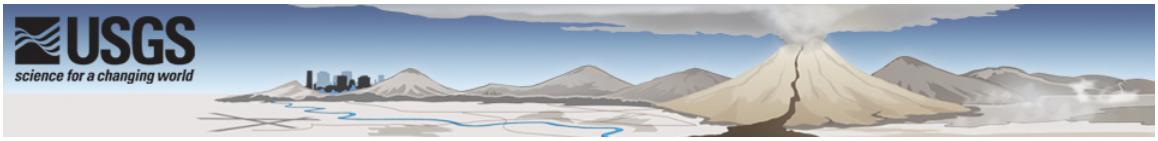

Volcano Hazards Program FAQs

Updated 2011

FAQs About Volcanic Eruptions

Q: Can an eruption at one volcano trigger an eruption at another nearby volcano (for example, within about 10 km)?

A: There are a few historic examples of simultaneous eruptions from volcanoes or vents located within about 10 km of each other, but it's very difficult to determine whether one might have caused the other. To the extent that these erupting volcanoes or vents have common or overlapping magma reservoirs and hydrothermal systems, magma rising to erupt from one volcano may effect the other volcano's "plumbing" system and cause some form of unrest, including eruptions. For example, the huge explosive eruption of Novarupta vent in Alaska triggered the summit of nearby Mt. Katmai volcano to collapse, thereby forming a new caldera (but no eruption!).

For a few of the historic examples of simultaneous eruptions from nearby volcanoes, scientists actually consider the individual volcanoes or vents to be part of a larger volcano complex consisting of overlapping stratovolcanoes, cinder cones, fissures, vents, and even calderas. In such cases, the erupting vents (or volcano) are actually part of the same volcano complex. For example, Tavurvur and Vulcan cones that erupted at nearly the same time in September 1994 are vents located within Rabaul Caldera in Papua New Guinea. In such cases, one eruption does not really "trigger" a nearby vent to erupt; instead, moving magma "leaks" to the surface at multiple sites.

In contrast to these examples of simultaneous eruptions at volcanoes with overlapping or related magma and hydrothermal systems, two of Earth's most active volcanoes that are located close to each other -- Mauna Loa and Kilauea in Hawaii -- have separate shallow magma reservoirs that don't seem to affect each other. Even though Kilauea Volcano is located on the southeastern flank of Mauna Loa (the summit calderas are only 33 km apart) and magma rising into both volcanoes originates from the same mantle hot spot, the chemistry of their magma is nevertheless distinct from each other. Furthermore analysis of the timing of historic eruptions strongly suggests that an eruption at one volcano does not cause or trigger an eruption at the other volcano.

For more information here are a few examples of simultaneous eruptions from nearby volcanoes or vents.

Q: Is there evidence for a cause and effect relationship between eruptions that occur at about the same time from volcanoes located hundreds to thousands of km apart?

A: No. Since there are on average between 50 and 60 volcanoes that erupt each year somewhere on Earth (about 1 every week), some of Earth's volcanoes may actually erupt within a few days or hours of each other. Upon closer inspection, however, the eruptions are almost always preceded by very different build-up periods in terms of time (days to weeks to months to years) and type of activity (earthquakes, ground deformation, gas emissions, and small eruptions). The "trigger" of this precursory activity is the key to understanding what

causes an eventual eruption at any one volcano, not the timing of significant eruptions hundreds to thousands of km apart.

According to the theory of plate tectonics, the location and frequency of volcanism on Earth is due primarily to the way in which our planet's surface is divided into large sections or plates and how they move relative to each other, and the formation of deep "thermal plumes" that rise from the core-mantle boundary about 3,200 km below the surface. These mechanisms and the fact that even nearby volcanoes erupt magma with different and often unique chemical composition (evidence that each volcano has a separate unique shallow magma reservoir) strongly suggests there is unlikely to be any cause and effect relationship between volcanic eruptions separated hundreds to thousands of km apart.

Q: Is there a relationship between large earthquakes (>M 6) that occur along major fault zones and nearby volcanic eruptions?

