Magma contains dissolved gases that are released into the atmosphere during eruptions. Gases are also released from magma that either remains below ground (for example, as an intrusion) or is rising toward the surface. In such cases, gases may escape continuously into the atmosphere from the soil, volcanic vents, fumaroles, and hydrothermal systems.

At high pressures deep beneath the earth's surface, volcanic gases are dissolved in molten rock. But as magma rises toward the surface where the pressure is lower, gases held in the melt begin to form tiny bubbles. The increasing volume taken up by gas bubbles makes the magma less dense than the surrounding rock, which may allow the magma to continue its upward journey. Closer to the surface, the bubbles increase in number and size so that the gas volume may exceed the melt volume in the magma, creating a magma foam. The rapidly expanding gas bubbles of the foam can lead to explosive eruptions in which the melt is fragmented into pieces of volcanic rock, known as tephra. If the molten rock is not fragmented by explosive activity, a lava flow will be generated.

Together with the tephra and entrained air, volcanic gases can rise tens of kilometers into Earth's atmosphere during large explosive eruptions. Once airborne, the prevailing winds may blow the eruption cloud hundreds to thousands of kilometers from a volcano. The gases spread from an erupting vent primarily as acid aerosols (tiny acid droplets), compounds attached to tephra particles, and microscopic salt particles.

Volcanic gases undergo a tremendous increase in volume when magma rises to the Earth's surface and erupts. For example, consider what happens if one cubic meter of 900°C rhyolite magma containing five percent by weight of dissolved water were suddenly brought from depth to the surface. The one cubic meter of magma now would occupy a volume of 670 m3 as a mixture of water vapor and magma at atmospheric pressure (Sparks et. al., 1997)! The one meter cube at depth would increase to 8.75 m on each side at the surface. Such enormous expansion of volcanic gases, primarily water, is the main driving force of explosive eruptions.

The most abundant gas typically released into the atmosphere from volcanic systems is water vapor (H2O), followed by carbon dioxide (CO2) and sulfur dioxide (SO2). Volcanoes also release smaller amounts of others gases, including hydrogen sulfide (H2S), hydrogen (H2), carbon monoxide (CO), hydrogen chloride (HCL), hydrogen fluoride (HF), and helium (He).

Examples of volcanic gas compositions, in volume percent concentrations

(from Symonds et. al., 1994)

Volcano

Tectonic Style

Temperature Kilauea Summit

Hot Spot

1170°C Erta` Ale

Divergent Plate

1130°C Momotombo

Convergent Plate

820°C

H20 37.1 77.2 97.1

C02 48.9 11.3 1.44

S02 11.8 8.34 0.50

H2 0.49 1.39 0.70

CO 1.51 0.44 0.01

H2S 0.04 0.68 0.23

HCl 0.08 0.42 2.89

HF --- --- 0.26

The volcanic gases that pose the greatest potential hazard to people, animals, agriculture, and property are sulfur dioxide, carbon dioxide, and hydrogen fluoride. Locally, sulfur dioxide gas can lead to acid rain and air pollution downwind from a volcano. Globally, large explosive eruptions that inject a tremendous volume of sulfur aerosols into the stratosphere can lead to lower surface temperatures and promote depletion of the Earth's ozone layer. Because carbon dioxide gas is heavier than air, the gas may flow into in low-lying areas and collect in the soil. The concentration of carbon dioxide gas in these areas can be lethal to people, animals, and vegetation. A few historic eruptions have released sufficient fluorine-compounds to deform or kill animals that grazed on vegetation coated with volcanic ash; fluorine compounds tend to become concentrated on fine-grained ash particles, which can be ingested by animals.

Sulfur dioxide (SO2)

The effects of SO2 on people and the environment vary widely depending on (1) the amount of gas a volcano emits into the atmosphere; (2) whether the gas is injected into the troposphere or stratosphere; and (3) the regional or global wind and weather pattern that disperses the gas. Sulfur dioxide (SO2) is a colorless gas with a pungent odor that irritates skin and the tissues and mucous membranes of the eyes, nose, and throat. Sulfur dioxide chiefly affects upper respiratory tract and bronchi. The World Health Organization recommends a concentration of no greater than 0.5 ppm over 24 hours for maximum exposure. A concentration of 6-12 ppm can cause immediate irritation of the nose and throat; 20 ppm can cause eye irritation; 10,000 ppm will irritate moist skin within minutes.

Emission rates of SO2 from an active volcano range from <20 tonnes/day to >10 million tonnes/day according to the style of volcanic activity and type and volume of magma involved. For example, the large explosive eruption of Mount Pinatubo on 15 June 1991 expelled 3-5 km3 of dacite magma and injected about 20 million metric tons of SO2 into the stratosphere. The sulfur aerosols resulted in a 0.5-0.6°C cooling of the Earth's surface in the Northern Hemisphere. The sulfate aerosols also accelerated chemical reactions that, together with the increased stratospheric chlorine levels from human-made chlorofluorocarbon (CFC) pollution, destroyed ozone and led to some of the lowest ozone levels ever observed in the atmosphere.

At Kilauea Volcano, the recent effusive eruption of about 0.0005 km3/day (500,000 m3) of basalt magma releases about 2,000 tonnes of SO2 into the lower troposphere. Downwind from the vent, acid rain and air pollution is a persistent health problem when the volcano is erupting.

Geologist with gas mask on rim of Pu`u `O`o crater, Kilauea Volcano, Hawai`i

SO2 causes air pollution Volcanic smog

Eruptions of Kilauea Volcano release large quantities of sulfur dioxide gas into the atmosphere that can lead to volcanic air pollution on the Island of Hawai`i. Sulfur dioxide gas reacts chemically with sunlight, oxygen, dust particles, and water to form volcanic smog known as vog.

Space Shuttle image over South America, Mission STS 43

SO2 effects Earth's surface temperature Global cooling and ozone depletion

Measurements from recent eruptions such as Mount St. Helens, Washington (1980), El Chichon, Mexico (1982), and Mount Pinatubo, Philippines (1991), clearly show the importance of sulfur aerosols in modifying climate, warming the stratosphere, and cooling the troposphere. Research has also shown that the liquid drops of sulfuric acid promote the destruction of the Earth's ozone layer.

Please see the web article, "Volcanic Gases and Climate Change Overview" for additional information.

Hydrogen sulfide (H2S)

Hydrogen sulfide (H2S) is a colorless, flammable gas with a strong offensive odor. It is sometimes referred to as sewer gas. At low concentrations it can irritate the eyes and acts as a depressant; at high concentrations it can cause irritation of the upper respiratory tract and, during long exposure, pulmonary edema. A 30-minute exposure to 500 ppm results in headache, dizziness, excitement, staggering gait, and diarrhea, followed sometimes by bronchitis or bronchopneumonia.

