for anyone or anything in their path. To figure out where magma is, scientists use thermal imaging. Where the ground is hottest, there's more magma. We told people to evacuate the areas near fissures because the magma comes out there. Lava flows travel downhill, so people in those areas should also evacuate. We are going to keep monitoring the area and other areas in the rift zones because eruptions are more likely there. We showed the areas on a map.
    - ***Sulfur dioxide*** gas is a hazard because it can be toxic if inhaled. Scientists measure how much gas is around the volcano and its vents, and they also monitor air quality around the island. People with trouble breathing should leave areas in which sulfur dioxide levels are high. Everyone else should stay inside.
    - ***Explosive eruptions*** are hazards because they can throw large rock and lava fragments into the air. When these projectiles fall, it's a hazard to people and equipment on the ground. Scientists can predict if there will be an explosive eruption at a crater by watching the level of the lava lake and whether it's going to **go below the water underground.** The areas nearby should be closed and people should stay away.

Image Credit: U.S. Geological Survey

Lesson 3: Final Project

REFLECTION

Summarize

1. Let the class know that the volcano continued erupting for months after the last data set they looked at. By May 31, flowing lava had destroyed 82 structures, and half of those were homes. By mid June, over 600 homes had been lost to lava in the East Rift Zone. However, scientists and public officials were able to work together to keep people safe by issuing messages online and on the radio, mandating evacuations, and continuing to monitor the volcano closely for changes.

Self-Assess

1. Have the pairs or teams use the **Hazard Response Plan Rubric** and self-evaluate their completed project.
2. Congratulate students on their work in predicting volcanic hazards and devising a response plan to keep the public safe.

EXTENSION

Gallery Walk

1. Display students' completed Hazard Response Plans. Have the rest of the class circulate and view each other's work. Consider having students use the rubric to evaluate each other's projects.

Follow the Eruption

1. Show the **Kīlauea Eruption Continues** slideshow, and ask students to share observations with a partner as they watch. The slideshow shows the progression of lava flows, including ocean entry, the building of a new cinder cone at Fissure 8, and explosions and collapse at the summit caldera and Halemaʻumaʻu crater. Students should look for the following as they watch:
   - Ways that the volcano interacts with Earth's air or water and/or changes the landscape
   - Hazards that scientists might predict or monitor