A: Sometimes, yes. A few historic large regional earthquakes (>M 6) are considered by scientists to be related to a subsequent eruption or to some type of unrest at a nearby volcano. The exact triggering mechanism for these historic examples is not well understood, but the volcanic activity probably occurs in response to a change in the local pressure surrounding the magma reservoir system as a consequence of (1) severe ground shaking caused by the earthquake; or (2) a change in the "strain" or pressure in the Earth's crust in the region surrounding where the earthquake occurred.

Historic Examples

Kilauea Volcano, Hawaii

1975:

A large earthquake (7.2 on the Richter Scale) struck the Big Island of Hawaii at 4:48 a.m. on November 29, 1975. It was centered about 28 kilometers southeast of Kilauea Volcano's summit caldera at a depth of 5 kilometers; the earthquake occurred within the volcano's south flank. The earthquake was preceded by numerous foreshocks, the largest of which was a 5.7 magnitude jolt at 3:36 the same morning, and was accompanied, or closely followed, by a tsunamis (seismic sea wave), massive ground movements, hundreds of aftershocks, and a short-lived eruption in Kilauea's summit caldera.

The eruption began at 5:32 a.m. from a 500-meter long fissure on the caldera floor and ended by 10:00 p.m. According to scientists at the USGS Hawaiian Volcano Observatory, the eruptive activity "was apparently triggered by the 7.2 magnitude earthquake. The small volume and brief duration of the eruption suggest that the shallow magma might not have reached the surface under its own buoyant energy without a triggering mechanism apparently provided by the violent ground shaking."

Source:

Tilling, Robert I., Koyanagi, Robert Y., Lipman, Peter W., Lockwood, John P., Moore, James G., and Swanson, Donald A., 1976, Earthquake and related catastrophic events, Island of Hawaii, November 29, 1975: A preliminary report: U.S. Geological Survey Circular 740, 33 p.

1868:

The largest historic earthquake (estimated between 7.5 and 8.1) on the Big Island occurred beneath the south flank of Mauna Loa Volcano on April 2, 1868. The earthquake was followed by a small eruption from Kilauea's southwest rift zone and from a fissure on the caldera wall that flooded the adjacent Kilauea Iki crater with lava. Also, within Kilauea's caldera, part of the floor subsided about 90 meters. This activity occurred nearly simultaneously with an eruption from the southwest rift zone of Mauna Loa volcano.

Source:

Macdonald, Gordon A., Abbott, Agatin T., and Peterson, Frank L., 1983 (2nd edition), Volcanoes in the Sea -- The geology of Hawaii: Honolulu, University of Hawaii Press, 517 p.

Mount Pinatubo, Philippines

Mount Pinatubo's huge explosive eruption on June 15, 1991, occurred within 11 months of a magnitude 7.8 earthquake that occurred about 100 kilometers northeast of the volcano. Many scientists have since asked, "Was the eruption triggered by, or otherwise related to the earthquake that had occurred on July 16, 1990?" A recent study by scientists of the Philippine Institute of Volcanology and Seismology and the U.S. Geological Survey Study suggests that there was indeed a relationship between the two events.

The study suggests that the "failure stress along faults of the Pinatubo area" after the big earthquake "were probably not a cause of Pinatubo's awakening. However, compressive stress on the magma reservoir and its roots was about 1 bar, possibly enough to squeeze a small volume of basalt into the overlying dacitic reservoir. Alternately, strong ground shaking associated with the Luzon earthquake might have done the same or triggered movement along previously stressed faults that in turn allowed magma ascent."

Source:

Bautista, B.C., Bautista, L.P., Stein, R.S., Barcelona, E.S., Punongbayan, R.S., Laguerta, E.P., Rasdas, A.R., Ambubuyog, G., and Amin, E.Q., Relationship of Regional and Local Structures to Mount Pinatubo Activity in: Newhall, C.G., Punongbayan, R.S. (eds.) Fire and mud: Eruptions and lahars of Mt. Pinatubo, Philippines, Philippine Institute of Volcanology and Seismology, Quezon City and University of Washington Press, Seattle p. 351- 370.