Carbon dioxide (CO2)

Volcanoes release more than 130 million tonnes of CO2 into the atmosphere every year. This colorless, odorless gas usually does not pose a direct hazard to life because it typically becomes diluted to low concentrations very quickly whether it is released continuously from the ground or during episodic eruptions. But in certain circumstances, CO2 may become concentrated at levels lethal to people and animals. Carbon dioxide gas is heavier than air and the gas can flow into in low-lying areas; breathing air with more than 30% CO2 can quickly induce unconsciousness and cause death. In volcanic or other areas where CO2 emissions occur, it is important to avoid small depressions and low areas that might be CO2 traps. The boundary between air and lethal gas can be extremely sharp; even a single step upslope may be adequate to escape death.

CO2 trapped in depressions can be lethal to people and animals Burning torch on end of stick, Nyamuragira Volcano, Zaire Smoldering cloth on end of stick, Nyamuragira Volcano, Zaire

When a burning piece of cloth is lowered into a hole that has a high concentration of CO2, the fire goes out. Such a condition can be lethal to people and animals.

Air with 5% CO2 causes perceptible increased respiration; 6-10% results in shortness of breath, headaches, dizziness, sweating, and general restlessness; 10-15% causes impaired coordination and abrupt muscle contractions; 20-30% causes loss of consciousness and convulsions; over 30% can cause death (Hathaway et. al., 1991).

Please see the web article, "Volcanic Gases and Climate Change Overview" for more information on Volcanic versus anthropogenic CO2 emissions.

Historical examples of the effects of carbon dioxide gas

\* Mammoth Mountain in Long Valley Caldera, California kills trees near Mammoth Mountain, California

Hydrogen Chloride (HCl)

Chlorine gas is emitted from volcanoes in the form of hydrochloric acid (HCl). Exposure to the gas irritates mucous membranes of the eyes and respiratory tract. Concentrations over 35 ppm cause irritation of the throat after short exposure; >100 ppm results in pulmonary edema, and often laryngeal spasm. It also causes acid rain downwind from volcanoes because HCl is extremely soluble in condensing water droplets and it is a very "strong acid" (it dissociates extensively to give H+ ions in the droplets).

Hydrogen Fluoride (HF)

Fluorine is a pale yellow gas that attaches to fine ash particles, coats grass, and pollutes streams and lakes. Exposure to this powerful caustic irritant can cause conjunctivitis, skin irritation, bone degeneration and mottling of teeth. Excess fluorine results in a significant cause of death and injury in livestock during ash eruptions. Even in areas that receive just a millimeter of ash, poisoning can occur where the fluorine content of dried grass exceeds 250 ppm. Animals that eat grass coated with fluorine-tainted ash are poisoned. Small amounts of fluorine can be beneficial, but excess fluorine causes fluorosis, an affliction that eventually kills animals by destroying their bones. It also promotes acid rain effects downwind of volcanoes, like HCl.

Secondary Gas Emissions

Another type of gas release occurs when lava flows reach the ocean. Extreme heat from molten lava boils and vaporizes seawater, leading to a series of chemical reactions. The boiling and reactions produce a large white plume, locally known as lava haze or laze, containing a mixture of hydrochloric acid and concentrated seawater.

White acid-rich steam plume rises from lava flows entering the sea

Laze plumes are very acidic

Extreme heat from lava entering the sea rapidly boils and vaporizes seawater, leading to a series of chemical reactions. The boiling and reactions produce a large white plume, locally known as lava haze or laze, which contains a mixture of hydrochloric acid (HCl) and concentrated seawater. This is a short-lived local phenomenon that only affects people or vegetation directly under the plume.

The hydrochloric acid (HCl) comes from the breakdown of seawater-derived chlorides during sudden boiling. Because the lava is largely degassed by the time it reaches the sea, any HCL coming from it is insignificant by comparison. Analyzed samples of the plume show that is is a brine with a salinity of about 2.3 times that of seawater and a pH of 1.5-2.0.

White acid-rich steam plume rises from lava flows entering the sea

Key seawater chloride breakdown reactions that produce HCl gas

\* MgCl2 (sea salt) + H2O (steam) = MgO (periclase) + 2HCl (HCl gas)

\* 2 NaCl (sea salt) + H2O (steam) = Na2O (sodium oxide) + 2 HCL (HCl gas)

\* CaCl2 (sea salt) + H2O (steam) = CaO (lime) + 2 HCL (HCl gas)

Avoid standing beneath a laze plume. Dense laze plumes, such as that shown here (Photograph by C.C. Heliker, February 10, 1994) contain as much as 10-15 parts per million of hydrochloric acid. These values drop off sharply as the plume moves away from the lava entry areas. During along-shore or on-shore winds, this plume produces acid rain that may fall on people and land along the coast. This rain (pH 1.5 to 2), often more acidic that lime juice or stomach acid, is very corrosive to the skin and clothing. Visitors to the lava entry areas should avoid standing directly in, under, or downwind of the laze plume.

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D. Griggs on March 13, 1985

Lava lake at Kupaianaha vent, Kilauea Volcano, Hawai`i

100 m diameter Lava lake, Kupaianaha vent Photograph by J.D. Griggs on

November 18, 1986

In 1986 when the eruption of Kilauea Volcano changed from the episodic fountaining of lava and gas at Pu`u O`o cone every few weeks (first image) to the continuous outpouring of lava from a new vent (second image) only 3 km away, the volcano began releasing a large, steady supply of sulfur dioxide gas into the atmosphere. During the episodic activity, enough time elapsed between fountaining episodes for the prevailing trade winds (brisk winds from the northeast of Hawai`i) to blow volcanic gas away from the island. When the eruption style changed, however, the daily release of as much as 2,000 tons of sulfur dioxide gas led to a persistent air pollution problem downwind.

Sulfur dioxide creates vog

Geologist on rim of Pu`u `O`o, Kilauea Volcano, Hawai`i

SO2 escapes from Pu`u `O`o vent

When sulfur dioxide (SO2)gas is released, it reacts chemically with sunlight, oxygen, dust particles, and water in the air to form a mixture of sulfate (S04-2) aerosols (tiny particles and droplets), sulfuric acid (H2SO4), and other oxidized sulfur species. Together, this gas and aerosol mixture produces a hazy atmospheric condition known as volcanic smog or "vog."

Vog creates hazy conditions

Eruption cloud is blown away from Pu`u `O`o vent, Kilauea Volcano, Hawai`i

Eruption cloud of volcanic gases from Pu`u `O`o Photograph by

R.W. Decker on March 1, 1983

View of Mauna Loa Volcano toward the west from the Hawaiian Volcano Observatory

Normal view Mauna Loa

View of Mauna Loa Volcano toward the west from the Hawaiian Volcano Observatory

Vog obscures Mauna Loa

Strong trade winds blow the eruption cloud from the Pu'u O'o vent toward the southwest and the southern part of the Island of Hawai`i (top left). The cloud consists primarily of water vapor and sulfur dioxide. Note that the cloud rises only a few hundred meters above the ground. The direction and velocity of the prevailing wind largely determine the intensity and general location of vog conditions on the Island of Hawai`i. Vog often accumulates against the southwest flank of Mauna Loa Volcano lower right) during normal tradewind conditions.