Image Credit: U.S. Geological Survey

Kīlauea Eruption Continues slideshow

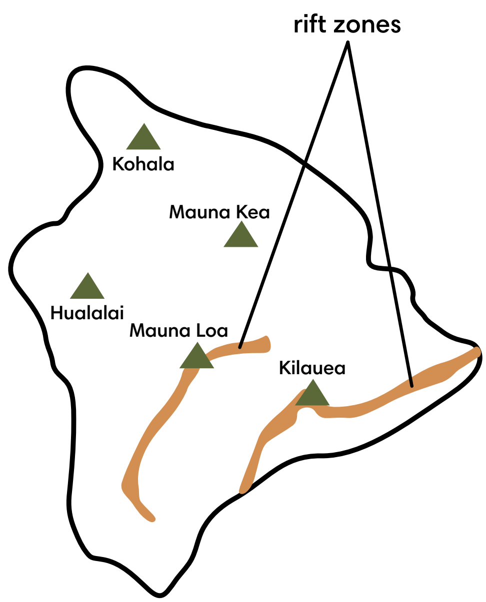
Continue Monitoring

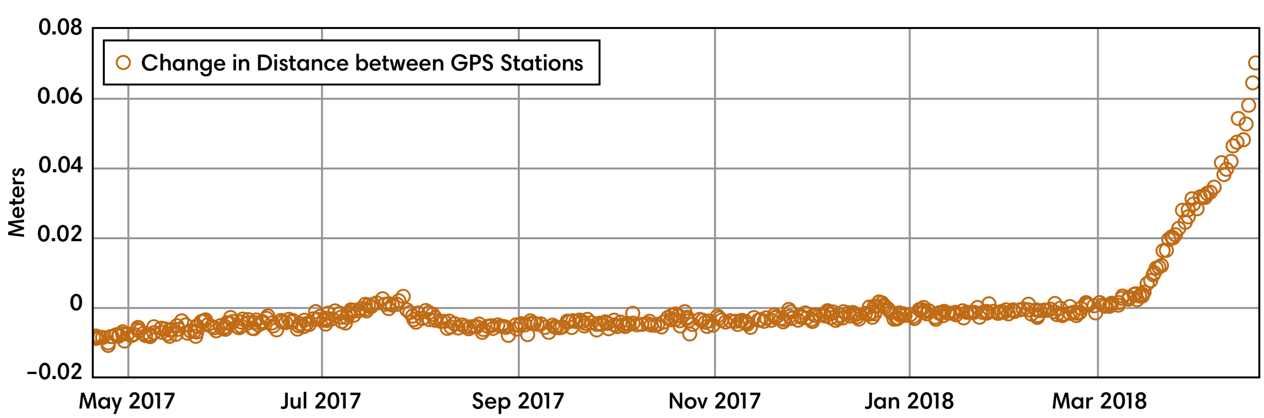
1. Have students continue to explore the updates and monitor information about the Kīlauea Volcano using the **USGS website**.

Hazard Response Plan Rubric

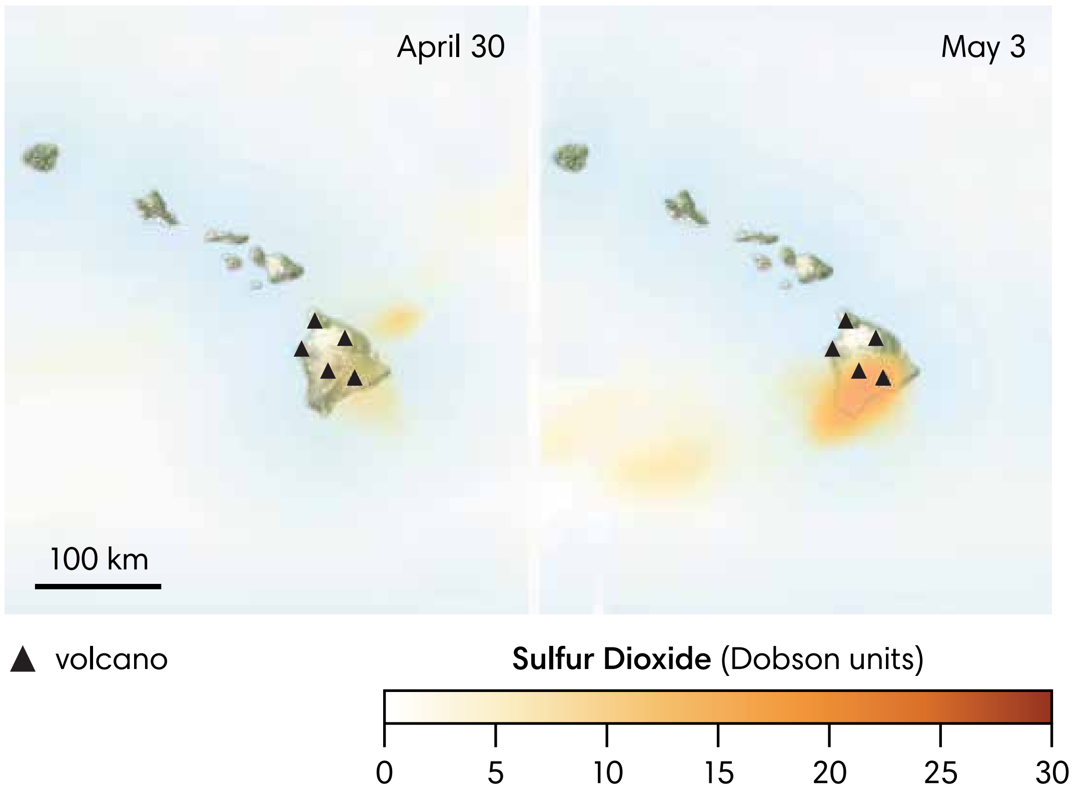
	4 Exceeds Expectations	3 Meets Expectations	2 Approaches Expectations	1 Below Expectations
Volcanic Hazards	Identifies and describes three volcanic hazards from Kīlauea.	Identifies and describes two volcanic hazards from Kīlauea.	Identifies and describes one volcanic hazard from Kīlauea.	Identifies but does not describe any volcanic hazards from Kīlauea.
Warning Signs	Describes how scientists monitor the volcano for specific warning signs of three identified hazards.	Describes how scientists monitor the volcano for specific warning signs of two identified hazards.	Describes how scientists monitor the volcano for specific warning signs of one identified hazard.	Inaccurately describes how scientists monitor the volcano for warning signs of a hazard.
Risks	Clearly explains which areas are most susceptible to risks from the hazards and why.	Explains which areas are most susceptible to risks from the hazards and why.	States which area(s) are most susceptible to risk from the hazard(s), but does not explain why.	Incompletely states which area(s) are most susceptible to risk from a volcanic hazard, and does not explain why.
Responses	Suggests actions for responding to three identified hazards, including what scientists and officials will do and what residents should do.	Suggests actions for responding to two identified hazards, including what scientists and officials will do and/or what residents should do.	Suggests an action for responding to one identified hazard, including what scientists and officials will do or what residents should do.	Suggests an action for responding to unidentified hazards, but does not specify whether scientists or residents should take the action.
Visuals	Includes a variety of accurate maps, images, graphs, and/or pieces of data that enhance the clarity of the plan.	Includes several accurate maps, images, graphs, and/or pieces of data that provide information in the plan.	Includes a few unclear or inaccurate maps, images, graphs, and/or pieces of data.	Includes no maps, images, graphs, and/or data that provide information in the plan.
Resource Type	Clearly specifies how the response plan will be accessible to the public on a national, state, or local level. The manner matches the format used (poster, video, etc.).	Clearly specifies how the response plan will be accessible to the public. The manner matches the format used (poster, video, etc.).	Specifies how the response plan will be accessible to the public, but the manner does not match the format used (poster, video, etc.).	Does not specify how the response plan will be available to the public.