Restless Calderas

A recent study of the historic activity at calderas from around the world showed that "caldera unrest occurred at least 79 times in close temporal association with regional

earthquakes or, in a few instances, with swarms of regional earthquakes. By close temporal association we mean within a time span that is short in relation to the usual recurrence intervals of both the regional earthquakes and the unrest, usually within a few months or less."

"Fifty regional earthquakes (most M 6 and above) were followed within hours to months of unrest at nearby calderas... Twenty seven of these episodes culminated in eruptions, and three others are continuing without eruptions as yet (Rabaul, Wrangell, and Yellowstone)." Rabaul caldera in Papua New Guinea erupted in 1994.

The authors also found that "at least 27 regional earthquakes occurred within 100 kilometers of a restless caldera during or shortly after caldera unrest" and concluded "that magma bodies beneath young calderas often react to changes in regional tectonic strain, and that unrest at calderas is sometimes a general, long-range precursor to regional earthquakes."

Source:

Newhall, Christopher, G., and Dzurisin, Daniel, 1988, Historic Unrest at Large Calderas of the World: U.S. Geological Survey Bulletin 1855, vol 1, p. 19-20.

Karymsky Volcano, Russia

For a recent example, see the May 1996 report on Karymsky Volcano on the Kamchatka Peninsula in Russia from the Smithsonian Institution's Bulletin of the Global Volcanism.

FAQ About Relationships Between Earthquakes and Volcanic Eruptions

Is there a relationship between earthquakes larger than magnitude 6 that occur along major fault zones and nearby volcanic eruptions?

Dawn, November 29, 1975 - Spatter from a part of the fissure on Kīlauea caldera floor east of Halema‘uma‘u.

After large earthquakes the question of whether such strong events can trigger nearby volcanic eruptions often comes up. The short answer to this question is: “not very often.” There are a few examples in the historical record that suggest a connection between large earthquakes and volcanic eruptions, but even these, on close inspection, do not show a simple causative relationship. The most unambiguous case of triggering is probably the November 29, 1975 magnitude (M) 7.2 Kalapana, Hawai‘i earthquake, which was immediately followed by a small, and short-lived eruption at Kīlauea volcano, Hawai‘i. However, in this case, the fault plane of the earthquake (i.e., the extent of the rupture) was directly beneath Kīlauea Volcano. Also, at the time of the earthquake, Kilauea was showing signs of pressurization and was likely poised to erupt soon anyway. Kīlauea is one of the most active volcanoes in the world, and erupted frequently in the decades before and after the 1975 earthquake.

May 24, 1960 - Ash-laden eruption plumes rise above fissure vent at Puyehue-Cordón Caulle, Chile. Photo by Oscar Gonzá-Ferrán (University of Chile). Archived with the Global Volcanism Program.

Another example of possible triggering occurred after the M9.5 Chile earthquake on May 22, 1960. About 38 hours after the mainshock, Puyehue-Cordón Caulle in Central Chile erupted violently after being inactive for more than 25 years. In this instance, as at Kīlauea above, it is likely that the fault rupture extended beneath the volcano.

Establishing a statistical correlation between large earthquakes and subsequent volcanic eruptions requires a long and accurate record of both seismic and volcanic activity. The global record of such activity is sparse, especially for events that occurred before 1900. While there are hints of connections in some cases, and a few convincing anecdotes, statistical analyses to date have shown only a weak correlation. And, even if a statistical correlation is shown, working to establish and explain a causal connection is another matter entirely.

There are speculations in the literature, some backed by detailed experiments, about what mechanisms might be behind volcanic triggering by large earthquakes. Mechanisms under consideration include:

1. Stress changes caused by large earthquakes may either compress or expand nearby magma reservoirs. In the former case, the compression could increase the reservoir pressure, while in the latter case, the

expansion could cause tensile (opening) fractures, around the reservoir. Either way, conditions promoting eruption may become more favorable after a large nearby earthquake.

2. High amplitude seismic waves passing through a magma reservoir may cause the nucleation of bubbles within the magma and/or the disturbance of previously stable layers within the reservoir. Bubble creation can increase magma pressure, and layer destabilization can cause reservoir "overturn" where dense layers of relatively gas-poor magma sink forcing gas-rich magma to rise. Either of these events could prompt an eruption.

