NPS Photo/J.Wei

Volcano Guide

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National Park Service, Geologic Resources Division
American Geosciences Institute

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Introduction to National Park System

The National Park System consists of 429 recognized locations that tell the story of America. These national parks, historical parks, historic sites, monuments, recreation areas, and sites with other designations (all informally called 'national parks') contain natural, cultural, and recreational resources that have national significance. The National Park Service (NPS), the agency in the Department of Interior that manages all national parks, "was established in 1916 to preserve the natural and cultural resources and values of the national parks for the enjoyment, education, and inspiration of present and future generations" (NPS Mission). The National Park Service reported 325.5 million recreation visits to national parks in 2023 (NPS Visitor Use Data).

National parks are in all 50 states, as well as in U.S. territories and commonwealths. National parks range from Yellowstone National Park, established in 1872 as the world's first national park, to Amache National Historic Site, a site that preserves the memory of incarceration of Japanese people during World War II, that was established in 2014.

National parks contain many kinds of natural and cultural resources, such as the tallest mountain in North America (Denali National Park), the lowest elevation on the continent (Death Valley National Park), the longest known cave system in the world (Mammoth Cave National Park), the site of the battle considered the turning point of the Civil War (Gettysburg National Military Park), the monuments of our nation's capital (e.g., the Lincoln Memorial, Martin Luther King, Jr. Memorial, Vietnam Veterans Memorial), and more. Most national parks also contain natural resources including trees, flowers, and other plants, wildlife including birds, fish, reptiles, and mammals, as well as geologic features like rocks, caves, mountains, plateaus, coasts, and volcanoes.

National parks can be thought of as America's largest classroom. Whether through formal education in a visitor center classroom, field trips and virtual visits, or during family vacations, people of all ages continue to learn about the ecological, geologic, cultural, and historic elements that are highlighted within the parks. Most of all, they are places of wonder and discovery for adults and children alike.

Volcanic resources within the parks include volcanoes and volcanic features, volcanic landforms, and volcanic deposits such as lava flows, are found in 94 national parks. The ages of volcanic resources in parks range from billion-year-old lava flows in Isle Royale National Park to the still-active volcanoes in Hawaiʻi Volcanoes National Park. Volcanic landscapes have been included in the National Park Service for their inspirational beauty, their stark and sometimes otherworldly appearances, and for the active processes that are ongoing in several parks where volcanism is still forming and reshaping the land. Volcanic landscapes also have significant geoheritage values, including those in the artistic, cultural, economic, educational, and recreational realms.

Most of the significant volcanoes in the United States are in national parks, including:

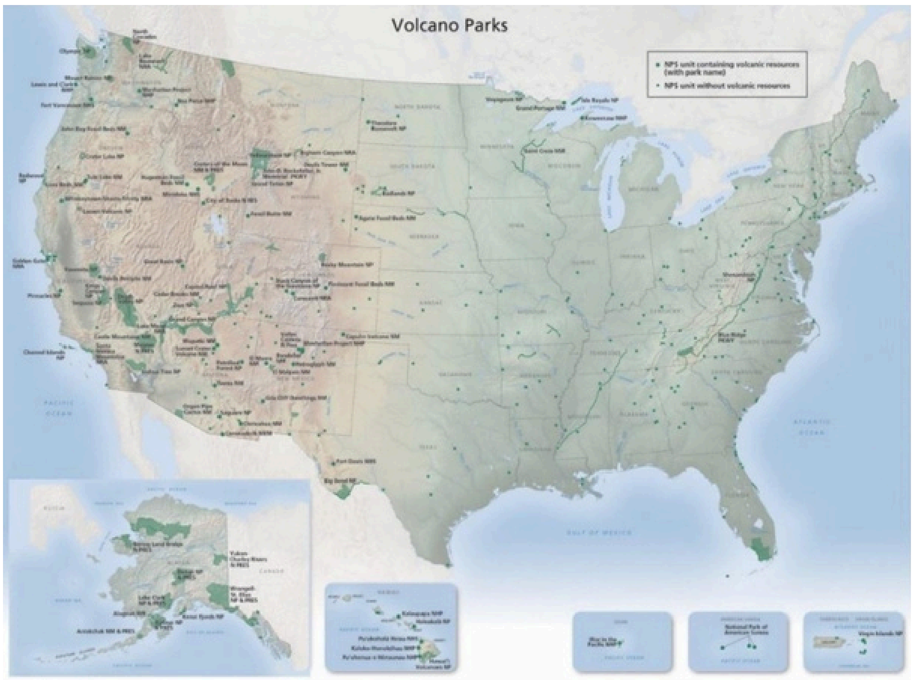
- Kīlauea, Mauna Loa, and Haleakalā in Hawai‘i;
- Katmai, Novarupta, Redoubt, Iliamna, and Aniakchak in Alaska;
- and in the lower 48 states, Lassen Peak (California), Crater Lake (Oregon), Mount Rainier (Washington), and Yellowstone (Wyoming, Montana, and Idaho).

Other national parks established for their volcanic resources include:

- Lava Beds National Monument (California),
- Devils Postpile National Monument (California),
- Craters of the Moon National Monument (Idaho),
- Sunset Crater Volcano National Monument (Arizona),
- Chiricahua National Monument (Arizona),
- Valles Caldera National Preserve (New Mexico),
- El Malpais National Monument (New Mexico), and
- Capulin Volcano National Monument (New Mexico).

Two national volcanic monuments, Mount St. Helens (Washington) and Newberry (Oregon), are managed by the US Forest Service.

The 94 parks with volcanic resources include those that contain a single volcano, larger volcanic fields (clusters of volcanoes), and/or outcroppings of volcanic rocks and deposits. This guide makes use of the many online resources developed by NPS related to the locations described above, and more. Many activities also use information and resources from the United States Geological Survey (USGS). The USGS monitors active volcanoes across the country and provides real-time information about volcanic activity. The guide is intended to introduce students to how volcanoes are formed, studied, named, and monitored.



Source: **NPS** graphic prepared by Allyson Mathis

Educational Context for Volcanoes

Volcanoes have played a crucial role in shaping the Earth's surface and influencing its ecosystems over Earth's history through processes that are still active today. The activities in this guide each contain a background section and educator instructions with corresponding handouts for learners. The educator instructions provide guidance about the activities and contain additional resources, discussion questions, and hands-on activities to aid learners' understanding. This understanding is further supported by the diagrams and images on the handouts that show the various aspects of volcanic activity. Beyond scientific significance, learning about volcanoes can instill a sense of wonder and appreciation for the natural world as a fundamental aspect of environmental education and stewardship. For these reasons, each activity in this guide has been connected with educational standards (based on the K-12 Framework and the Next Generation Science Standards--NGSS) and the United Nations Sustainable Development Goals (SDGs)

Science Education Connections:

Studying volcanoes gives learners a chance to explore science concepts, such as the creation of igneous, the movement of plate tectonics, and the environmental effects of volcanic eruptions. These processes can also be studied through the lens of how geoscientists think about the natural world: temporal and spatial thinking, Earth's features and resources, and the monitoring of natural hazards.

Temporal and Spatial Thinking: Temporal thinking allows learners to explore the wide range of timescales of volcanic events, from sudden eruptions to gradual geologic processes, like erosion, that change landscapes following volcanic activity. Temporal and spatial thinking can build across grades, first considering the impact of geologic events at varying time scales, then adding in spatial thinking by asking middle and high school learners to visualize the global effects of volcanic activity. Learners can further gain insight into how volcanoes and other geoscience processes interact at varying scales by developing and using models, facilitating a complete understanding of the role of volcanic activity in Earth's systems.

NGSS Performance Expectations: 2-ESS1-1, MS-ESS2-2, HS-ESS2-1.

Science and Engineering Practices:
- Analyzing and Interpreting Data
- Constructing Explanations
- Designing Solutions
- Developing and Using Models

Disciplinary Core Ideas:
- ESS2.A: Earth's Materials and Systems
- ESS2.B: Plate Tectonics and Large-Scale System Interactions
- ESS3.B: Natural Hazards

Cross-Cutting Concepts:
- Patterns
- Cause and Effect
- Scale Proportion and Quantity
- Stability and Change
- Influence of Engineering, Technology, and Science on Society and the Natural World

Earth's Features and Resources: Exploring the relationship between volcanic activity and the distribution of natural resources helps scientists and communities make informed decisions about resource utilization and disaster preparedness, while also contributing to our understanding of Earth's processes. Learners can explore these relationships by examining maps to study the spatial distribution of volcanic features, which allows for the identification of patterns and understanding that geologic processes create natural resources (e.g., rocks and minerals, fertile soils, and geothermal energy sources). Middle and high school learners can build upon these patterns by constructing scientific explanations for the uneven distributions of mineral, soil, and energy resources due to past and current volcanic activity.

NGSS Performance Expectations: 4-ESS2-2, MS-ESS3-1, HS-ESS3-1.

Monitoring Natural Hazards: While volcanic activity can be introduced as a natural hazard, looking at how volcanoes are monitored can allow learners to explore how the geosciences and engineering can work together to reduce the impact of volcanic hazards. Learners can consider and compare solutions to reduce the impacts of natural Earth processes on humans, including designing structures to withstand volcanic eruptions and improving monitoring systems to enhance early warning capabilities. Middle and high school learners can also analyze and interpret data on volcanic eruptions and on the patterns and precursors associated with volcanic activity to gain insights into the development of predictive models and early warning systems. Volcano monitoring contributes to more effective disaster preparedness and resilience.

NGSS Performance Expectations: 4-ESS3-2, MS-ESS3-2, HS_ESS3-1.

SDG CONNECTIONS

The following SDGs are related to volcanic activity and its impacts on both the environment and human populations. These goals can provide real-world contexts in which learners can apply their understanding of volcanic processes to global issues that affect people all around the world.

SDG 2: Zero Hunger: Volcanic eruptions can disrupt agricultural activities, leading to food shortages and hunger in affected regions. However, volcanic soils can be fertile due to their minerals. Understanding volcanic activity helps in predicting and monitoring its impact on agricultural lands, contributing to food security efforts.