Kīlauea Eruption Images



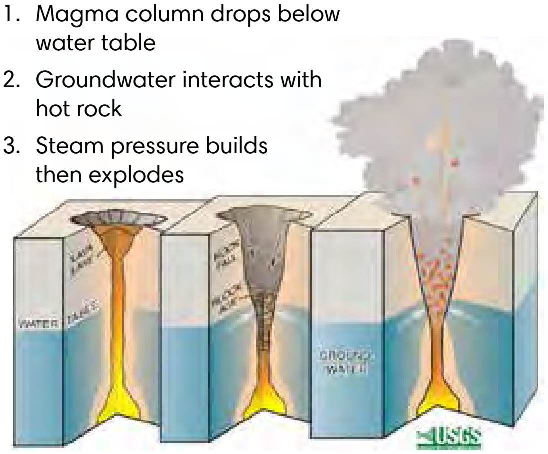


Kīlauea Eruption Images

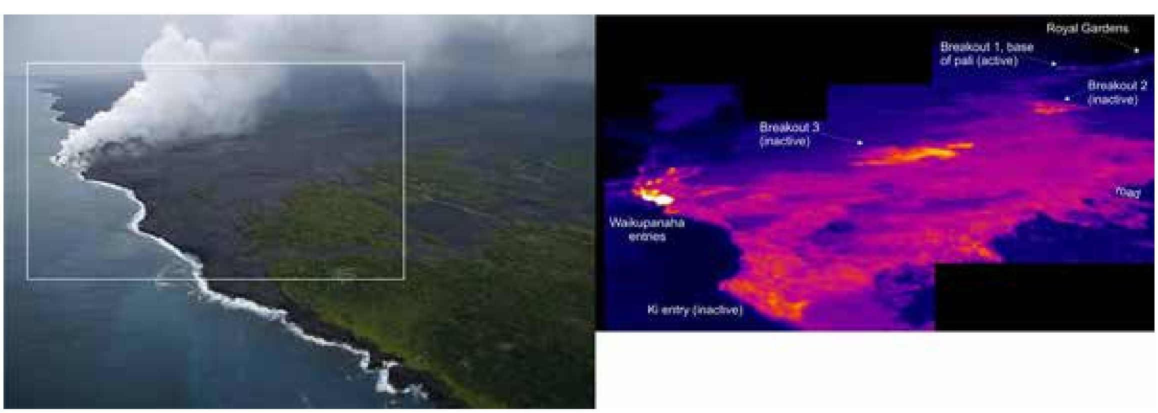


Explosive eruptions can occur when

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



Kīlauea Eruption Images



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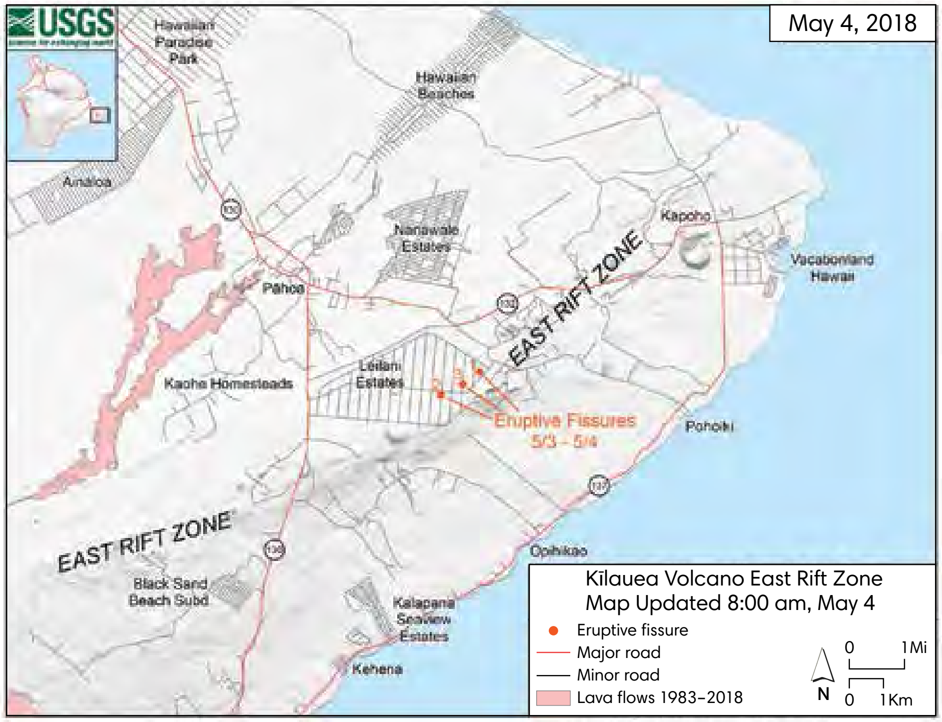

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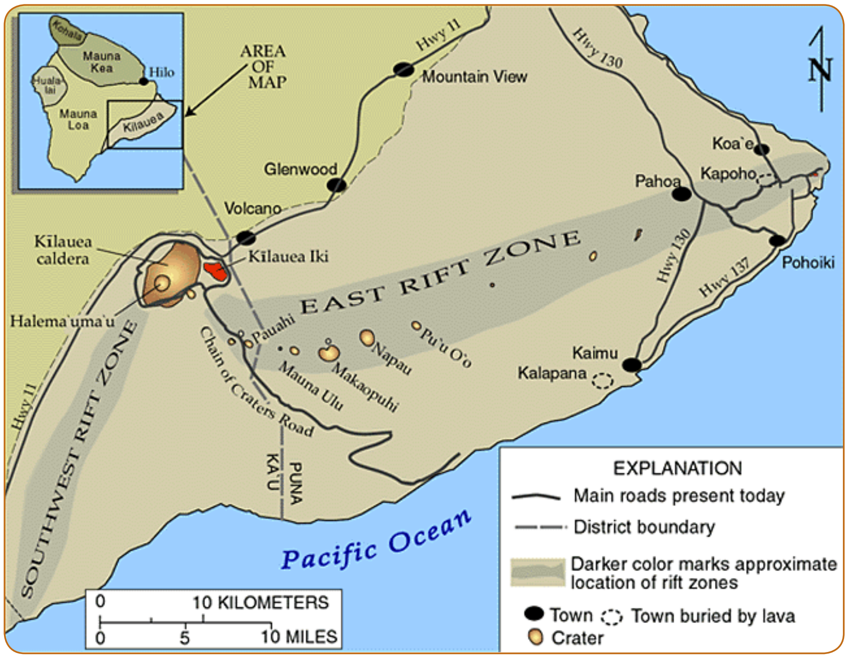