Trade winds concentrate vog on leeward side of Hawai`i

Shaded-relief map of the Island of Hawai`i

Shaded-relief map of the Island of Hawai`i

This digital shaded-relief map shows the usual wind conditions on the island of Hawai`i. Moderate to strong trade winds carry gases and vog from Kilauea Volcano around the southern tip of the island where the gas tends to accumulate on the leeward or "kona" coast. During these usual conditions, vog often becomes trapped by daytime (onshore) and night-time (offshore) breezes (double-headed arrows). During the day, onshore sea breezes carry vog up the slopes of Hualalai and Mauna Loa volcanoes, and into the topographic saddle between Mauna Loa and Mauna Kea. When the landmass cools in the evening, cooler, denser air and vog flow back down to the coast. However, when the trade winds are light or absent or when winds blow from the south, much of the vog stays on the eastern side of the island where it sometimes moves into the city of Hilo.

Vog and acid rain affect water quality

House and water-catchment tank

Photograph by J.D. Griggs

Many residents on the island of Hawaii depend on rainwater collected by rooftop catchment systems for drinking water. The continuous release of volcanic gases, especially sulfur dioxide, causes rainwater to become acidic downwind of Kilauea's erupting vents. When it falls on roofs, this acid rain leaches lead from roofing nails and paint. The lead-contaminated rainwater then fills the water catchment tanks, creating a health hazard.

1992-1997 SO2 emissions rates from Kilauea Volcano's east rift zone

Averaged SO2 emissions (in metric tons) from Kilauea's east rift zone as measured by vehicle-based COSPEC along Chain of Craters Road, 1992 through 1997. The black vertical bars represent the standard deviation of all traverses on a single day. These measurements have typically provided the best integrated estimate of Kilauea's ERZ SO2 release. Figure is reproduced from Elias, 1998 (see references below). This report is available online.

More about vog

Fact sheet, Volcanic Air Pollution -- A Hazard in Hawai`i

Volcano Watch articles, from the USGS Hawaiian Volcano Observatory

\* Vog -- a 1999 owners guide for Big Island Residents, Feb. 1999

\* Greenhouse gases in our backyard, Oct. 1998

\* Increases in vog may not mean increases in volcanic activity, July 1997

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Volcanic ash vs sulfur aerosols

The primary role of volcanic sulfur aerosols in causing short-term changes in the world's climate following some eruptions, instead of volcanic ash, was hypothesized by scientists in the early 1980's. They based their hypothesis on the effects of several explosive eruptions in Indonesia and the world's largest historical effusive eruption in Iceland.

Scientists studied three historical explosive eruptions of different sizes in Indonesia--Tambora (1815), Krakatau (1883), and Agung (1963). They noted that decreases in surface temperatures after the eruptions were of similar magnitude (0.18-1.3 °C). The amount of material injected into the stratosphere, however, differed greatly. By comparing the estimated amount of ash vs. sulfur injected into the stratosphere by each eruption, it was suggested that the longer residence time of sulfate aerosols, not the ash particles which fall out within a few months of an eruption, was the paramount controlling factor (Rampino and Self, 1982).

In contrast to these explosive eruptions, one of the most severe volcano-related climate effects in historical times was associated with a largely nonexplosive eruption that produced very little ash--the 1783 eruption of Laki crater-row in Iceland. The eruption lasted 8-9 months and extruded about 12.3 km3 of basaltic lava over an area of 565 km2. A bluish haze of sulfur aerosols all over Iceland destroyed most summer crops in the country; the crop failure led to the loss of 75% of all livestock and the deaths of 24% of the population (H. Sigurdsson, 1982). The bluish haze drifted east across Europe during the 1783-1784 winter, which was unusually severe.

Clearly, these examples suggested that the explosivity of an eruption and the amount of ash injected into the stratosphere are not the main factors in causing a change in Earth's climate. Instead, scientists concluded that it must be the amount of sulfur in the erupting magma.

The eruption of El Chichon, Mexico, in 1982 conclusively demonstrated this idea was correct. The explosive eruption injected at least 8 Mt of sulfur aerosols into the atmosphere, and it was followed by a measureable cooling of parts of the Earth's surface and a warming of the upper atmosphere. A similar-sized eruption at Mount St. Helens in 1980, however, injected only about 1 Mt of sulfur aerosols into the stratosphere. The eruption of Mount St. Helens injected much less sulfur into the atmosphere--it did not result in a noticeable cooling of the Earth's surface. The newly launched TOMS satellite (in 1978) made it possible to measure these differences in the eruption clouds. Such direct measurements of the eruption clouds combined with surface temperatures make it possible to study the corrleation between volcanic sulfur aerosols (instead of ash) and temporary changes in the world's climate after some volcanic eruptions.

Volcanic interactions with the atmosphere

Diagram physical and chemical processes of volcanic gas interactions in atmosphere

Figure modified by K. McGee et. al.,

from R. Turco, in Volcanism and

Climate Change, 1992

The most significant impacts from large explosive eruptions come from the conversion of sulfur dioxide (SO2) to sulfuric acid (H2SO4), which condenses rapidly in the stratosphere to form fine sulfate aerosols. The aerosols increase the reflection of radiation from the Sun back into space and thus cool the Earth's lower atmosphere or troposphere; however, they also absorb heat radiated up from the Earth, thereby warming the stratosphere.

Ozone depletion promoted by volcanic sulfur aerosols.

The sulfate aerosols also promote complex chemical reactions on their surfaces that alter chlorine and nitrogen chemical species in the stratosphere. This effect, together with increased stratospheric chlorine levels from chlorofluorocarbon (CFC) pollution, generates chlorine monoxide (ClO), which destroys ozone (O3).

USGS Global Change Research Program

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* [Publications](http://volcanoes.usgs.gov/publications/index.php)
* [Observatories](http://volcanoes.usgs.gov/vhp/observatories.php)

**Lahars and Their Effects**

[[Erosion scar marks lahar pathway in Guali River valley, Nevado del 
Ruiz, Colombia](http://volcanoes.usgs.gov/hazards/lahar/ruiz.php)](http://volcanoes.usgs.gov/hazards/lahar/ruiz.php)

[Gualí River valley. Photograph by R. Janda on December 18, 1985](http://volcanoes.usgs.gov/hazards/lahar/ruiz.php)

Lahar is an Indonesian term that describes a hot or cold mixture of water and rock fragments flowing down the slopes of a volcano and (or) river valleys. When moving, a lahar looks like a mass of wet concrete that carries rock debris ranging in size from clay to boulders more than 10 m in diameter. Lahars vary in size and speed. Small lahars less than a few meters wide and several centimeters deep may flow a few meters per second. Large lahars hundreds of meters wide and tens of meters deep can flow several tens of meters per second--much too fast for people to outrun.

As a lahar rushes downstream from a volcano, its size, speed, and the amount of water and rock debris it carries constantly change. The beginning surge of water and rock debris often erodes rocks and vegetation from the side of a volcano and along the river valley it enters. This initial flow can also incorporate water from melting snow and ice (if present) and the river it overruns. By eroding rock debris and incorporating additional water, lahars can easily grow to more than 10 times their initial size. But as a lahar moves farther away from a volcano, it will eventually begin to lose its heavy load of sediment and decrease in size.