SDG 3: Good Health and Well-Being: Volcanic eruptions release harmful gases and particulate matter into the atmosphere, which can adversely affect respiratory health and overall well-being of nearby populations. Studying volcanoes aids in early warning systems and preparedness measures, safeguarding public health during volcanic events.

SDG 7: Affordable and Clean Energy: Geothermal energy can be sourced from active volcanic sites and provides a largely renewable and clean energy option for power generation. Research on volcanic processes and geothermal reservoirs supports the development of efficient and affordable geothermal energy projects, contributing to the goals of sustainable energy access.

SDG 8: Decent Work and Economic Growth: Volcanic regions require monitoring and ongoing study, in addition to attracting tourists due to their unique landscapes and geological features. Sustainable tourism initiatives around volcanoes create job opportunities and foster economic growth in local communities.

SDG 9: Industry, Innovation, and Infrastructure: Understanding volcanic hazards is crucial for designing resilient infrastructure in volcanic regions. Innovations in monitoring technologies and infrastructure design enhance resilience against volcanic threats, supporting sustainable development in these areas.

SDG 11: Sustainable Cities and Communities: Volcanic risk assessment and land-use planning are essential for building resilient cities and communities in volcanic regions. Integrating scientific knowledge about volcanic activity into urban planning processes ensures safer and more sustainable development practices.

SDG 12: Responsible Consumption and Production: Sustainable management of volcanic resources, such as minerals and geothermal energy, is vital for responsible consumption and production practices. Balancing resource extraction with environmental conservation preserves the integrity of volcanic ecosystems and supports sustainable development goals.

SDG 13: Climate Action: Volcanic eruptions can release significant amounts of greenhouse gases and aerosols into the atmosphere, affecting weather and global climate patterns. Research on volcanic contributions to climate change can help us understand natural climate variability over Earth’s history, which can then inform climate mitigation efforts.

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Introductory Activity: Where are Volcanoes Located?

Objective: Learners will analyze maps to identify the distribution of volcanoes and volcanic rocks across the country.

Introduction: The United States is home to several types of volcanoes and volcanic landscapes, which are appreciated as natural wonders, and also hold significant scientific importance. Studying them helps us understand fundamental geological processes and their potential effects. The National Park Service (NPS) has 94 parks that contain volcanoes, evidence of volcanic activity, or volcanic deposits, which allows for preservation of these areas so they can be studied and monitored, while still being accessible to the public.

Have learners:

1. Study the map of volcanoes around the world, then discuss the following questions:

- *Describe any patterns or trends that you see.*
- *Does it seem like there are more areas where volcanoes are found together, or by themselves?*
- *How are there areas of volcanic rock in places where there are not currently active volcanoes?*

2. Study a map of volcanic rocks found in the United States.

- *Identify areas that have volcanic rock but not active volcanoes.*
- *What might this tell you about past volcanic activity in these areas?*

3. Examine NPS units with volcanoes or evidence of volcanic activity.

Explore the NPS Master List of parks with volcanic features:

- Read the “Introduction,” paying special attention to the breakdown of the parks with volcanic resources into groups with three levels of significance: Primary Resources, High Significance, and Moderate Significance.
- Look through the table “Master List of Parks with Volcanic Resources” to locate a park from each category.
- Explore the list of links below the table for each of the parks you chose.
- Use images and text from the websites to describe why each park was put into a specific category.
- Discuss each of the explanations that have been created and how similar and/or different the parks are in each category of significance.

Look back at the park websites you researched. Look for statements that tell why the park was established. Also, look for statements that tell about features that are special examples of a type of geology, or are unique in some way. These statements can give an idea of the reasons the location was made into a park.

- *What are some of those statements for the parks you looked at?*
- *What kinds of reasons do they give for making it a park?*
- *Why do you think so many volcanoes and volcanic features are within NPS Units?*

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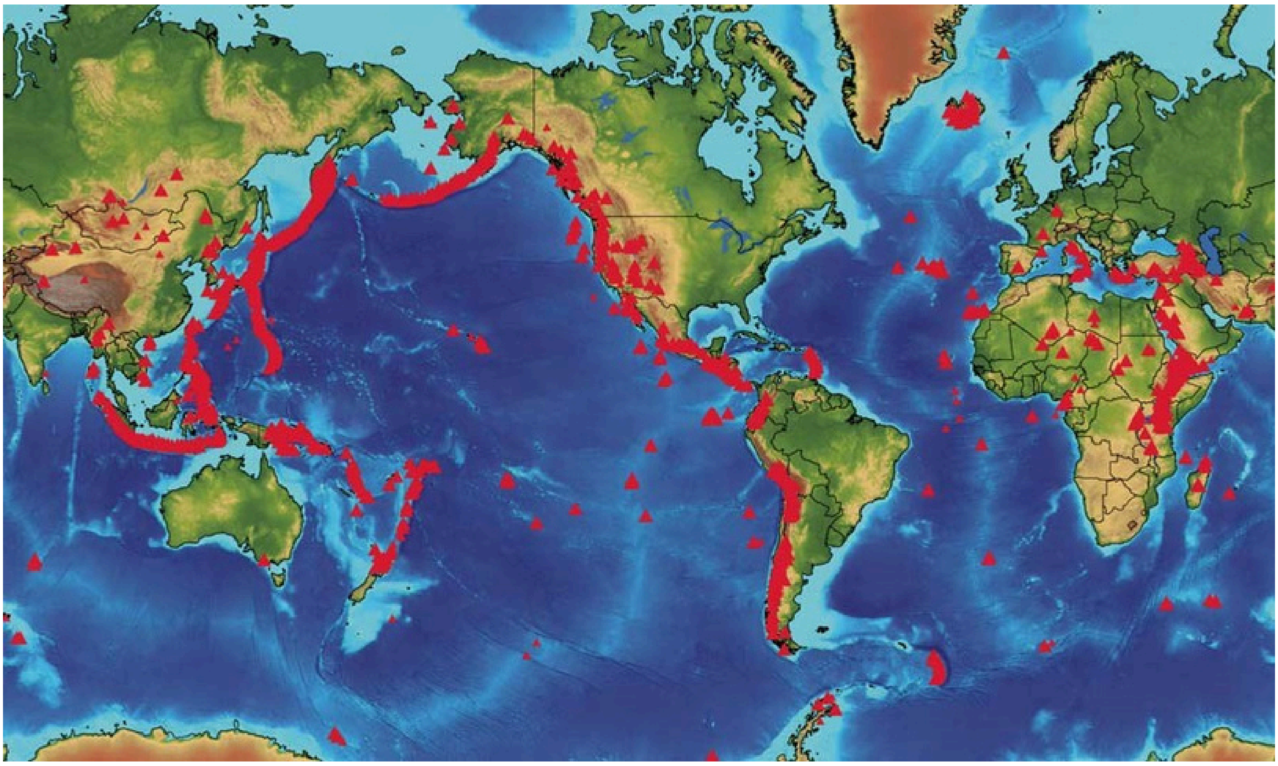
Handout: Where are Volcanoes Located?

The map below shows the location of volcanoes on Earth that have been active in the last 10,000 years.



Source: **NPS**

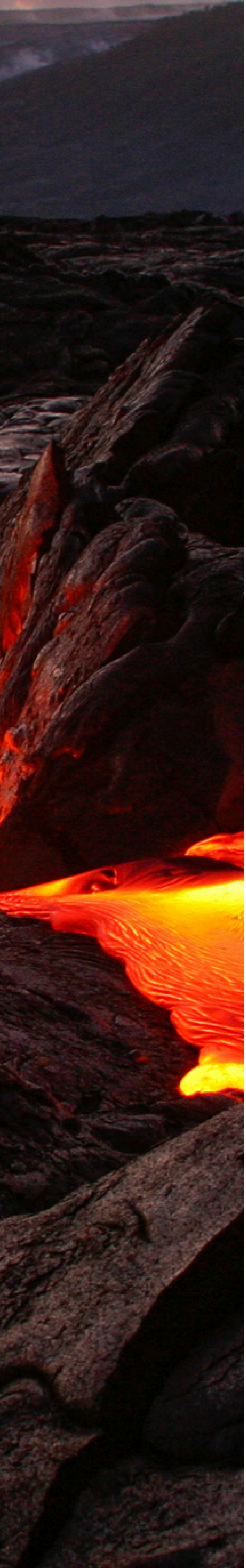
- Describe any patterns you see.

- Why do you think volcanoes are found in these locations?

The map below shows the locations of volcanic rocks in the United States

Source: **USGS**

- Look back at the map showing the locations of volcanoes. Identify any volcanic rocks that are not near volcanoes. How do you think these rocks got in these locations?



Volcanic Processes

Studying volcanic eruptions and the formation of volcanic landforms allows scientists and others to comprehend the Earth's inner workings. Such knowledge aids in predicting volcanic behavior, mitigating risks associated with eruptions, and safeguarding human lives and infrastructure in volcanic regions. It also provides insights into the dynamic processes that drive the movement of tectonic plates and changes in the Earth’s crust. Learning about volcanoes also helps people understand Earth's history. Volcanic rocks, tephra, tuff, and other deposits serve as archives of past eruptions, providing invaluable information about past environmental conditions. Scientific study of these geological records contributes to determinations of past climate conditions, tracking of how tectonic plates have moved, and explanations for changes in the biodiversity seen in the fossil record. Furthermore, the study of volcanoes fosters interdisciplinary learning, integrating concepts from geology, chemistry, physics, biology, and environmental science. This multidisciplinary approach cultivates critical thinking skills and problem-solving abilities essential for addressing complex environmental challenges.

Activity: Why Volcanoes Form

Objective: Learners will understand the relationship between the mantle, movement of tectonic plates, the location of hotspots, and the formation of volcanoes.

Introduction: Volcanoes form at two primary locations: plate boundaries and hotspots. Understanding the motion of Earth's tectonic plates can help explain where active volcanoes are located.