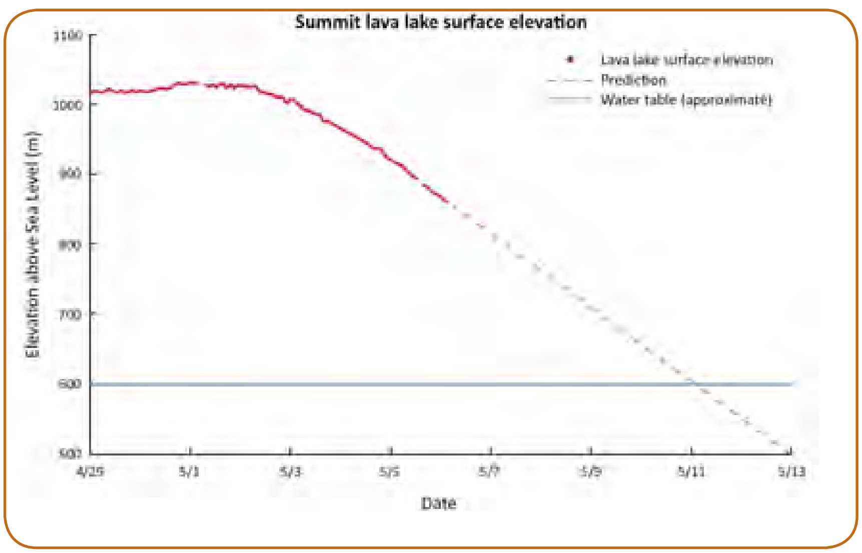

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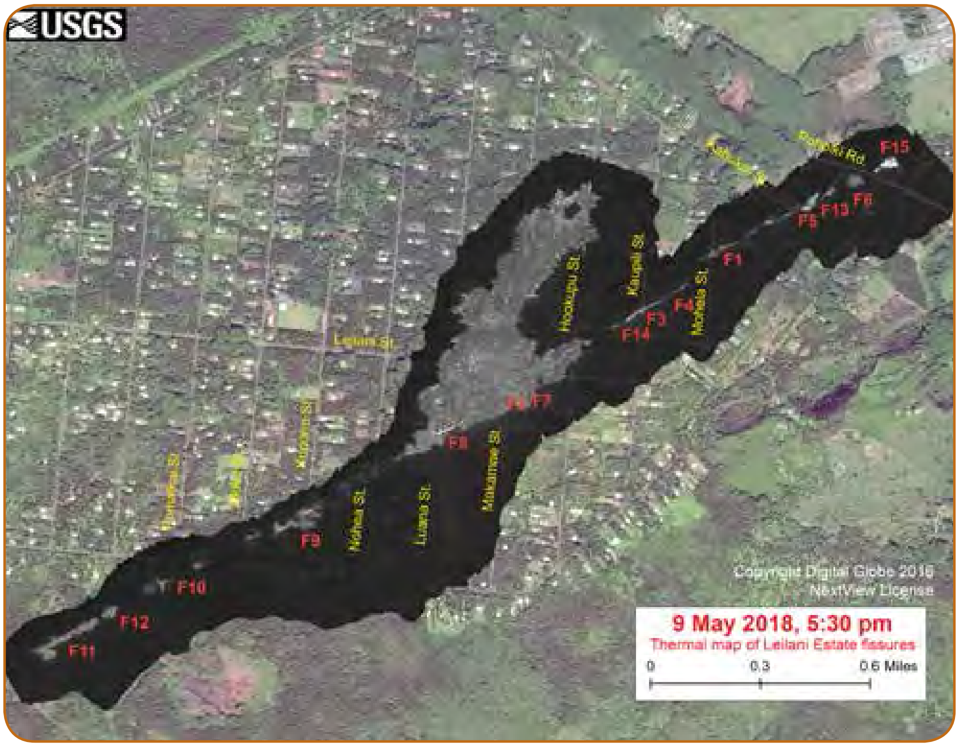