Eruptions may trigger one or more lahars directly by quickly melting snow and ice on a volcano or ejecting water from a crater lake. More often, lahars are formed by intense rainfall during or after an eruption--rainwater can easily erode loose volcanic rock and soil on hillsides and in river valleys. Some of the largest lahars begin as landslides of saturated and hydrothermally altered rock on the flank of a volcano or adjacent hillslopes. Landslides are triggered by eruptions, earthquakes, precipitation, or the unceasing pull of gravity on the volcano.

Lahars almost always occur on or near stratovolcanoes because these volcanoes tend to erupt explosively and their tall, steep cones are either snow covered, topped with a crater lake, constructed of weakly consolidated rock debris that is easily eroded, or internally weakened by hot hyrothermal fluids. Lahars are also common from the snow- and ice-covered shield volcanoes in Iceland where eruptions of fluid basalt lava frequently occur beneath huge glaciers.

The scenarios listed below illustrate most of the mechanisms by which lahars are generated. For convenience, we've grouped the mechanisms according to whether a volcano is erupting, has erupted, or is quiet. Each mechanism is illustrated with one or more case studies.

**Lahar Scenarios**

**Lahars During Eruptions**

* [Muddy River, May 18, 1980](http://volcanoes.usgs.gov/hazards/lahar/index.php)
* [Melting of snow and ice](http://volcanoes.usgs.gov/hazards/lahar/snow.php) by pyroclastic flows and lava flows
* [Nevado del Ruiz, Colombia](http://volcanoes.usgs.gov/hazards/lahar/ruiz.php), 1985
* [Villarrica volcano, Chile](http://volcanoes.usgs.gov/hazards/lahar/villarrica.php), 1984

**Lahars After Eruptions**

* [Heavy rainfall](http://volcanoes.usgs.gov/hazards/lahar/rain.php) can lead to erosion and lahars
* Sudden release of water caused by [lake breakouts](http://volcanoes.usgs.gov/hazards/lahar/lake.php)

**Lahars Without Eruptions**

* [Sudden landslides](http://volcanoes.usgs.gov/hazards/lahar/slide.php) at volcanoes can trigger lahars
* [Huila Volcano, Colombia](http://volcanoes.usgs.gov/hazards/lahar/huila.php), 1994 - Earthquake and Landslide induced
* [Casita Volcano, Nicaragua](http://volcanoes.usgs.gov/hazards/lahar/casita.php), 1999
* [What's that cloud upriver?](http://volcanoes.usgs.gov/hazards/lahar/santiaguito89.php) An eyewitness account of a lahar triggered by rainfall in Guatemala.
* [Ontake volcano, Japan](http://volcanoes.usgs.gov/hazards/lahar/ontake.php), 1984

Lahars racing down river valleys and spreading across flood plains tens of kilometers downstream from a volcano often cause serious economic and environmental damage. The direct impact of a lahar's turbulent flow front or from the boulders and logs carried by the lahar can easily crush, abrade, or shear off at ground level just about anything in the path of a lahar. Even if not crushed or carried away by the force of a lahar, buildings and valuable land may become partially or completely buried by one or more cement-like layers of rock debris. By destroying bridges and key roads, lahars can also trap people in areas vulnerable to other hazardous volcanic activity, especially if the lahars leave deposits that are too deep, too soft, or too hot to cross.

After a volcanic eruption, the erosion of new loose volcanic deposits in the headwaters of rivers can lead to severe flooding and extremely high rates of sedimentation in areas far downstream from a volcano. Over a period of weeks to years, post-eruption lahars and high-sediment discharges triggered by intense rainfall frequently deposit rock debris that can bury entire towns and valuable agricultural land. Such lahar deposits may also block tributary stream valleys. As the area behind the blockage fills with water, areas upstream become inundated. If the lake is large enough and it eventually overtops or breaks through the lahar blockage, a sudden flood or a lahar may bury even more communities and valuable property downstream from the tributary.

**Lahars can destroy by direct impact**

Building foundation left behind by lahars in Armero, 
Colombia

Photograph by T. Pierson in November 1985. This cement foundation is all that remains of a building that was crushed and carried away by the direct impact of a lahar as it swept through Armero, Colombia. The building was near the main channel of the Lagunillas River and took the full force of the lahar that swept 74 km from Nevado del Ruiz volcano on November 13, 1985.

**Lahars can lead to increased deposition of sediment**

Lahar deposits covering agricultural land, Mount 
Pinatubo, Philippines

Photograph by T. Pierson on August 23, 1991 In the years since the 15 June 1991 eruption of Mount Pinatubo in the Philippines, sediment carried by rain-induced lahars have displaced more than 50,000 people from their homes and covered at least 400 km2 of rich agricultural land. This view of the Abacan River shows sediment deposited on farmland and a nearby community within 2 months of Pinatubo's explosive eruption. Nearly all the post-eruption lahars have been caused by intense rainfall, especially during typhoons and monsoon season, which easily erodes the loose pyroclastic-flow deposits that fill the headwaters of all rivers draining the volcano.

**Lahars can block tributary streams**

[Lahar-dammed lake downstream from Mount Pinatubo, 
Philippines](http://volcanoes.usgs.gov/Hazards/Effects/PinaLake_caption.html)

Photograph by C. Newhall on August 30, 1994 This lake formed in 1994 behind a blockage created chiefly by lahar deposits in the Pasig-Portrero River about 12 km from Mount Pinatubo in the Philippines, though some secondary pyroclastic flows may have contributed (the river flows right to left). After a moderate rainfall, the lake broke out on the night of 22 September 1994. A sudden surge of water swept downstream, increasing in size as the rushing water eroded sediment from previous lahar deposits. Approximately 25 people were killed by the lake breakout, mostly in a community located about 15 km downstream.

**Lahars can bury valleys and communities with debris**

[House partially buried by lahar deposits downstream 
from Unzen Volcano, Japan](http://volcanoes.usgs.gov/Hazards/Effects/UnzenHome_caption.html)

Photograph by T. Pierson on February 3, 1995 Hundreds of lahars sweeping down from nearby Unzen Volcano in Japan buried, crushed, or carried away more than a thousand homes like this one along the Mizunashi River. Between August 1992 and July 1993, lahars triggered by heavy rains damaged about 1,300 houses. Each period of heavy rain required the sudden evacuation of several thousand residents along two rivers heading on the volcano. The deposits from these lahars consisted chiefly of lava fragments derived from partial collapses of the summit lava dome located 5 to 8 km upstream.

**Pyroclastic Flows and Their Effects**

**About Pyroclastic Flows**

Pyroclastic flows are high-density mixtures of hot, dry rock fragments and hot gases that move away from the vent that erupted them at high speeds. They may result from the explosive eruption of molten or solid rock fragments, or both. They may also result from the nonexplosive eruption of lava when parts of dome or a thick lava flow collapses down a steep slope. Most pyroclastic flows consist of two parts: a basal flow of coarse fragments that moves along the ground, and a turbulent cloud of ash that rises above the basal flow. Ash may fall from this cloud over a wide area downwind from the pyroclastic flow.

**Pyroclastic Flows**

[](http://volcanoes.usgs.gov/Imgs/Jpg/PFeffects/30423808-027_caption.html)

...destroy by   
direct impact.

