
Eruption on the island of Hawaii, 1984 (USGS)

Learning Objectives

Your goals in studying this chapter are to:

- Understand exactly what an earthquake is and the related terminology.
- Understand the types of faults and seismic waves
- Understand how earthquakes are measured.
- Understand the kinds of damage earthquakes can cause.
- Understand earthquake mitigation measures, including basic principles of seismic engineering.
- Understand earthquake risk in the United States.
- Understand the limitations of earthquake prediction.
- Understand earthquake preparedness.

USGS

Types of Volcanic Eruptions

During an episode of activity, a volcano commonly displays a distinctive pattern of behavior. Some mild eruptions merely discharge steam and other gases, whereas other eruptions quietly extrude quantities of lava. The most spectacular eruptions consist of violent explosions that blast great clouds of gas-laden debris (pulverized rock) into the atmosphere.

The type of volcanic eruption Is often labeled with the name of a well-known volcano where characteristic behavior is similar--hence the use of such terms as "Strombolian," "Vulcanian," “Plinian,“ "Hawaiian," and others. Some volcanoes may exhibit only one characteristic type of eruption during an interval of activity--others may display an entire spectrum of types.

In a **Strombolian-type** eruption, huge clots of molten lava burst from the summit crater to form luminous arcs through the sky. Collecting on the flanks of the cone, lava clots combined to stream down the slopes in fiery rivulets. Strombolian eruptions affect only the volcano’s slopes.

In contrast, the eruptive activity of Parícutin Volcano in 1947 demonstrated a **Vulcanian**-type eruption, in which a dense cloud of ash-laden gas explodes from the crater and rises thousands of feet above the peak. Vulcanian eruptions affect the local region because ash is carried high into the atmosphere. In the photo at right, steaming ash forms a whitish cloud near the upper level of the cone.

A Strombolian eruption at Tungurahua, Ecuador in 1999 (USGS)

A Vulcanian eruption at Parícutin Volcano, Mexico, 1947. (USGS)

In a **Plinian** eruption, great quantities of ash-laden gas are violently erupted to form mushroom-shaped cloud high in the atmosphere. They are typified by the eruption of Mount Vesuvius in Italy in A.D. 79 that buried Pompeii. Plinian eruptions are the most powerfully explosive of all eruptions. Dust and ash can reach the highest levels of the atmosphere, where winds can carry them around the world. These eruptions are named after Pliny the Elder, an ancient Roman military commander and naturalist who described the eruption of Vesuvius in 79 A.D. as reaching high into the sky and shaped like a stone pine (which has spreading branches near its top. See the accompanying photo). Modern examples of Plinian eruptions include Mount St. Helens in 1980 and Mt. Pinatubo, Philippines, in 1991.

A **pyroclastic flow** or **nuée ardente** (glowing cloud) can occur in two different ways: 1) when an explosive eruption sends a massive quantity of gas, dust, ash, and lava fragments high into the air, and those materials fall back onto the slopes of the volcano; or 2) when a lava dome at the summit of a volcano collapses, sending hot avalanches down the slopes. They form tongue-like, glowing avalanches that move downslope at velocities that can exceed 120 miles per hour. As the dense materials move down-slope, they compress the air in front of them and glide on a friction-free cushion, causing them to accelerate to surprising speeds. Pyroclastic flows contain not only rocks and dust at high temperatures, but toxic gases that can extend beyond the ends of the avalanche. Such eruptive activity can cause great destruction and loss of life if it occurs in populated areas, as demonstrated by the devastation of St. Pierre during the 1902 eruption of Mont Pelée on Martinique in the Caribbean.

A stone pine at Pompeii, Italy, with Mt. Vesuvius in the background. (BYUI)

Photos of Plinian eruptions -- Mt. Spurr, Alaska in 1992 (left) and Chaiten, Chile in 2008 (above). (USGS)

Pyroclastic flows cascaded down canyons on the Mayon volcano in the Philippines in 1984. Notice the fertile volcanic soils that have drawn people to live near the volcano. (USGS)

When the lava dome at the summit of Colima volcano in western Mexico grew too large to be stable, it avalanched down the slopes. The dust cloud here is rising from the avalanche on the ground. The photo was taken in 1998. (USGS)

"**Hawaiian**" eruptions may begin along fissures or fractures that serve as linear vents. In fissure-type eruptions molten, incandescent lava spurts from a fissure and feeds lava streams that flow downslope. In central-vent eruptions, a fountain of fiery lava can spurt to a height of several hundred feet or more to form a cone. Lava flows downhill like water, a major difference being that lava hardens as it cools, filling up the low places. Lava may collect in old craters to form lava lakes, or feed radiating flows.