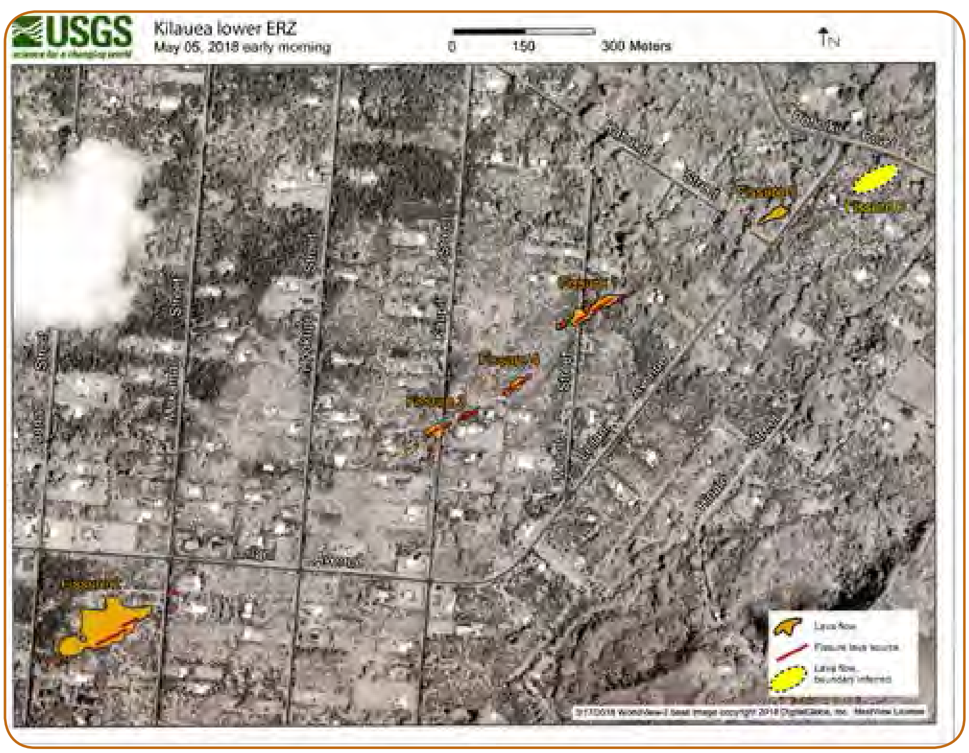

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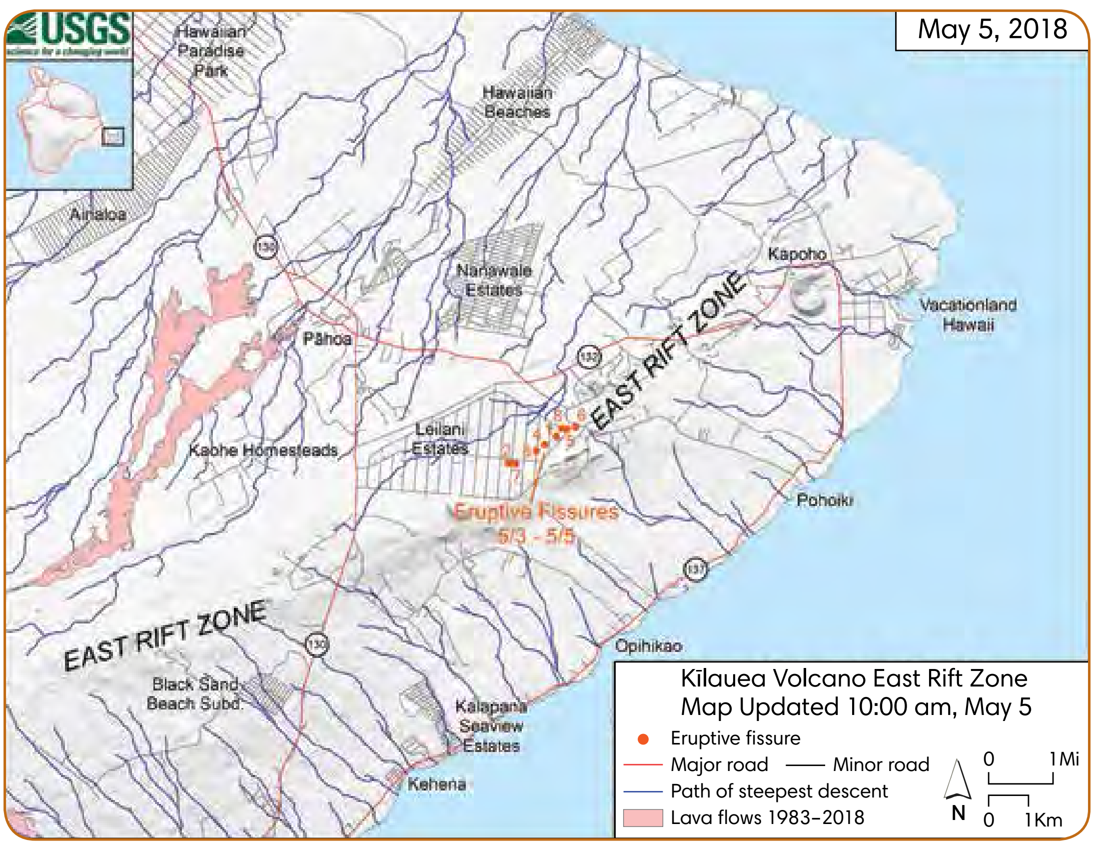