Have learners:

1. Read about the layers of the Earth and label the diagram.
2. Complete an activity using a lava lamp to model how magma can rise to form a volcano.
3. Add to the diagram to show how magma reaches the Earth's surface.
4. Learn about Plate Boundaries:
   - Read about Earth's tectonic plates to see that the outermost crust is broken into plates that move over the aesthenosphere.
   - Highlight the plate boundaries where most volcanoes are located, then discuss:
   - **Discuss:** *At which type(s) of boundary do volcanoes form? What is it about these boundaries that allows volcanoes to form?*
   - Explore a park along a plate boundary.
5. Learn about Hotspots:
   - Observe a model of hot spot island formation.
   - Use an animation to study the stages of volcanic islands formed by hotspots.
   - Use the diagram to explain why Hawaii is an island chain, not just one island.
6. Compare the map of the area under the western United States to the map of Hawaii.
   - **Discuss:** *How are they similar? How are they different? How can their similarities help determine the direction the plate is moving?*
   - Draw an arrow on the map to show the direction of plate movement.
   - **Discuss:** *How does volcanic activity at a hotspot compare to activity at a plate boundary? Is volcano formation at a hotspot more similar to volcano formation at divergent or convergent boundaries? Give evidence for your answer.*
   - Explore a park at a hotspot.

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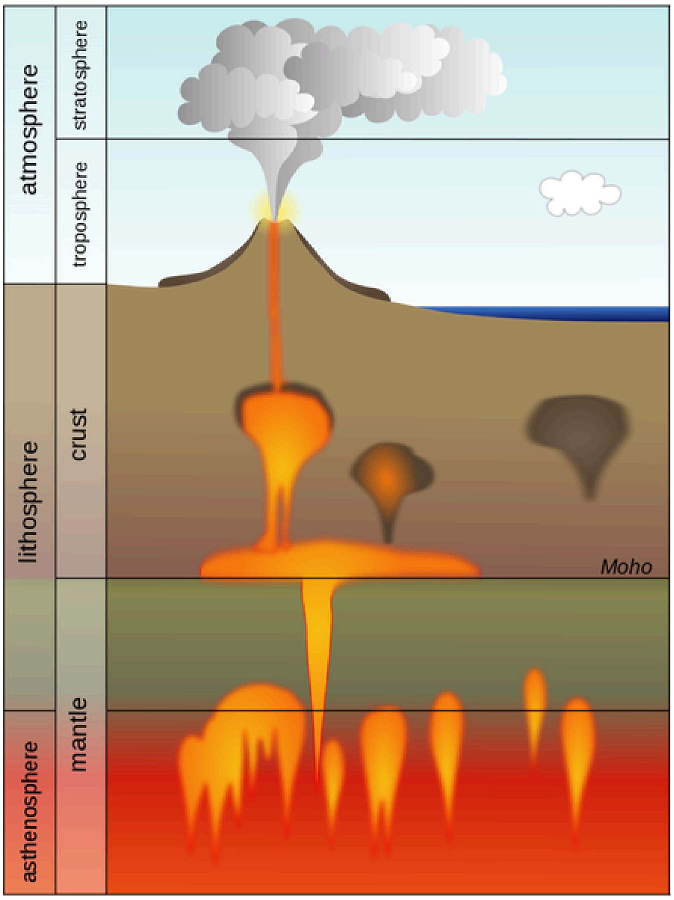
Handout: Why Volcanoes Form

The diagram below shows three of Earth's layers as related to volcanic activity.

Next to each layer, describe how each layer is involved in or affected by a volcanic eruption:

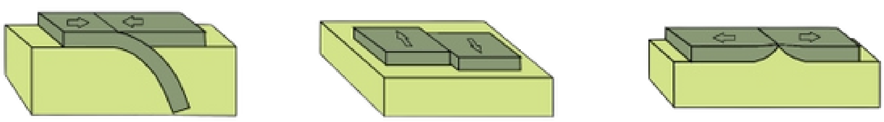


Source: modified from **USGS**

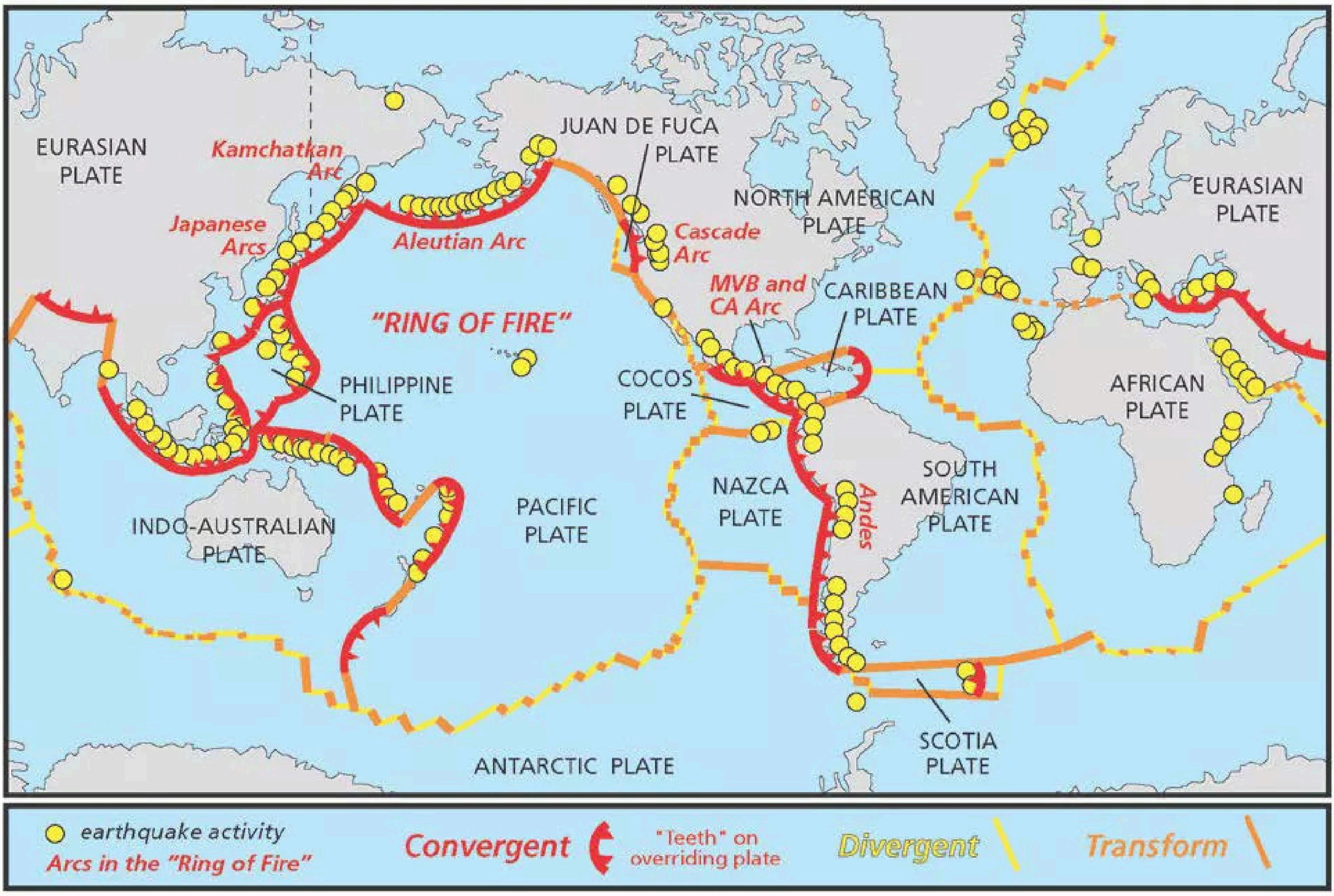
The diagrams below show three types of plate boundaries. The arrows show the direction of plate movement.

Match the descriptions to the diagrams.

- Convergent Boundary: where two tectonic plates collide.
- Divergent Boundary: where two tectonic plates are moving away from each other.
- Transform Boundary: where two tectonic plates move past each other.



Modified from **NPS**



Source: **M.Bitton**, basado en Hasterok, Derrick (8 June 2022). **New maps of global geological provinces and tectonic plates**. *American Institute of Physics - Phys.org*. Retrieved on 27 March 2023.

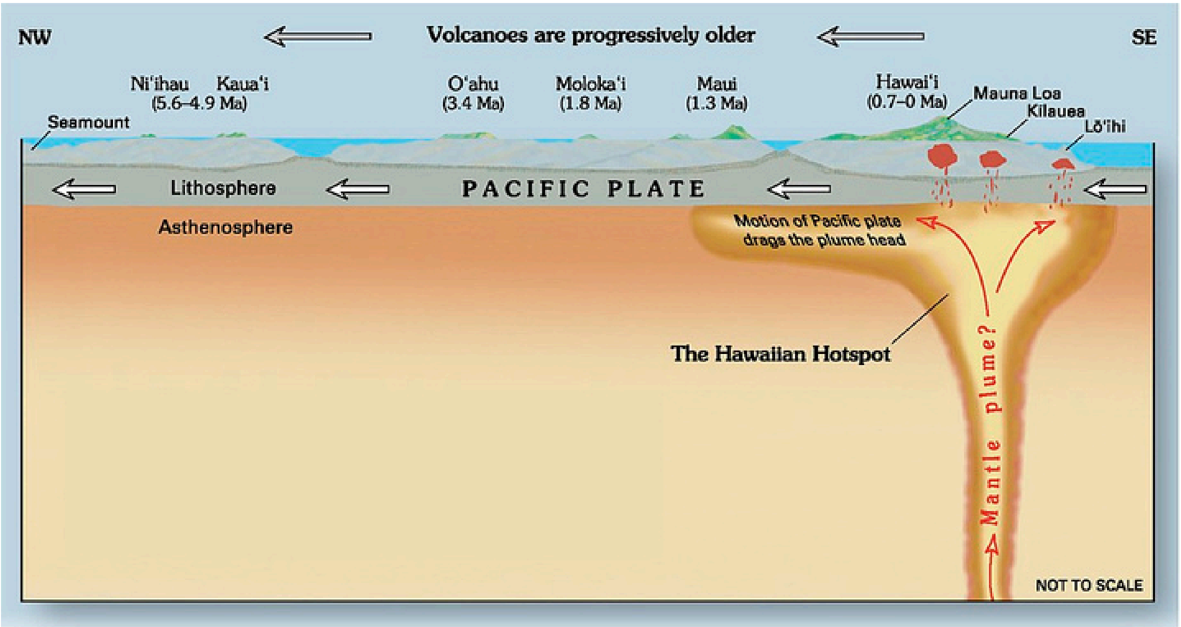
This is a map that shows the tectonic plates that Earth's crust is broken into. These plates are pushed in different directions by the mantle moving underneath them.