Fissure eruption on Mauna Loa in 1984. Because magma moves upward through the crust through fractures, it naturally erupts from fractures when it first reaches the surface. (USGS)

Fountains (background) and lava flows (streams) on Mauna Loa, Hawaii in 1984. (USGS)

Mount St. Helens in Washington state experienced a Plinian eruption on May 18, 1980. In this view toward the north, you can see the lateral blast (pyroclastic flow) heading northward, thankfully away from the photographer's airplane. The blast was triggered when the northern 1/3 of the mountain collapsed in the largest landslide ever filmed. The blast traveled up to 670 miles per hour, and leveled the forest for up to 19 miles from the volcano (below). (NPS)

Geysers, Fumaroles, and Hot Springs

Geysers, **fumaroles** (also called *solfataras*), and hot springs are generally found in regions of young volcanic activity. Surface water percolates downward through the rocks below the Earth's surface to high-temperature regions surrounding a magma reservoir, either active or recently solidified but still hot. There the water is heated, becomes less dense, and rises back to the surface along fissures and cracks.

Fumaroles are one of the most significant volcanic hazards, hurting or killing hundreds each year.

Erupting geysers provide spectacular displays of underground energy suddenly unleashed, but their mechanisms are not completely understood. Large amounts of hot water are presumed to fill underground cavities. The water, upon further heating, is violently ejected when a portion of it suddenly flashes into steam. This cycle can be repeated with remarkable regularity, as for example, at Old Faithful Geyser in Yellowstone National Park, which erupts on an average of about once every 90 minutes.

Old Faithful Geyser, Yellowstone National Park, Wyoming. (USGS)

Fumaroles, which emit mixtures of steam and other gases, are fed by conduits that pass through the water table before reaching the surface of the ground. Hydrogen sulfide (H2S), one of the typical gases issuing from fumaroles, readily oxidizes to sulfuric acid and native sulfur. This accounts for the intense chemical activity and brightly colored rocks in many thermal areas.

Hot springs occur in many thermal areas where the surface of the Earth intersects the water table. The temperature and rate of discharge of hot springs depend on factors such as the rate at which water circulates through the system of underground pathways, the amount of heat supplied at depth, and the extent of dilution of the heated water by cool ground water near the surface.

Black Growler steam vents (fumaroles), Norris Basin, Yellowstone National Park, Wyoming.

Mammoth Hot Springs, Yellowstone National Park, Wyoming.