[](http://volcanoes.usgs.gov/Imgs/Jpg/PFeffects/3041135-092_caption.html)

...bury sites with   
hot rock debris.

[](http://volcanoes.usgs.gov/Imgs/Jpg/PFeffects/20110906-049_caption.html)

...melt snow and   
ice to form lahars.

[](http://volcanoes.usgs.gov/Imgs/Jpg/PFeffects/32424296-082_caption.html)

...burn forests,   
crops, and buildings.

**Effects of Pyroclastic Flows**

A pyroclastic flow will destroy nearly everything in its path. With rock fragments ranging in size from ash to boulders traveling across the ground at speeds typically greater than 80 km per hour, pyroclastic flows knock down, shatter, bury or carry away nearly all objects and structures in their way. The extreme temperatures of rocks and gas inside pyroclastic flows, generally between 200°C and 700°C, can cause combustible material to burn, especially petroleum products, wood, vegetation, and houses.

Pyroclastic flows vary considerably in size and speed, but even relatively small flows that move less than 5 km from a volcano can destroy buildings, forests, and farmland. And on the margins of pyroclastic flows, death and serious injury to people and animals may result from burns and inhalation of hot ash and gases.

Pyroclastic flows generally follow valleys or other low-lying areas and, depending on the volume of rock debris carried by the flow, they can deposit layers of loose rock fragments to depths ranging from less than one meter to more than 200 m. Such loose layers of ash and volcanic rock debris in valleys and on hillslopes can lead to lahars indirectly by:

1. Damming or blocking tributary streams, which may cause water to form a lake behind the blockage, overtop and erode the blockage, and mix with the rock fragments as it rushes downstream (for example, see this case study at Pinatubo Volcano, Philippines)

2. Increasing the rate of stream runoff and erosion during subsequent rainstorms. Hot pyroclastic flows and surges can also directly generate lahars by eroding and mixing with snow and ice on a volcano's flanks, thereby sending a sudden torrent of water surging down adjacent valleys (see case study from Nevado del Ruiz volcano, Colombia).

# Volcano Landslides and their Effects

Landslides are large masses of rock and soil that fall, slide, or flow very rapidly under the force of gravity. These mixtures of debris move in a wet or dry state, or both. Landslides commonly originate as massive rockslides or avalanches which disintegrate during movement into fragments ranging in size from small particles to enormous blocks hundreds of meters across. If the moving rock debris is large enough and contains a large content of water and fine material (typically, >3-5 percent of clay-sized particles), the landslide may transform into a lahar and flow downvalley more than 100 km from a volcano!

Volcano landslides range in size from less than 1 km3 to more than 100 km3. The high velocity (>100 km/hr) and great momentum of landslides allows them to run up slopes and to cross valley divides up to several hundred meters high. For example, the landslide at Mount St. Helens on May 18, 1980, had a volume of 2.5 km3, reached speeds of 50-80 m/s (180-288 km/hr), and surged up and over a 400 m tall ridge located about 5 km from the volcano!

Landslides are common on volcanoes because their massive cones (1) typically rise hundreds to thousands of meters above the surrounding terrain; and (2) are often weakened by the very process that created them--the rise and eruption of molten rock. Each time magma moves toward the surface, overlying rocks are shouldered aside as the molten rock makes room for itself, often creating internal shear zones or oversteepening one or more sides of the cone. Magma that remains within the cone releases volcanic gases that partially dissolve in groundwater, resulting in a hot acidic hydrothermal system that weakens rock by altering rock minerals to clay. Furthermore, the tremendous mass of thousands of layers lava and loose fragmented rock debris can lead to internal faults and fault zones that move frequently as the cone "settles" under the downward pull of gravity.

These conditions permit a number of factors to trigger a landslide or to allow part of a volcano's cone to simply collapse under the influence of gravity:

* intrusion of magma into a volcano
* explosive eruptions (magmatic or phreatic--steam-driven explosions)
* large earthquake directly beneath a volcano or nearby (typically >M5)
* intense rainfall that saturates a volcano or adjacent tephra-covered hillslopes with water, especially before or during a large earthquake.

A landslide typically destroys everything in its path and may generate a variety of related activity. Historically, landslides have caused explosive eruptions, buried river valleys with tens of meters of rock debris, generated lahars, triggered waves and tsunami, and created deep horseshoe-shaped craters.

By removing a large part of a volcano's cone, a landslide may abruptly decrease pressure on the shallow magmatic and hydrothermal systems, which can generate explosions ranging from a small steam explosion to large steam- and magma-driven directed blasts. A large landslide often buries valleys with tens to hundreds of meters of rock debris, forming a chaotic landscape marked by dozens of small hills and closed depressions. If the deposit is thick enough, it may dam tributary streams to form lakes in the subsequent days to months; the lakes may eventually drain catastrophically and generate lahars and floods downstream.

Landslides also generate some of the largest and most deadly lahars, either by transforming directly into a lahar or, after it stops moving, from dewatering of the deposit. Historically, however, the most deadly volcano landslide occurred in 1792 when sliding debris from Mt. Mayuyama near Unzen Volcano in Japan slammed into the Ariaka Sea and generated a wave on the opposite side that killed nearly 15,000 people.

On a volcano, landslides typically carve deep gashes into its cone or create large horseshoe-shaped craters hundreds of meters deep and more than a kilometer in width.

#### Volcanic landslides can...

[Sketch of volcano landslide and directed blast, Mount St. Helens, 
Washington](http://volcanoes.usgs.gov/Imgs/Gif/Drawings/30210600-084_large.gif)

trigger volcanic   
explosions.

The illustration shows the landslide (green) and directed blast (red) that occurred during the first few minutes of the eruption of Mount St. Helens in 1980.

Before the eruption, an estimated 0.11 km3 of dacite magma had intruded into the volcano (equivalent to sphere about 600 m in diameter!). The rising magma forced the volcano's north flank (right side of illustration) outward about 150 m and heated the volcano's ground water system, causing many steam-driven explosions (phreatic eruptions).

The hot magma and surrounding hydrothermal system were unroofed by the landslide (green), and the resulting rapid depressurization caused a series of steam- and volcanic-gas-driven explosions. The explosions burst through part of the landslide, blasting rock debris northward. The resulting pyroclastic surge quickly overran the landslide and spread over ridges and valleys across an area of 550 km2.

[House partially buried by a lahar deposit, Mount St. Helens, 
Washington](http://volcanoes.usgs.gov/Imgs/Jpg/MSH/30410914-057_large.jpg)

generate lahars that  
travel far   
downstream.

This house is partially buried in a lahar deposit that was formed by the dewatering of a large volcano landslide from Mount St. Helens, Washington. Early on the morning of May 18, 1980, the landslide swept into the upper North Fork Toutle River valley and came to rest within about 22 km of the volcano. The landslide deposit, however, was saturated with water, and contained snow and ice blocks from the volcano's former glaciers. As soon as the landslide stopped moving, water percolated to the top of the deposit and poured across its irregular surface, forming many lahars that merged as they rushed down the valley. The peak flow swept from the deposit about 5 hours after the landslide was emplaced!