- Rank the three types of plate boundaries (convergent, divergent, and transform) by how often volcanoes are found along them: 1-most volcanoes, 2-some volcanoes, 3-little to no volcanoes.

- Are there any volcanoes not on plate boundaries? How do you think they form

The Hawaiian Islands are a chain of volcanoes not associated with a plate boundary. The following diagram shows how a hotspot – a mantle plume in the middle of a tectonic plate – releasing lava and creating volcanoes.

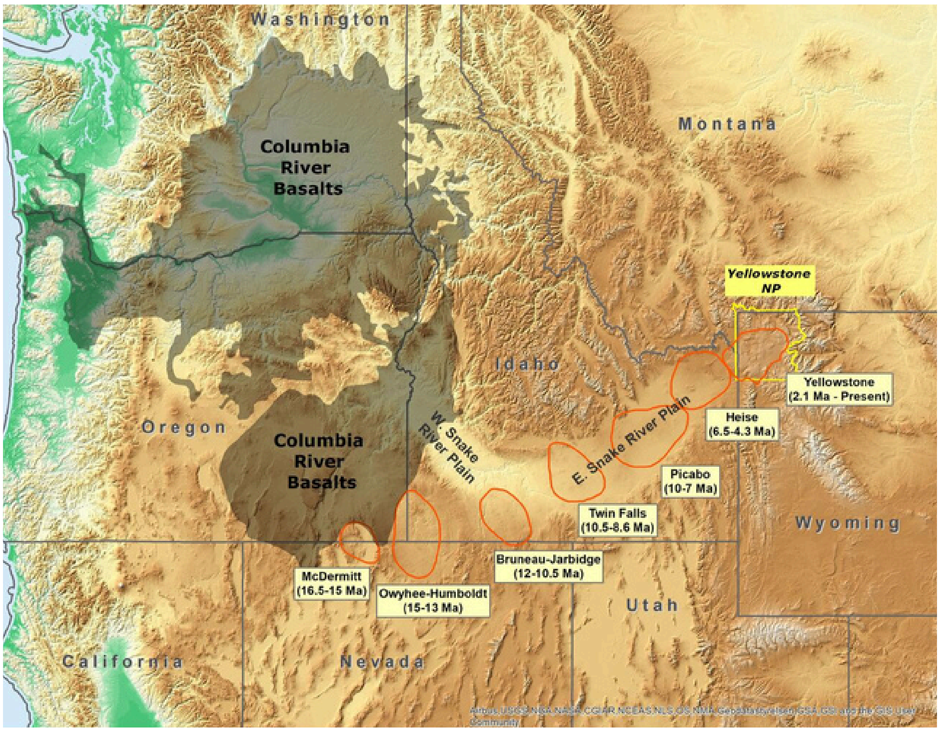
Use the diagram to explain why Hawaii is an island chain, not just one island.



Source: Joel E. Robinson, **USGS**

A similar pattern has been identified in the Western continental United States.

Given the information on the following map, draw an arrow to show the most likely direction of plate movement:



Source: **USGS**

Activity: Types of Volcanoes and Volcanic Features

Objective: Learners will use diagrams to describe differences and similarities between the different types of volcanoes and why each type forms.

Introduction: A Volcano is a vent where molten rock material emerges from the Earth's interior and the mountain or cone that forms around that vent during eruption(s).
Volcanoes exhibit a diverse range of shapes and sizes. The three main types of volcanoes vary widely in size and shape.

The appearance of any given volcano depends on a variety of factors including:

- Composition and viscosity of the magma
- Gas content of the magma
- Types of eruption, styles of eruption, and eruption rates
- Volume of erupted magma
- Age of the volcano

Have learners:

1. Label the three main types of volcanoes, then discuss the following questions:
- *What are the similarities between these three volcano types?* Highlight them on the diagrams.
- *What feature makes each volcano type unique? Make an argument about the defining feature of each volcano type. Why did you choose these features?*
2. Compare the sizes of each volcano type. Consider how this might relate to their features.
3. Identify each NPS volcano picture as a cinder cone, composite volcano, or shield volcano.
4. Explore NPS Units with each volcano type.

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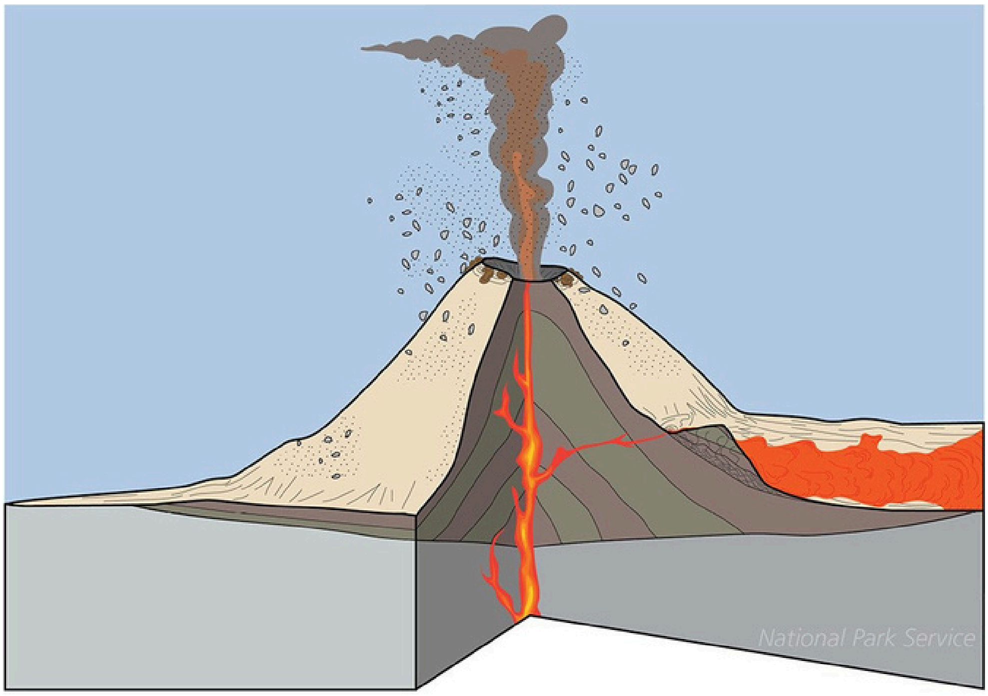
Handout: Types of Volcanoes and Volcanic Features

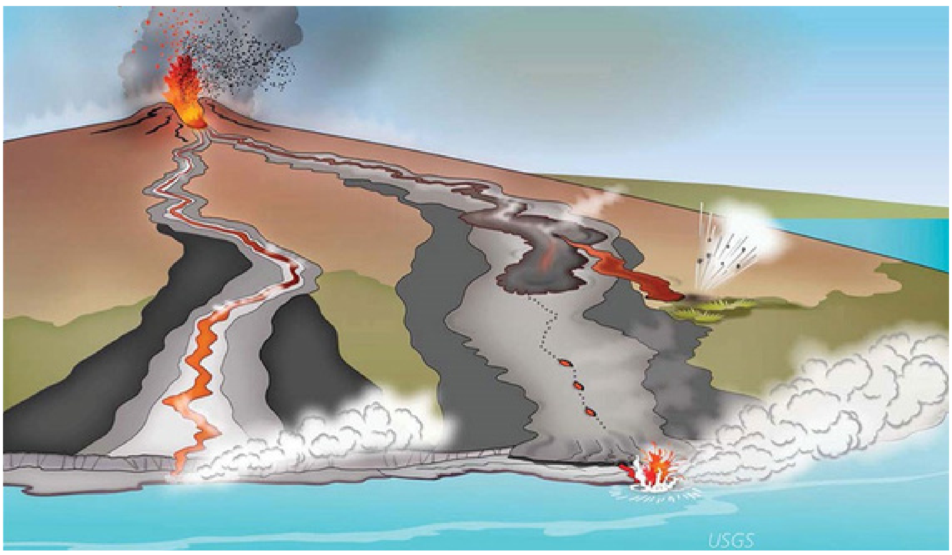
Label the features of each of the three types of volcanoes