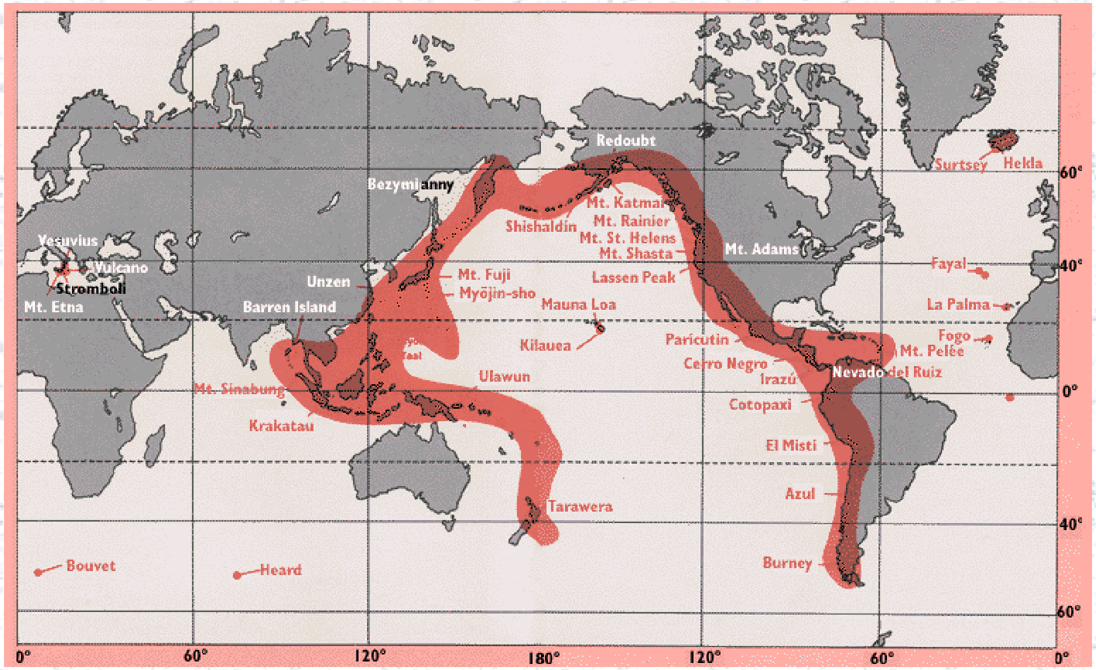
Plate Tectonics and Volcanoes

Plate Tectonics explains the locations and types of the world's volcanoes. They occur primarily at plate boundaries and hot spots. Plate Tectonics even explains the types of volcanic rocks and why they occur in specific locations.

Rhyolite occurs primarily on continental crust, where there is a large supply of silica. **Andesite** is found primarily at divergent plate boundaries. **Basalt** forms at divergent plate boundaries and hot spots, and is the most abundant rock type on earth's surface because it forms the entire bedrock of the ocean floors.

There are more than 500 active volcanoes (those that have erupted at least once within recorded history) in the world, 50 of which are in the United States (Hawaii, Alaska, Washington, Oregon, and California)--although many more are hidden under the seas. Most active volcanoes are strung like beads along, or near, the margins of the continents, and more than half encircle the Pacific Ocean as a "Ring of Fire." The Ring is, of course, the convergent plate boundaries that rim the Pacific.

Many volcanoes are in and around the Mediterranean Sea. Mount Etna in Sicily is the largest and highest of these mountains. Italy's Vesuvius is the only active volcano on the European mainland. Near the island of Vulcano, the volcano Stromboli has been in a state of nearly continuous, mild eruption since early Roman times. At night, sailors in the Mediterranean can see the glow from the fiery molten material that is hurled into the air. Very appropriately, Stromboli has been called "the lighthouse of the Mediterranean.



Map showing the distribution of some of the Earth's 500 active volcanoes. (USGS)
To find a volcano in Google Earth or Google Maps, try entering its name (or the name of a nearby city) in the search box.

Volcano Monitoring and Research

Perhaps "modern" volcanology began in 1912, when Thomas A. Jaggar, Head of the Geology Department of the Massachusetts Institute of Technology, founded the Hawaiian Volcano Observatory (HVO), located on the rim of Kilauea's caldera. It has been run by the U.S. Geological Survey since 1948. The USGS now also operates volcano observatories at the Cascades (CVO), Alaska (AVO), and Yellowstone (YVO, in partnership with University of Utah), where volcanologists, geologists, geochemists, and seismologists study and monitor the volcanoes. Any warnings about activity would come through these organizations. You can find other global volcano observatories at this link: http://www.wovo.org/observatories/ You should take a few minutes to look at the HVO's Kilauea pages, where you can look at webcams, photos, videos, and more of the ongoing Kilauea eruption.

HVO website CVO website YVO website AVO website

For current global volcanic activity, see http://www.volcanodiscovery.com/volcano_news.html

Steam and gas cloud rising from the summit caldera of Kilauea Volcano. (BYUI)

BYU-Idaho faculty and students at he U.S. Geological Survey's Hawaiian Volcano Observatory on the caldera rim of Kilauea Volcano. (BYUI)

In the past few decades, scientists have learned that eruptions are preceded by a definite set of events. Eruptions don't sneak up on them any more. These lessons were successful at Mount St. Helens in 1980 and Mt. Pinatubo, Philippines, in 1991.

<u>These are the signs of a pending eruption:</u>

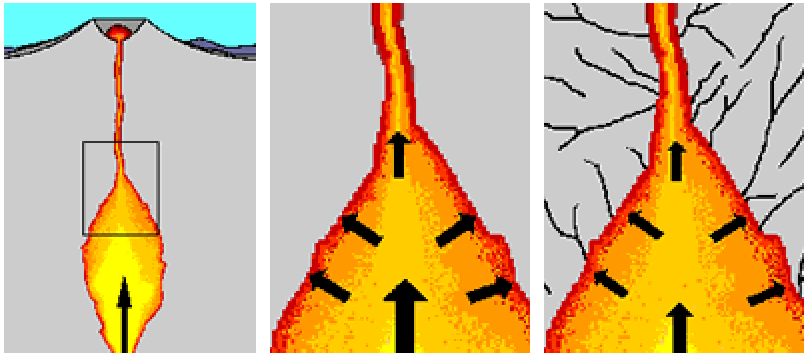
1. **Ground swelling or tilt**. Volcanoes gradually swell or "inflate" in building up to an eruption because of the influx of magma into the volcano's reservoir or "plumbing system"; with the onset of eruption, pressure is immediately relieved and the volcano rapidly shrinks or "deflates." A wide variety of instruments, including precise spirit-levels, electronic tiltmeters, high-precision GPS, and electronic-laser beam instruments, can measure changes in the slope or "tilt" of the volcano or in vertical and horizontal distances with a precision of only a few parts in a million.