The lahar flowed down the Toutle River throughout the afternoon and evening, reaching its peak at midnight about 60 km downstream from the volcano. The lahar destroyed roads, bridges, and homes.

Many volcano landslides do not stop so close to their source, but instead keep moving by transforming directly into a lahar. These lahars can be extremely hazardous because of their size and mobility (they may travel more than 100 km). **Photograph by L. Topinka in 1981**

[](http://volcanoes.usgs.gov/Imgs/Jpg/Unzen/MayuyamaSlide_large.jpg)

cause waves and   
tsunamis in a lake   
or ocean.

View of Mt. Mayuyama is toward the north (**Photograph by T. Casadevall in 1991**). Mt. Mayuyama is one of the dacite lava domes that form the Unzen Volcano complex on Kyushu Island, Japan. The east flank of Mt. Mayuyama collapsed without warning on May 21, 1792, and generated a landslide that swept through Shimabara City and slammed into the Ariaka Sea. The displacement of water triggered a tsunami along the adjacent shoreline of Shimabara Peninsula (visible above and right of Mayuyama) and also 17-23 km across the Ariaka Sea in neighboring provinces. The landslide and tsunami killed nearly 15,000 people, Japan's worst historical volcanic disaster.

Scientists have interpreted the conspicuous hummocks along the shore as part of a landslide deposit that occurred before 1792. Maps submitted to the Tokugawa Shogunate in 1792 as the official documents of the Shimabara Catastrophe clearly show the existence of small islands before the disaster struck.

Other historical volcano landslides are known to have generated tsunami, including:

* landslide from Kamagatake volcano on Hokkaido Island, Japan, in 1640 killed 700 people
* landslide from Oshima-Oshima Volcano on Hokkaido Island, Japan, in 1741-42 killed 1,474 people on Hokkaido and northern Honshu
* landslide from Augustine Volcano, Alaska, in 1883 triggered a tsunami that swept across Cook Inlet onto the Kenai Peninsula but caused no damage

[](http://volcanoes.usgs.gov/Imgs/Jpg/MSH/30212265-050_caption.html)

bury river valleys   
with rock debris.

A scientist stands on one of the many small hills called hummocks that form the chaotic surface of a massive landslide deposit in the upper North Fork Toutle River valley below Mount St. Helens volcano (10 km in distance). Before the landslide and eruption on May 18, 1980, a forest grew on this part of the valley floor, and a highway followed the meandering river to Spirit Lake, a popular recreation area.

The landslide deposit extends about 22 km from the volcano and buries the river valley to an average depth of about 45 m. In places, the deposit is nearly 200 m thick! The landslide covers an area of about 60 km2.

An exceptionally large landslide deposit was discovered at Mount Shasta shortly after the eruption of Mount St. Helens. This landslide has a volume of about 45 km3--nearly 20 times larger than the one that buries the North Fork Toutle River valley (above)--and it covers an area of 675 km2. **Photograph by L. Topinka in 1981.**

[Coldwater Lake, blocked by landslide deposit, Mount St. Helens, 
Washington](http://volcanoes.usgs.gov/Imgs/Jpg/MSH/Coldwater1981_Topinka_caption.html)

dam tributary   
streams to form lakes.

View is looking northwest up the valley of former Coldwater Creek, now filled with a lake. When the landslide from Mount St. Helens slid into the North Fork Toutle River valley (foreground), it blocked the flow of Coldwater Creek. Water backed up behind the landslide deposit, gradually forming a lake about 8 km long and 55 m deep. The landslide was rushed down the Toutle valley from right to left.

Concern about the sudden breakout of water from Coldwater Lake from failure of the drebris dam or overtopping and subsequent erosion of the dam, led the Corps of Engineers in 1981 to control the lake level by excavating an outlet channel that delivers water to the Toutle River.

The fan-shaped delta on the southeast shore of Coldwater Lake forms where a stream from South Fork Coldwater Creek pours into the lake. The delta began to grow quickly when water from Spirit Lake was diverted into Coldwater Creek beginning in 1985. A long tunnel was drilled through a ridge to deliver water from Spirit Lake into South Fork Coldwater Creek in order to stabilize the level of Spirit Lake. **Photograph by L. Topinka on January 13, 1984.**

[](http://volcanoes.usgs.gov/Imgs/Jpg/MSH/30210600_056_caption.html)

create a crater or  
scar on volcano.

View is looking south into the crater of Mount St. Helens formed by an enormous landslide on May 18, 1980. The newly-formed crater is about 2 km wide (east-west), 3 km long (north-south), and about 600 m deep. The landslide removed about 2.3 km3 from the volcano's cone, which towered 1,035 m above the crater floor!

Large horseshoe-shaped craters, open at one end, have long been noted in many volcanic regions around the world. The origin of these breached craters has been controversial, but since the landslide and eruption of Mount St. Helens in 1980, many have been interpreted by scientists as the result of a landslide.

If a large landslide creates a horseshoe-shaped crater that exposes a volcano's eruptive vent, the deep crater will likely direct subsequent volcanic activity (lava flows, pyroclastic flows, or lahars) toward its breached opening. A new hazard assessment may be necessary to determine the way in which volcano-hazard areas downslope from the crater may have changed. **Photograph by C.D. Miller in 1980.**

### All cases can be found on our old site

#### Historical landslides

* [Mount St. Helens, Washington](http://volcanoes.usgs.gov/hazards/lahar/snow.php), 1980
* [Otake volcano, Japan](http://volcanoes.usgs.gov/hazards/lahar/ontake.php), 1984
* [Huila Volcano, Colombia](http://volcanoes.usgs.gov/hazards/lahar/huila.php), 1994
* [Casita Volcano, Nicaragua](http://volcanoes.usgs.gov/hazards/lahar/casita.php), 1999

#### Pre-historical landslides

* Landslides at [Mount Rainier volcano, Washington](http://volcanoes.usgs.gov/hazards/landslide/rainier.php)
* Examples of [volcanic landslide deposits](http://volcanoes.usgs.gov/hazards/landslide/examples.php) from the United States and around the world
* [Activity](http://volcanoes.usgs.gov/activity/index.php)
* [Learn](http://volcanoes.usgs.gov/about/index.php)
* [Images](http://volcanoes.usgs.gov/images/index.php)
* [Hazards](http://volcanoes.usgs.gov/hazards/index.php)
* [Publications](http://volcanoes.usgs.gov/publications/index.php)
* [Observatories](http://volcanoes.usgs.gov/vhp/observatories.php)

**Lava Flows and their Effects**

[](http://volcanoes.usgs.gov/Imgs/Jpg/MaunaLoa/16112441_061_caption.html)

Fluid basalt lava flow,   
Mauna Loa, Hawai`i

Lava flows are streams of molten rock that pour or ooze from an erupting vent. Lava is erupted during either nonexplosive activity or explosive lava fountains. Lava flows destroy everything in their path, but most move slowly enough that people can move out of the way. The speed at which lava moves across the ground depends on several factors, including (1) type of lava erupted and its viscosity; (2) steepness of the ground over which it travels; (3) whether the lava flows as a broad sheet, through a confined channel, or down a lava tube; and (4) rate of lava production at the vent.