Cinder Cone Volcano



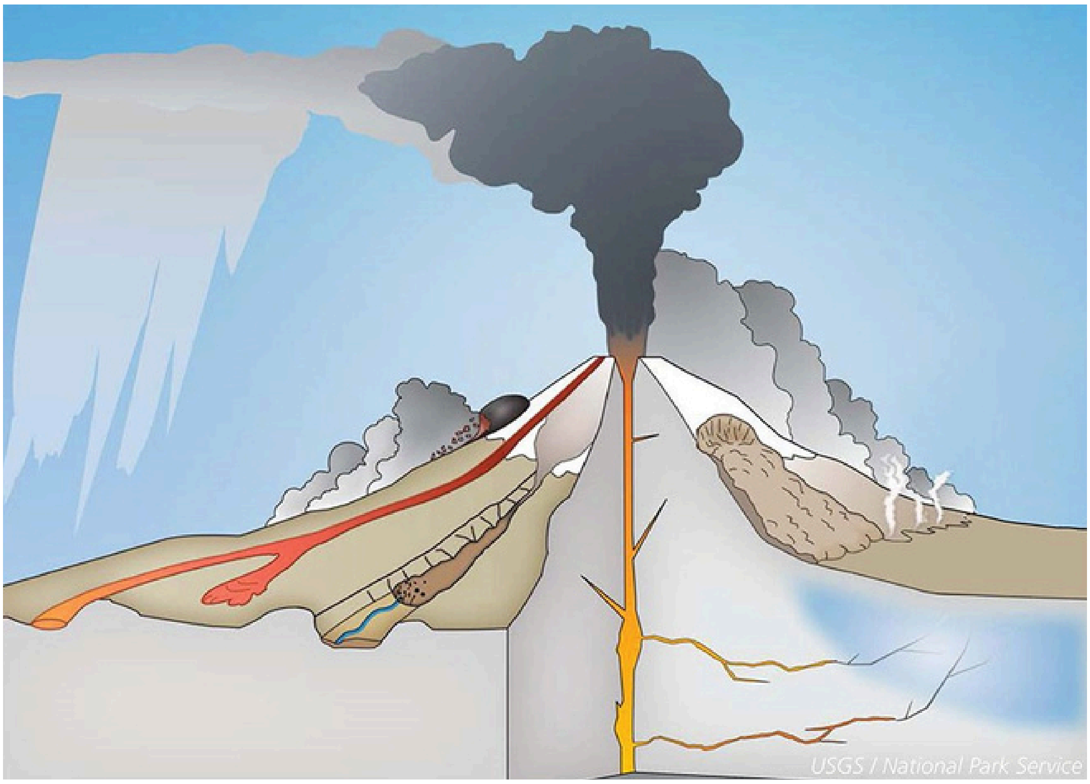
Source: modified from **NPS**

Shield Volcano



Source: modified from **USGS illustration**

Composite Volcano

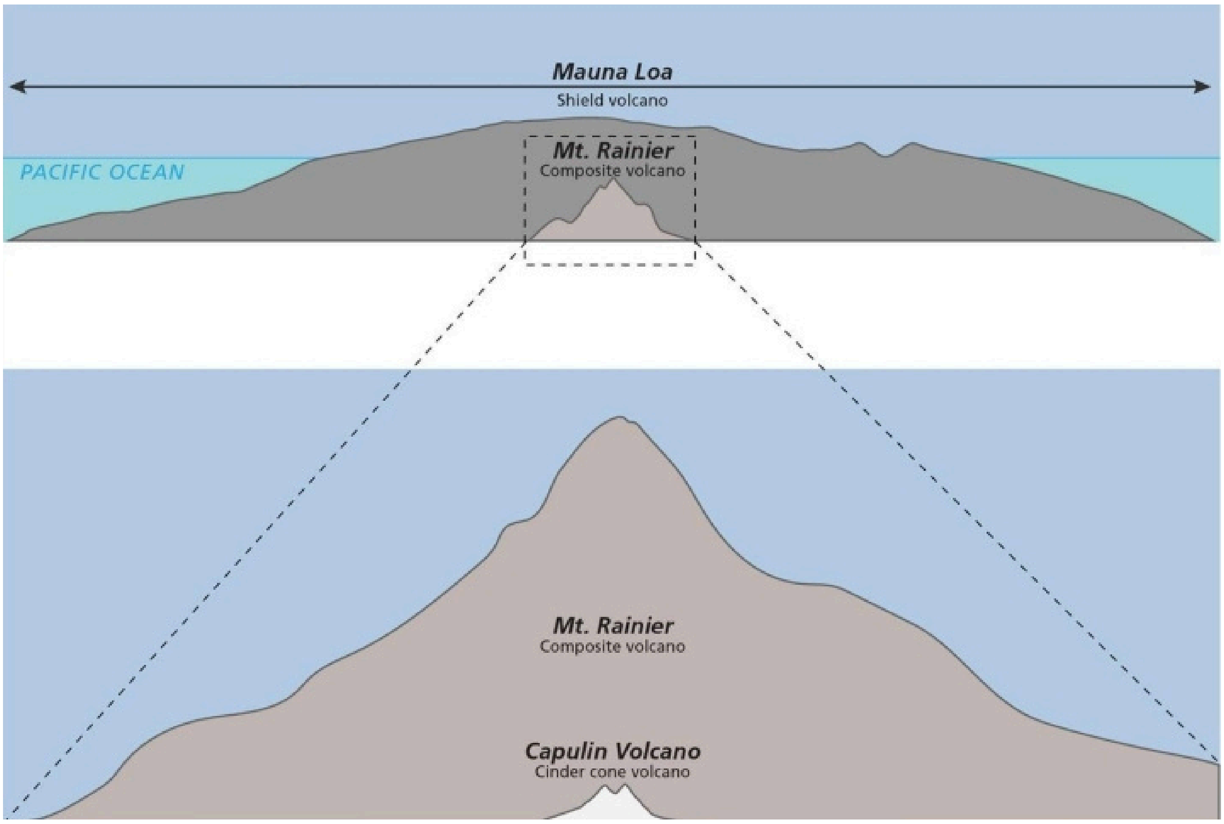


Source: modified from **USGS illustration**

- Describe two similarities between the three volcano types. Why do you think all volcanoes have these features?

- Identify a feature that is unique to each volcano. How does each of the features make the volcanoes differ from the other types

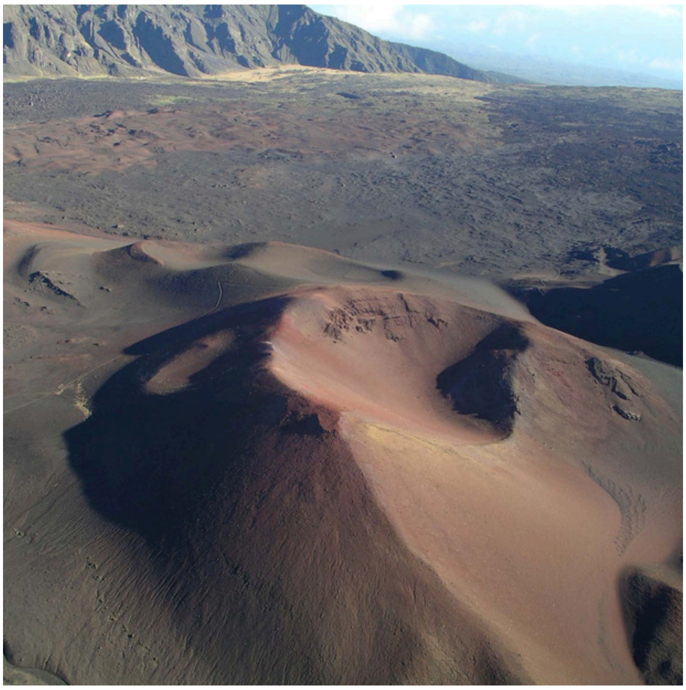
The size of volcanoes varies depending on the volcano type:



Source: **NPS**

- Compare the relative size of each volcano type.

Source: **Lake Clark National Park** (Iliamna Volcano)



Source: **Haleakalā National Park** (Ka Moa o Pele)

Source: **Sierra Grande**, viewed from Capulin Volcano National Monument

Activity: Lava Flows

Objective: Learners will understand how viscosity impacts the shape of lava flows, and the features formed during volcanic eruptions.

Introduction: Lava flows occur during effusive eruptions. Characteristics of the lava being erupted (most prominently its composition and viscosity) strongly impact the size and shape of lava flows.

Basalt is the most common type of volcanic rock because most lava flows are made of basalt. Basaltic lavas have low silica and low viscosity, meaning that they form thin lava flows that may travel many miles from the vent. Basaltic lava flows have two types of characteristic surfaces—ropy (Pāhoehoe) or rough (‘A‘ā)—that result from minor variation in viscosity and temperature. Features found in solidified lava flows provide important information of the dynamics that occurred while they were active.

Andesite and rhyolite are progressively more viscous than basalt, and they form shorter and steeper flows. Andesite lava usually make block flows. Rhyolite is so viscous that sometimes lava erupted from a vent is unable to travel away from it, and instead forms a lava dome over it.

Have learners:

1. Discuss viscosity and how the viscosity of magma and lava can affect volcanic eruptions.
2. Work in groups to complete an activity on viscosity.
3. Identify the likely composition of some lava flows erupted from national park volcanoes.
4. Learn about the main characteristics of lava flows of different compositions.
5. Learn about the forms of basaltic lava flows, as basaltic lava is the most common type.
6. Complete an activity to investigate how layers of lava build up after volcanic eruptions.
7. Revisit their comparisons of the volcanic eruptions to describe how the viscosity of the magma likely affected the eruptions.
8. Watch a video of lava moving through a lava tube and consider how they form.
9. Analyze images of lava flows to determine the direction of flow and how some areas can be spared during an eruption (kīpukas).

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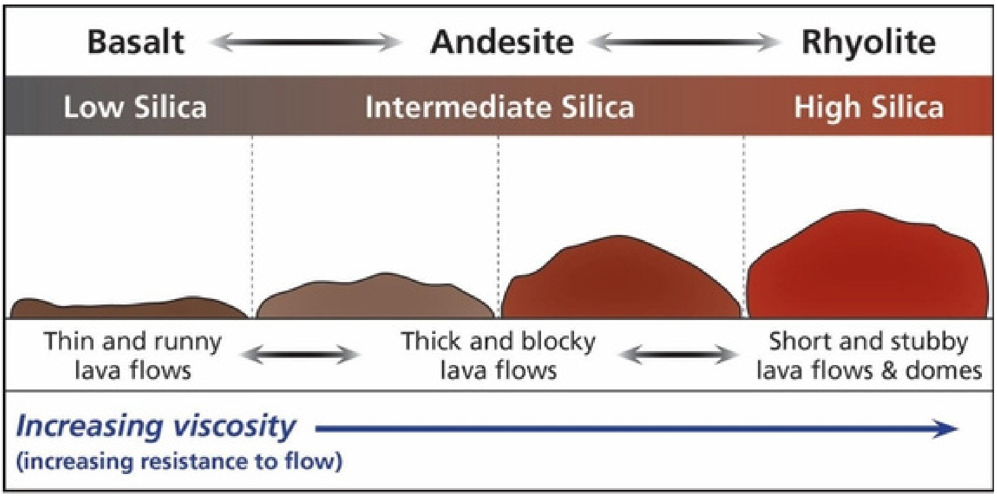
Handout: Lava Flows

The composition and viscosity of lava ranges and can affect how it flows



Source: modified by Allyson Mathis for NPS

- Which type of lava flow has the potential to spread over the widest area? Explain your answer.