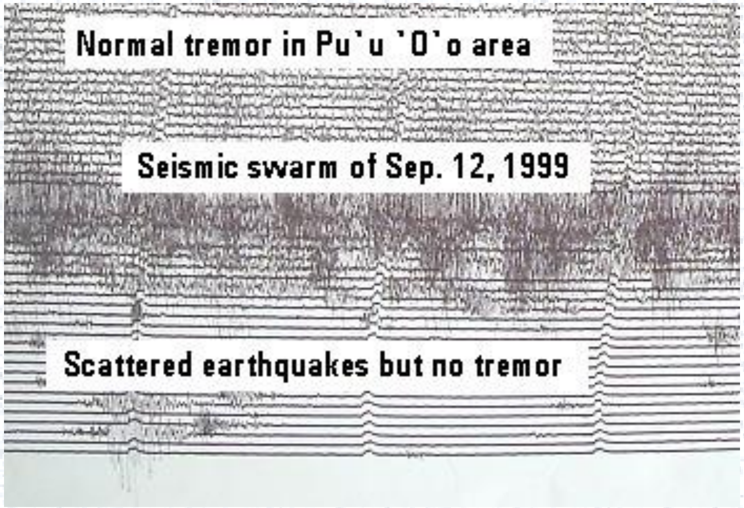
2. **Swarms of quakes and magmatic tremor**. Scientists make a precise determination of the location and magnitude of earthquakes via a well-designed seismic network. As the volcano inflates by the rise of magma, the enclosing rocks are deformed to the breaking point to accommodate magma movement. When the rock ultimately fails to permit continued magma ascent, earthquakes result. Magmatic (or volcanic) tremor is harmonic vibrations that echo inside magma. They are distinct from rock-breaking or tectonic earthquakes by their lack of distinct p- and s-wave arrivals and their distinct long, tapered shape. By carefully mapping out the variations with time in the locations and depths of earthquake foci, scientists in effect can track the subsurface movement of magma, horizontally and vertically.

3. **Increased gas emissions**. Gases are the lightest component of magma, and so they commonly are the first to rise through fractures to the ground surface. Gas emissions increase as magma gets closer to the surface.

Local changes in the magnetic field have also been noted preceding and accompanying some eruptions, and such changes are believed to reflect temperature effects and/or the content of magnetic minerals in the magma.

High pressure in a magma chamber can fracture the surrounding rock, causing small "rock-breaking" quakes. (USGS)





Example of a magmatic tremor on a seismogram. (USGS)

Suggested Reading

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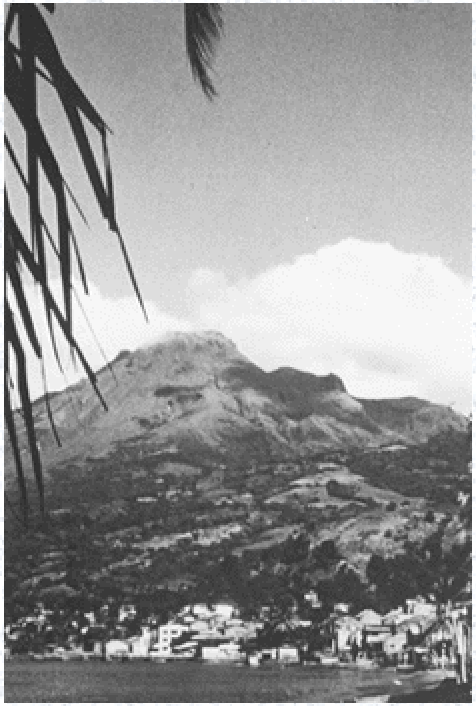

The port city of St. Pierre on the island of Martinique; Mont Pelée is in the background. In 1902, this city was entirely destroyed by pyroclastic flows. About 30,000 people died.