Fluid basalt flows can extend tens of kilometers from an erupting vent. The leading edges of basalt flows can travel as fast as 10 km/hour on steep slopes but they typically advance less than 1 km/hour on gentle slopes. But when basalt lava flows are confined within a channel or lava tube on a steep slope, the main body of the flow can reach velocities >30 km/hour.

Viscous andesite flows move only a few kilometers per hour and rarely extend more than 8 km from their vents. Viscous dacite and rhyolite flows often form steep-sided mounds called lava domes over an erupting vent. Lava domes often grow by the extrusion of many individual flows >30 m thick over a period of several months or years. Such flows will overlap one another and typically move less than a few meters per hour.

[`A`a lava flow moves through intersection, Royal Gardens 
subdivision, Kilauea Volcano, Hawai`i](http://volcanoes.usgs.gov/Imgs/Jpg/Kilauea/30212265-054_large.jpg)

`A`a lava flow moves through an intersection   
in the Royal Garderns subdivision on the south   
flank of Kilauea Volcano, Hawai`i. Photograph   
by J.D. Griggs in 1984.

Everything in the path of an advancing lava flow will be knocked over, surrounded, or buried by lava, or ignited by the extremely hot temperature of lava. When lava erupts beneath a glacier or flows over snow and ice, meltwater from the ice and snow can result in far-reaching lahars. If lava enters a body of water or water enters a lava tube, the water may boil violently and cause an explosive shower of molten spatter over a wide area. Methane gas, produced as lava buries vegetation, can migrate in subsurface voids and explode when heated. Thick viscous lava flows, especially those that build a dome, can collapse to form fast-moving pyroclastic flows.

Deaths caused directly by lava flows are uncommon because most move slowly enough that people can move out the way easily and flows usually don't travel far from the vent. Death and injury can result when onlookers approach an advancing lava flow too closely or their retreat is cut off by other flows. Deaths attributed to lava flows are often due to related causes, such as explosions when lava interacts with water, the collapse of an active lava delta, asphyxiation due to accompanying toxic gases, pyroclastic flows from a collapsing dome, and lahars from meltwater.

Other natural phenomena such as hurricanes, tornadoes, tsunami, fires, and earthquakes often destroy buildings, agricultural crops, and homes, but the owner(s) can usually rebuild or repair structures and their businesses in the same location. Lava flows, however, can bury homes and agricultural land under tens of meters of hardened black rock; landmarks and property lines become obscured by a vast, new hummocky landscape. People are rarely able to use land buried by lava flows or sell it for more than a small fraction of its previous worth.

[](http://volcanoes.usgs.gov/Imgs/Jpg/Kilauea/30210600-046_large.jpg)

Lava buries or   
surrounds everything...

Lava erupted from Kilauea Volcano covers part of Highway 130 on the southeast coast of the Island of Hawai`i. By the end of 1998, lava from the Pu`u` `O`o - Kupaianaha eruption covered about 13 km of the highway to depths as great as 25 m. Between 1983 and 1998, lava flows covered an area of 99.7 km2 (38.5 mi2).

Because lava flows can completely block roads and highways that may serve as the only evacuation route for people threatened by an advancing flow, it is vital for communities that could be inundated with lava to develop emergency-response plans.

More information about the [Pu`u `O`o - Kupaianaha eruption](http://wwwhvo.wr.usgs.gov/kilauea/summary/main.html) is available from the USGS Hawaiian Volcano Observatory.

[](http://volcanoes.usgs.gov/Imgs/Jpg/Kilauea/30210600-045_large.jpg)

Intense heat of lava   
melts or burns

One of the chief threats of lava flows to property owners is that the flows may burn buildings and homes even if the flow doesn't reach the structure. This house caught fire from the intense heat of an advancing `a`a flow (note red glow of flow left of the house).

Basalt has the highest temperature of any lava, typically between about 1170-1100°C (~2140-2000°F). The other lava types (andesite, dacite, and rhyolite) form cooler flows with temperatures between about 1000-800°C (~1800-1500°F); some flows can still move slowly at temperatures as low as about 600°C (~1100°F).

[](http://volcanoes.usgs.gov/Imgs/Jpg/Vatnajokull/Vatnajokull-19961003_large.jpg)

Lava melts snow and   
ice to form jökulhlaups   
and lahars.

**View of eruption crater and ash-covered Vatnajökull glacier about 36 hours after the eruption had broken through the ice.** By this time, the area of subsidence had grown to about 9 km long and 2-3 km wide. The eruption continued for about another 10 days, and meltwater from the glacier flowed into the Grímsvötn caldera. On October 1, water level in the caldera's subglacial lake was about 1410 m; by October 16, the water level had risen to 1504 m, an increase of 94 m! According to scientists monitoring the activity, lava erupting from the fissure was piled up on the ground beneath the glacier, "forming a mountain ridge which in places is expected to be 200 m high."

On October 16, scientists stated that the meltwater, which had been accumulating under the ice shelf in the Grímsvötn caldera lake, could begin draining at any time to trigger a jökulhlaup (glacial outburst flood). On November 5 the expected jökulhlaup began. **Photograph courtesy of Magnús Tumi Guðmundsson. Science Institute, University of Iceland. October 1, 1996, 12:30 p.m.**

[](http://volcanoes.usgs.gov/Imgs/Jpg/Colima/19981122Pf_large.jpg)

Collapsing lava flows  
trigger pyroclastic flows.

Aerial view of Colima Volcano moments after a lava flow on the upper flank of the volcano collapsed; the photograph is tilted slightly (horizon is in upper right). The white plume is rising directly from the summit of the volcano. The tan-colored ash cloud on the volcano's flank (left side in this view) is rising from a pyroclastic flow. The fast-moving pyroclastic flow was caused by the collapse of a thick lava flow that was extruding from the summit area and oozing down the volcano's steep upper cone. When the lava flow collapsed, the hot lava broke apart into fragments ranging in size from boulders to tiny ash particles and swept down the volcano under the influence of gravity to form the pyroclastic flow; the flow reached a maximum distance of 4.5 km from the summit. **Photograph courtesy of Abel Cortes, Colima Volcano Observatory, University of Colima, November 22, 1998.**

[**Photo glossary**](http://volcanoes.usgs.gov/images/pglossary/) **starting points**

* [`A`a flows](http://volcanoes.usgs.gov/images/pglossary/aa.php)
* [Pahoehoe (includes links to more additional textures)](http://volcanoes.usgs.gov/images/pglossary/pahoehoe.php)
* [Lava flows (includes additional features and characteristics)](http://volcanoes.usgs.gov/images/pglossary/LavaFlow.php)

**Kilauea Volcano, Hawai`i**

* [Timeline of recent Kilauea activity](http://hvo.wr.usgs.gov/kilauea/timeline/)
* [Spectacular show underway at lava ocean entry](http://hvo.wr.usgs.gov/volcanowatch/2008/08_07_17.html)
* [Pele revisits Royal Gardens (lava flows)](http://hvo.wr.usgs.gov/volcanowatch/2008/08_02_28.html)
* [Kalapana covered by flows, 1990](http://hvo.wr.usgs.gov/kilauea/history/1990Kalapana/)
* [Kaphoho covered by flows, 1960](http://hvo.wr.usgs.gov/kilauea/history/1960Jan13/)
* [Summit Eruption of Kilauea Volcano, in Kilauea Iki Crater, 1959](http://hvo.wr.usgs.gov/kilauea/history/1959Nov14/)