- Identify the likely composition of the following lava flows. Explain your answers.

Source: **NPS**, Lassen Volcanic National Park

Source: **USGS**

Source: **USGS**, Novarupta, Katmai National Park

Lava Flow Forms

Most basaltic lava flows are of one of two main types:

- **Pāhoehoe** – Lava flows with smooth, billowy, or ropy surfaces
- **ʻAʻā** – Lava flows with rough or jagged surfaces They form due to small differences in temperature, viscosity, and other characteristics.

The image below shows lava from a current eruption moving over hardened rock from a previous eruption.

Source: **USGS**, Hawaiʻi Volcanoes National Park

- Make an argument about the lava- is the current eruption the same type of lava as the previous eruption? How can you tell? Use observations from the image to support your argument.

- What else would you want to know about the lava and the rocks to add to your argument?

Lava tubes are channels in the interior of lava flows through which molten lava travels:

Source: **USGS**

- How do you think lava tubes form?

- Why do you think some lava tubes are empty after an eruption ends?

Direction of Lava Flows

Source: **NPS**

- Draw an arrow showing the direction of flow in the photo.

- Describe how you were able to determine the direction of flow.

Kīpukas are areas that do not get buried by a lava flow:

Source: **USGS**

- Why do you think these areas were not buried by lava?

- How do you think that kīpukas are important to the ecology of volcanic areas?

Activity: Volcanic Rocks and Deposits (Evidence of Past Eruptions)

Objective: Learners will use the locations of volcanic rocks, as well as ash and other volcanic deposits, as evidence for past volcanic activity.

Introduction: Volcanic rocks and deposits of volcanic ash and tephra offer valuable evidence of past eruptions, aiding scientists in reconstructing volcanic history and understanding future hazards. Highly explosive eruptions create features like obsidian flows and volcanic ash deposits. Volcanic deposits, such as pyroclastic flows, lahars, and tephra layers, provide critical insights into eruption dynamics and hazard potential. By studying these rocks and deposits, scientists can assess the frequency, magnitude, and style of past volcanic activity, contributing to better volcanic risk management and preparedness strategies.

Have learners:

1. Complete one or more activities to learn about igneous rocks, such as:
   - Modelling the formation of igneous rocks.
   - Comparing images of the most common types of volcanic igneous rocks.
   - Observing igneous rock samples and minerals commonly found in igneous rocks.
2. Learn about ash and tephra deposits.
   - Make a hypothesis on the map on the handout to indicate how far they think the ash spread from the largest Yellowstone eruption.

Observe the map of the three largest eruptions on the Yellowstone Plateau:

- Lava Creek Eruption (630,000 years ago), Mesa Falls Eruption (1.3 million years ago), Huckleberry Ridge Eruption (2.1 million years ago).
- Indicate a point on the map where they could dig and find evidence of all three of these eruptions.

Discuss:

- *Which ash bed would be farthest beneath the surface? Why is this?*
- *What factors might affect the spread of ash from a volcanic eruption?*

3. Complete an activity to better understand the spread of ash and tephra.
4. Learn about gases emitted from volcanoes.

Discuss:

- *Why are gases are released by volcanoes? What is their source?*
- *Why are gases released from some volcanoes even if it is not erupting?*
- *What effects might these gases have on people and the environment?*
- *How do gases released by volcanoes contribute to climate change?*

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Handout: Volcanic Rocks and Deposits (Evidence of Past Eruptions)

Basalt: The most common volcanic rock formed from lava flows.

Compare the two types of basalt

Basalt

Vesicular Basalt

Sources: **James St. John via Flickr**

Similarities:

Differences:

Compare other types of volcanic rocks formed by lava flows:

Dacite

Rhyolite

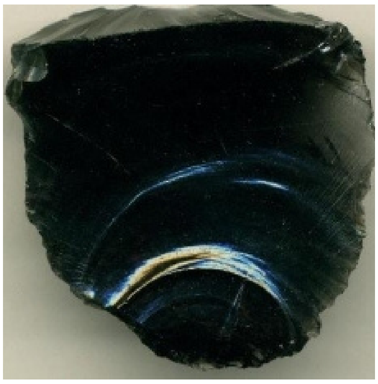
Andesite

- Which of these rock types is most similar to basalt? What is your evidence?

- How do the other two volcanic rocks compare to basalt? How are they different?

Volcanic glass:


Pumice


Obsidian


Scoria

Source: **James St. John via Flickr**

- Compare the three main types of volcanic glass. Why do you think they differ?

Volcanoes also often spew volcanic ash and tephra (rock fragments and debris) over a much wider range than lava flows.

Three of the largest eruptions in the U.S. occurred on the Yellowstone Plateau, indicated by the red oval on the map. Use a colored pencil to indicate how far you think the ash from its largest eruption spread.

What factors do you think affect the spread of ash?

Activity: Volcanic Landforms

Objective: Learners will use diagrams to identify and describe the formation of the various landforms that are evidence of past volcanic activity.

Introduction: Volcanic landforms encompass a diverse array of features shaped by volcanic activity. While volcanoes themselves can be iconic landscapes, many other landforms exist where dormant volcanoes or past eruptions have occurred. Calderas are immense depressions often formed by the collapse of a volcanic summit during a major eruption that empties the magma chamber underneath it. Additionally, volcanic fissures, vents, and lava domes are notable features that contribute to the varied landscape shaped by volcanic forces. Understanding these diverse landforms is crucial studying past volcanic impacts and the dynamic processes shaping the Earth's surface.

Have learners:

1. Compare images of volcanic craters and volcanic calderas.
   - Convert the diameters of all four features to the same units to compare their size (meters is recommended).
   - Match each feature to its likely cause.
2. Consider how volcanic activity leads to the formation of hydrothermal features.
   - Explore more detail, including temperature the temperature range, of hydrothermal features.
   - Explore a park with numerous fumaroles and hydrothermal features:
     Yellowstone National Park
     Lassen Volcanic National Park
3. Explore NPS Units with erosional volcanic landforms.

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Handout: Volcanic Landforms

Volcanic Craters

Sunset Crater. 1 mile diameter

Cinder Cone. 900 ft diameter

Volcanic Calderas

Aniakchak Caldera, Alaska. 10.5 km diameter

Crater Lake. 6 mile diameter

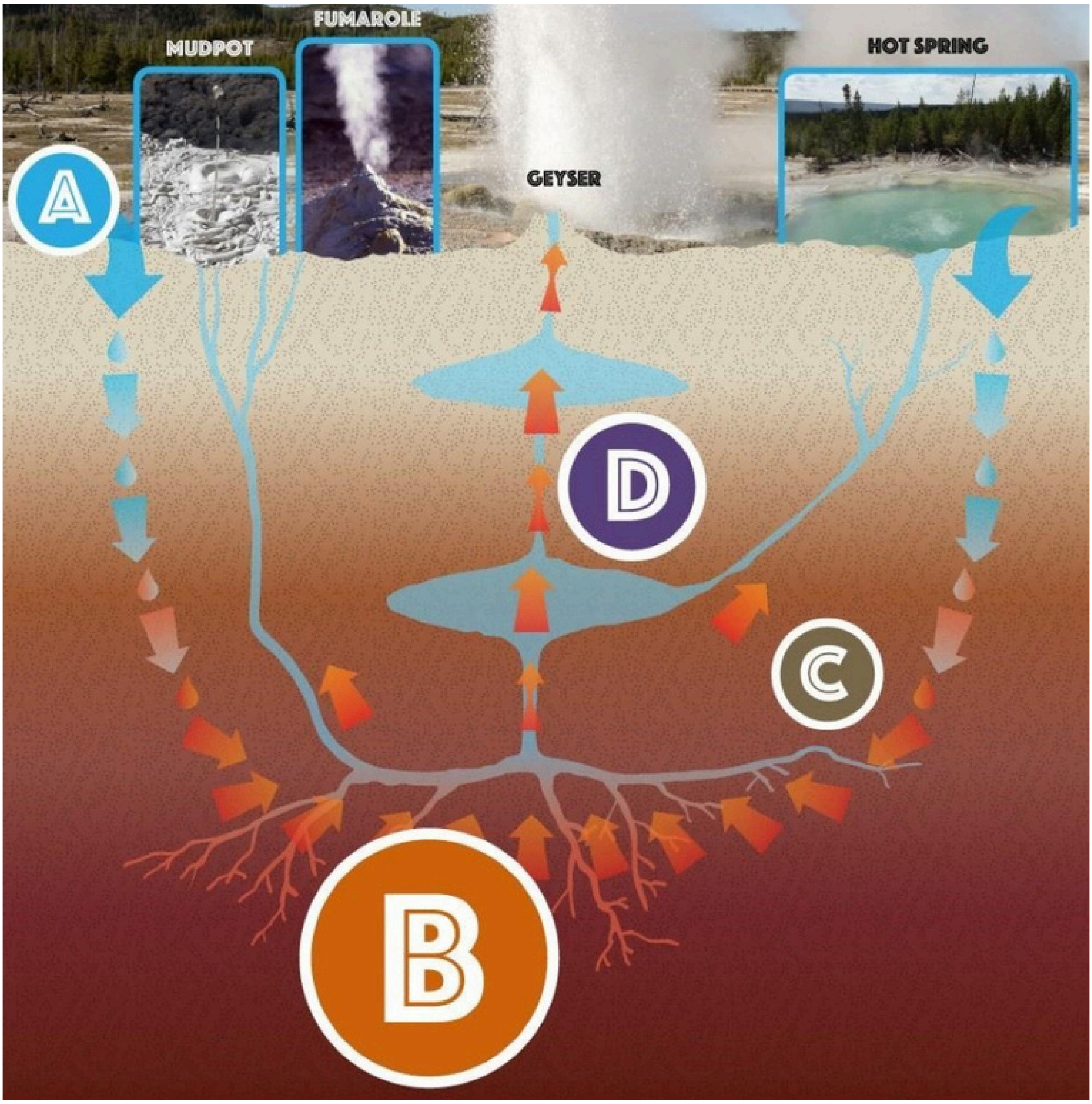
Compare the size of each volcanic crater and caldera. List them from largest to smallest.