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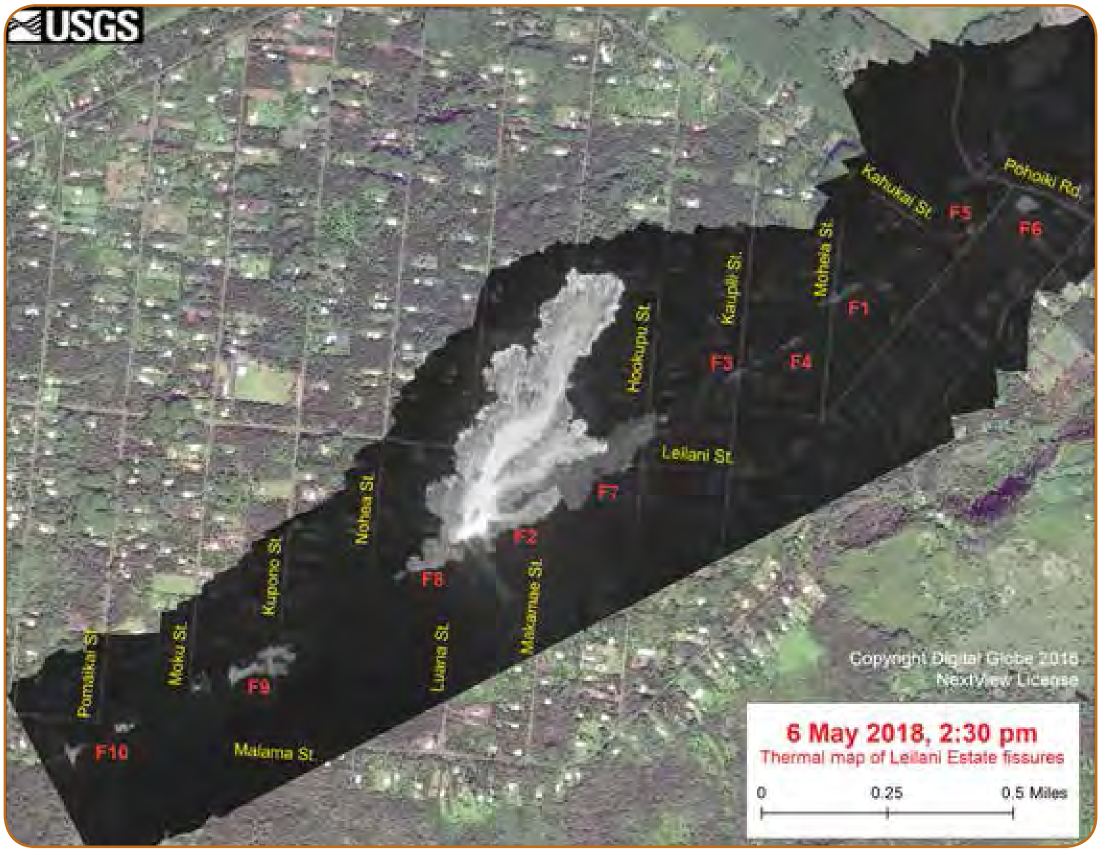

Kīlauea Eruption Images