**Mauna Loa Volcano, Hawai`i**

* [Summary of the 1984 eruption that threatened Hilo, Hawai`i](http://hvo.wr.usgs.gov/maunaloa/history/1984.html)
* [Large 1950 eruption sent lava into sea in less than 4 hours](http://hvo.wr.usgs.gov/maunaloa/history/50_06_01/)
* [Activity](http://volcanoes.usgs.gov/activity/index.php)
* [Learn](http://volcanoes.usgs.gov/about/index.php)
* [Images](http://volcanoes.usgs.gov/images/index.php)
* [Hazards](http://volcanoes.usgs.gov/hazards/index.php)
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* [Observatories](http://volcanoes.usgs.gov/vhp/observatories.php)

**Volcanic Hazards: Tephra, including volcanic ash**

[](http://volcanoes.usgs.gov/Imgs/Jpg/Tephra/30210599-008_caption.html)

Mount St.   
Helens,   
Washington;   
eruption column

[](http://volcanoes.usgs.gov/Imgs/Jpg/Tephra/dds24-112_caption.html)

Kilauea Volcano,  
Hawai`i; lava   
fountain

Tephra is a general term for fragments of volcanic rock and lava regardless of size that are blasted into the air by explosions or carried upward by hot gases in eruption columns or lava fountains. Such fragments range in size from less than 2 mm (ash) to more than 1 m in diameter. Large-sized tephra typically falls back to the ground on or close to the volcano and progressively smaller fragments are carried away from the vent by wind. Volcanic ash, the smallest tephra fragments, can travel hundreds to thousands of kilometers downwind from a volcano.

|  |  |  |  |
| --- | --- | --- | --- |
| [Tephra sample: block of dacite lava erupted by Mount St. Helens](http://volcanoes.usgs.gov/Imgs/Jpg/Tephra/30210599_014_caption.html)  **Mount St. Helens Tephra: block** | [Tephra sample: volcanic ash erupted by Mount St. Helens on May 18,  1980](http://volcanoes.usgs.gov/Imgs/Jpg/Tephra/30410914_075_caption.html)  **Mount St. Helens Tephra: ash & pumice** | [Tephra sample: reticulite, Kilauea Volcano](http://volcanoes.usgs.gov/Imgs/Jpg/Tephra/DAS10151998_043_caption.html)  **Kilauea Tephra: reticulite** | [Tephra sample: Pele's hair, Kilauea Volcano](http://volcanoes.usgs.gov/Imgs/Jpg/Tephra/30410914_030_caption.html)  **Kilauea Tephra: Pele's hair** |
| Tephra consists of a wide range of rock particles (size, shape, density, and chemical composition), including combinations of pumice, glass shards, crystals from different types of minerals, and shattered rocks of all types (igneous, sedimentary, and metamorphic). A great [variety of terms](http://volcanoes.usgs.gov/hazards/tephra/tephraterms.php) are used to describe the range of rock fragments thrown into the air by volcanoes. The terms classify the fragments according to size, shape, or the way in which they form and travel. | | | |

**Volcanic ash: how far will it fall downwind from an erupting volcano?**

[](http://volcanoes.usgs.gov/Imgs/Jpg/Pinatubo/16112441-008_large.jpg)

Pumice and ash cover   
cars and airport runways

Ash usually covers a much larger area and disrupts the lives of far more people than the other more lethal types of volcano hazards. Unfortunately, the size of ash particles that fall to the ground and the thickness of ashfall downwind from an erupting volcano are difficult to predict in advance. Not only is there a wide range in the size of an eruption that might occur and the amount of tephra injected into the atmosphere, but the direction and strength of the prevailing wind can vary widely.

**Case Histories, tephra distribution downwind from eruption**

* [Tephra Falls of the 1991 Eruptions of Mount Pinatubo](http://pubs.usgs.gov/pinatubo/paladio/index.html)  
  online report from Fire and Mud: eruptions and lahars of Mount Pinatubo, Philippines.
* [Tephra fall from Mount St. Helens, Washington, on May 18, 1980](http://volcanoes.usgs.gov/hazards/tephra/mshtephradist.php)  
  graph, ash thickness and particle size downwind from volcano

**Potential Effects of Volcanic Ash**

Volcanic ash is highly disruptive to economic activity because it covers just about everything, infiltrates most openings, and is highly abrasive. Airborne ash can obscure sunlight to cause temporary darkness and reduce visibility to zero. Ash is slippery, especially when wet; roads, highways, and airport runways may become impassable. Automobile and jet engines may stall from ash-clogged air filters and moving parts can be damaged from abrasion, including bearings, brakes, and transmissions.

|  |  |  |  |
| --- | --- | --- | --- |
| [Ashfall brings darkness to Montserrat following eruption of  Soufriere Hills volcano](http://volcanoes.usgs.gov/Imgs/Jpg/SoufHills/32424296-060_caption.html) | [House destroyed by ashfall, Rabaul Caldera, Papua New Guinea](http://volcanoes.usgs.gov/Imgs/Jpg/Rabaul/32923351-012_caption.html) | [Ash stirred up by moving vehicles on city street, Philippines](http://volcanoes.usgs.gov/Imgs/Jpg/Pinatubo/32923351-029_caption.html) | [Tractor mixes ash into the underlying soil, Philippines](http://volcanoes.usgs.gov/Imgs/Jpg/Pinatubo/32923351-035_caption.html) |
| **Daylight turns into darkness...** | **Roofs may collapse from added weight...** | **Machinery and vehicles will be abraded...** | **Farmland will be covered...** |
|  | | | |
| [Vehicles on ash-covered road, Philippines](http://volcanoes.usgs.gov/Imgs/Jpg/Pinatubo/32923351-045_caption.html) | [Electrical switching facility, Philippines](http://volcanoes.usgs.gov/Imgs/Jpg/Pinatubo/32923351-026_caption.html) | [Ash-covered drainage canal, Philippines](http://volcanoes.usgs.gov/Imgs/Jpg/Pinatubo/32923351-027_caption.html) | [Close view of ash-filled gutter, Montserrat](http://volcanoes.usgs.gov/Imgs/Jpg/SoufHills/32923351-036_caption.html) |
| **Roads will be slippery, blocked, or blocked...** | **Power systems may shut down...** | **Waste-water systems may clog...** | **Gutters may fill and collapse...** |

**More About Tephra**

* [Actions to take for an ashfall](http://volcanoes.usgs.gov/ash/todo.html).
* Scientists use [numerous terms to describe tephra](http://volcanoes.usgs.gov/hazards/tephra/tephraterms.php)
* Volcanic ash is a [serious hazard for jet aircraft](http://volcanoes.usgs.gov/hazards/tephra/ashandaircraft.php)