Match these two landforms to its likely cause:

- The collapse of land following an eruption can form a ______________________________.
- The collapse of land located above a volcano's primary magma chamber that has emptied forms a ____.

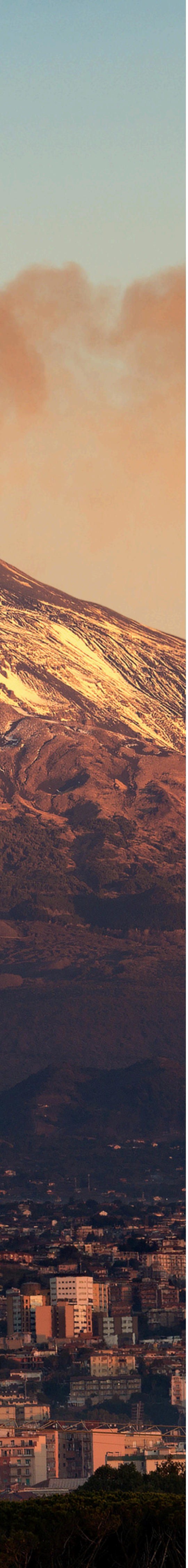
Give reasoning for your answer.

Hydrothermal Features



Source: **NPS**

- In your own words, describe the processes shown in the diagram of hydrothermal features that occur near volcanic activity.



Volcanoes and People

Studying how volcanoes affect people is crucial due to the inherent natural hazards associated with volcanic activity and the significance that people place on volcanic landscapes.

Volcanic eruptions involve a variety of hazards, including explosions and blasts, lava flows, ashfall, volcanic gases, and others; the effects of which can spread far beyond the site of an eruption. These hazards may pose significant risks to human life, property, and infrastructure. Understanding the mechanisms of volcanic hazards, their impacts on communities, and how to implement effective risk management strategies are essential for minimizing the potential devastation that may be caused by volcanic eruptions.

Beyond their immediate threats, volcanoes hold immense geoheritage value, making the study of their impact on people imperative for preserving cultural and natural heritage sites. Many volcanic regions are rich in geological features, such as fertile agricultural lands, caves, and hot springs. These sites serve as real-time laboratories, offering insights into Earth's geological processes and environmental history.

Exploring the impact of volcanoes on people involves diverse career opportunities in fields such as disaster management, environmental monitoring, and geotourism. Volcanologists study volcanic processes and hazards, conducting research to better understand and monitor volcanic behavior. Disaster management professionals use information about volcanoes to develop emergency preparedness plans and response strategies to safeguard communities living near active volcanoes. Additionally, careers in geotourism involve guiding visitors safely within volcanic sites, educating them about geological phenomena, and promoting sustainable tourism practices that respect the cultural and environmental significance of volcanic landscapes.

Activity: Volcanoes as Natural Hazards

Objective: Learners will explain how volcanoes pose a threat to humans, infrastructure, and ecosystems, and will describe how monitoring of volcanic activity can be used to minimize the negative effects of volcanic activity.

Introduction: Volcanoes pose significant natural hazards, threatening lives, property, and infrastructure in their vicinity.

The primary hazards associated with volcanic activity include:

- Eruptions, explosions, and blasts. Explosive eruptions may include explosions and blasts that can devastate large regions surrounding a volcanic vent.
- Earthquakes may be caused by moving magma within and underneath a volcano and create seismic hazards.
- Lava flows may travel many miles from a vent and bury anything in their path.
- Pyroclastic flows are fast-moving currents of hot gas, ash, and rock fragments that destroy everything in their path and are almost always deadly to humans and animals.
- Volcanic ash and tephra may be ejected high into the atmosphere where it may form clouds and travel great distances before falling to the Earth. Ash clouds can disrupt air travel. Volcanic ash may damage crops and cause respiratory issues.
- Lahars are volcanic mudflows that may be triggered by volcanic activity or by precipitation or melting snow. Lahars can travel many miles from volcanoes and are one of the most destructive of all volcanic hazards.
- Volcanic gases including carbon dioxide (CO2) sulfur dioxide (SO2), hydrogen sulfide (H2S), and others are emitted during eruptions, and sometimes continuously from fumaroles. With the exception of water vapor, these gases present geohazards because they can be toxic or even lethal.

Additionally, volcanic eruptions can induce other hazards such as landslides, tsunamis, and wildfires. Understanding and monitoring volcanic activity is essential for creating evacuation plans, informing emergency response efforts, and safeguarding vulnerable populations living in volcanic regions.

Have learners:

1. Brainstorm factors that they would want to monitor around volcanoes to help predict when they might erupt. Study this USGS graphic to give ideas about how volcanoes are monitored.
2. Mark on the map of Hawai'i where they might place monitoring stations.
   - Read about the weather in Hawai'i, as well as when these volcanoes last erupted, in addition to other information that could inform them where to best place monitoring stations.
3. Read the new NPS site on Monitoring Volcanoes, then view the U.S. Geological Survey's Volcano Monitoring site.
   - In the menu on the right of the screen, choose Regions, then in the dropdown menu, select Hawai'i.
   - Zoom in on the largest island.
   - In the menu on the right, choose Instruments, then go through each one to see where different monitoring stations are located.
   - Compare the locations of stations to the sites they chose.

Discuss:

- *Are any of the volcanoes currently active?*
- *How can you tell? Choose Volcanoes in the right menu to see the key for which volcanoes are being actively monitored. If there are none currently in Hawaii, choose another region where a volcano is marked yellow or orange.*
- *What might each instrument be measuring?* Click on some of the stations to see the data that they output. Research each instrument and its functions in monitoring volcanic activity. View videos that summarize how USGS monitors volcanoes: Deformation, Gas Monitoring, Earthquakes (alternatively, volcano seismicity).
- *Why do volcanic gases have to be monitored?* Investigate more about volcanic gases by completing this activity.

4. Mark on the map which areas are most likely to be affected by the secondary hazards related to volcanic activity:
   - Landslides
   - Tsunamis
   - Wildfires
   - Ashfall
5. Discuss the image of ashfall after the eruption of Katmai. What hazards does this pose to humans?
6. Research a recent volcanic eruption and how it affected the area nearby. Prepare a news broadcast to inform residents of the hazards near them and actions to take to protect themselves.

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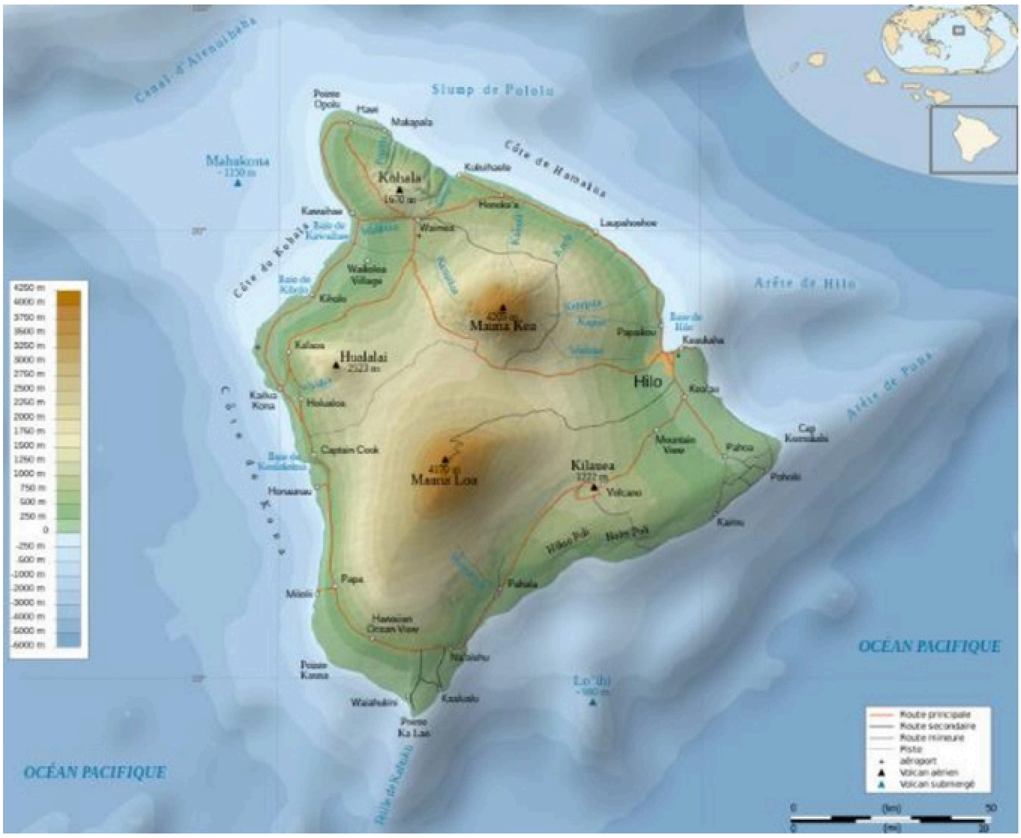
Handout: Volcanoes as Natural Hazards

Brainstorm factors that could be monitored around a volcano to help predict when it might erupt:

The map below shows the height of the land compared to sea level on Hawai'i's largest island.



Source: © **Sémhur** / CC-BY-SA-4.0

Green areas are the lowest parts of the island, while brown areas are the highest.

Mark on the map where you would place monitoring stations.
What else would you want to know about the island and the volcanoes so that monitoring stations are in the right place?

Ashfall after the eruption of Katmai

Source: **NPS**

- Make observations of the image, showing ashfall after an eruption.

- What threat might this pose to humans?

Activity: Volcanoes and Geoheritage

Objective: Learners will use data to describe populations that have a history of inhabiting land near volcanoes and the connection those populations have to the history of the land.

Introduction: Overall, while acknowledging their hazards, people value volcanoes for their scientific, aesthetic, recreational, and economic significance. Volcanoes are vital for geological research, providing insights into Earth's inner workings and the processes shaping the planet's surface. They also support unique ecosystems, sometimes hosting rare species adapted to extreme environments. Furthermore, volcanic eruptions enrich surrounding lands by depositing nutrient-rich ash and lava flows, creating some of the world's most fertile soils. This fertility supports agricultural practices, sustaining communities and economies. Additionally, volcanoes attract tourists and enthusiasts fascinated by their beauty and unique attributes. Volcanic landscapes offer opportunities for recreation, adventure, and cultural exploration, contributing to local economies.

Have learners:

1. Read through the geoheritage values defined by the National Park Service.
2. Brainstorm ideas on the learner handout about the scientific, economic, cultural, and aesthetic/artistic value of volcanoes.
3. **Scientific:** Geothermal energy, fertile lands created when volcanic deposits are broken down, insight into plate tectonics and the mantle's composition, atmospheric effects of eruptions.
4. **Economic:** Tourism, geothermal energy, products made from igneous rocks (building materials, artwork, pumice), farming near volcanoes.
5. **Cultural:** Stories passed down about volcanoes, eruptions forcing evacuations or moving to new areas, agricultural societies' reliance on volcanoes.
6. **Aesthetic/Artistic:** Unique landforms, inspirational, change frequently.
7. Write an argument for the conservation/preservation of lands around volcanoes, such as making National Parks at these sites.
8. Learn about the traditional knowledge of prehistoric eruptions. Describe how people's lives may have changed following the volcanic eruption.

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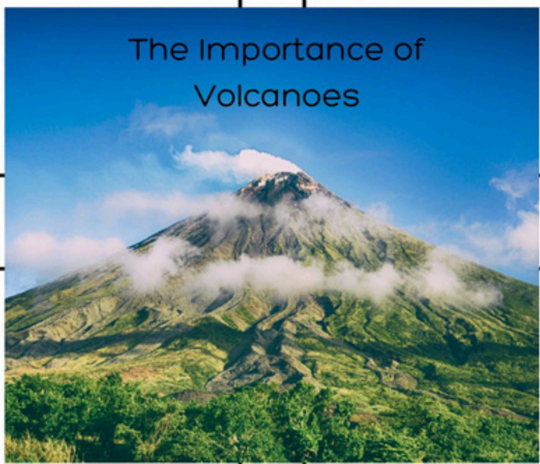
Handout: Volcanoes and Geoheritage

Aesthetic/Artistic

Scientific



Economic

Cultural

Use the information you collected above to explain why people live near volcanoes.

Activity: Volcano-Related Careers

Objective: Learners will be able to describe various careers and their involvement in our understanding of volcanoes and volcanic activity.

Introduction: Careers related to volcanoes encompass a diverse range of disciplines and opportunities. From scientists to emergency response workers to tour guides, there are a range of jobs that center around the understanding of and appreciation for volcanoes. These careers offer opportunities for exploration, discovery, and making a positive impact on society and the environment.

Have learners:

1. Research the volcano-related careers on the learner handout: Volcanologist, Tour Guide, Planetary Geologist, Natural Resource Specialists, Agricultural Workers, and Meteorologist.
2. *Which of these careers would you most like to have and why?*
3. *What other careers can you think of that are related to volcanoes and volcanic activity?*
4. Brainstorm and research other volcano-related careers, such as: Healthcare workers, Alpine Botanist, Disaster management/Emergency Response, Mining, Structural Geologist, Atmospheric Scientists, Forest Fire Specialist, Environmental Scientist, Geothermal Energy Industry, and others.
5. Discuss volcanic sites as places where astronauts train and the benefits of studying these regions before traveling to other planets or moons.

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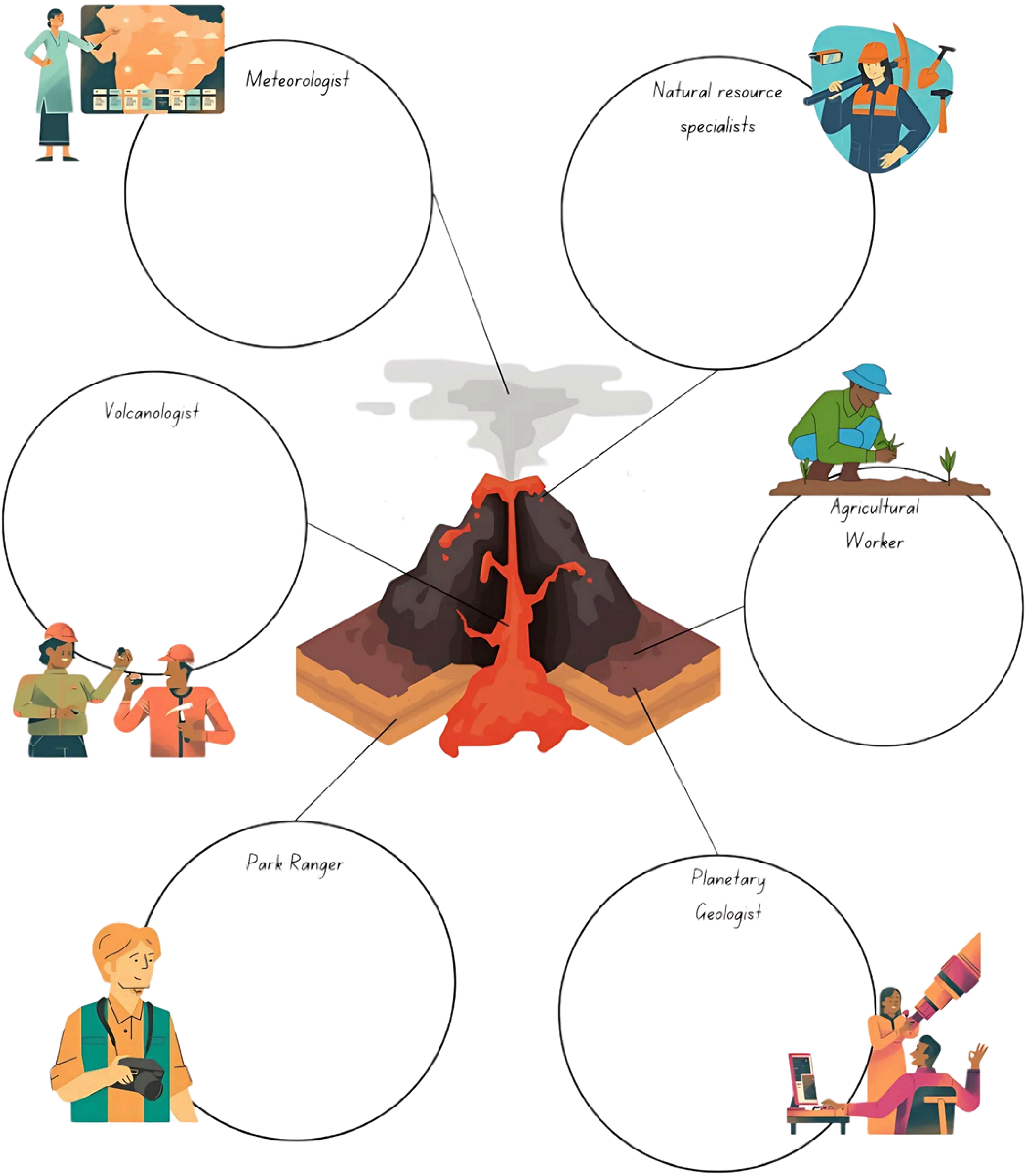
Handout: Volcano-Related Careers



Source: **NPS**

Why do you think that the Apollo astronauts trained in the area around Sunset Crater Volcano?

Activity: Virtual Exploration of National Parks with Volcanoes

Objective: Learners will virtually tour National Parks that contain volcanoes to see the range of formations and associated activity throughout the United States.

Introduction: Virtual tours play a vital role in studying volcanoes, offering immersive experiences that also support safety and the preservation of unique sites in the U.S. These tours provide access to remote and hazardous volcanic sites, allowing researchers, learners, and enthusiasts to explore volcanic landscapes and features from the safety of their homes or classrooms. By integrating multimedia content such as videos, images, and interactive maps, virtual tours enhance understanding of volcanic processes, landforms, and hazards. They enable real-time monitoring of volcanic activity, fostering collaboration among scientists and facilitating data collection and analysis. Additionally, virtual tours promote outreach and education, reaching broader audiences worldwide and inspiring interest in geoscience and natural phenomena.

Have learners:

1. Look over the NPS Master List of parks with volcanic features to choose a park they are interested in learning more about.
2. Complete the planning worksheet to create a slide deck, infographic, or other presentation method to share about the park they chose.
3. Alternatively, complete one of the following to virtually explore a site with volcanic activity and features:
4. Virtual Scavenger Hunt of Hawai'i Volcanoes National Park
5. Sunset Crater Volcano Web Quest
6. Yellowstone Distance Learning

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Handout: Virtual Exploration of National Parks and Units with Volcanoes

Explore

Volcanic features

Use the prompts below to consider what information you want to include in a presentation about a National Park or Unit that contains volcanic features or activity.

Park/Unit Name: ______________________________

Information from Master List:

State:

Age:

Landform Type(s):

Resource Significance:

Details about volcanic features/activity, including ideas for images.

Other non-volcanic geologic features:

Environment of the area:

Why should people visit this park/unit?

Resources that will be used to create the presentation:

National Park Service

The National Park Service preserves unimpaired the natural and cultural resources and values of the national park system for the enjoyment, education, and inspiration of this and future generations. The Park Service cooperates with partners to extend the benefits of natural and cultural resource conservation and outdoor recreation throughout this country and the world. The Geologic Resources Division assists the National Park Service and partners in the servicewide coordination, support, and guidance necessary to understand and implement science-informed stewardship of geologic and associated park resources; reduce impacts from energy, mineral, and other development; and protect visitor values.

P.O. Box 25287, Denver, CO 80225 | www.nps.gov

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