3. Violent shaking during large earthquakes can create landslides, fractures, and other major ground disturbances that can affect shallow magma reservoirs, such as Kilauea's in 1975, that are poised to erupt anyway.

There is clear evidence that large, distant earthquakes can, and do, trigger swarms of small earthquakes in active hydrothermal systems, such as those in Yellowstone and Long Valley calderas. This phenomenon has been observed at many volcanoes following large earthquakes; the M7.9 Denali Fault earthquake in Alaska is a good example. However, small earthquake swarms such as these are typically only recorded by sensitive seismic instrumentation and certainly do not fall into the category of an eruption.

Conversely, volcanic activity is known to trigger earthquakes. For example, swarms of small earthquakes, rarely larger than M5, can accompany the upward movement of magma through the Earth's crust. Also, large volumes of magma that rise from deep within the lower crust to shallower depths are thought to perturb the stress field around a volcano, possibly triggering small earthquakes up to 25 km away.

In conclusion, while it is possible that large earthquakes can trigger volcanic eruption in some cases, this connection is not well understood and as such not very useful for predicting the behavior of volcanoes. Data from well-designed local volcano monitoring networks remain the only reliable means for detecting volcanic unrest and forecasting volcanic activity.

Further Reading

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Frequently Asked Questions About Volcano Monitoring

To anticipate the awakening or reawakening of a volcano, volcanologists watch for changes caused by moving or pressurizing magma and associated changes in the hydrothermal system surrounding the magma. Magma moving toward the surface can cause swarms of earthquakes; swelling, subsidence, or cracking of the volcano's flanks; and changes in the amount or types of gases that are emitted from a volcano. The USGS continuously monitors many volcanoes in the states of Washington, Oregon, California, Hawaii, Alaska, and Wyoming (Yellowstone) to detect unusual activity.

Q: Why is it important to monitor volcanoes?

A: The United States and its territories contain 169 geologically active volcanoes, of which 54 volcanoes are a very high or high threat to public safety [National Volcano Early Warning System (NVEWS)]. Many of these volcanoes have erupted in the recent past and will erupt again in the foreseeable future. As populations increase, areas near volcanoes are being developed and aviation routes are increasing. As a result, more people and property are at risk from volcanic activity. Future eruptions could affect hundreds of thousands of people. To help prevent loss of life and property, the U.S. Geological Survey and its partners monitor these volcanoes, and issue warnings of impending eruptions.

Real-time monitoring of volcanoes, with the use of volcano seismology, gas, thermal, and surface deformation measurements, permits scientists to anticipate with varying degrees of certainty, the style and timing of an eruption. While our present state of knowledge does not allow us to predict the exact time and place of eruptions, we can detect changes from usual behavior that precede impending eruptions. We communicate these changes in our volcano updates. The information in the volcano updates allows scientists, public officials, and people in communities at risk to make preparations that can reduce losses during an eruption. Because volcanoes can erupt with little warning, continuous monitoring is important even if a volcano is not showing signs of activity.

Q: Why is monitoring volcanoes important to aviation?

A: Most of the U.S. volcanoes can pose a serious hazard to domestic and/or international aviation. Below is a summary of KLM Flight 867, a Boeing 747 with more than 240 passengers aboard, that encountered ash from the 1989 eruption of Mt. Redoubt near Anchorage, Alaska. The ash encounter provides an example of how volcano monitoring is important to domestic and international aviation. The following account is summarized by Captain Terry McVenes, Executive Air Safety Chairman Air Line Pilots Association, International before the Committee on Commerce, Science, and Transportation Subcommittee on Disaster Prevention and Prediction. U.S. SENATE March 16, 2006.

To classify this encounter as one presenting grave danger for those 240 passengers and that crew is an understatement! All four engines of this aircraft failed within 59 seconds! A false cargo compartment fire warning indication required special attention by the crew. All normal airspeed indications failed! The

avionics compartments containing all of the radio, radar, electronic systems monitoring, and communications systems, all overheated and individual systems failed. The sophisticated electronic cockpit displays became an electronic nightmare [and the cockpit filled with smoke]. While ash was contaminating the engines and causing them to flame out, it was also contaminating electrical compartments and shorting electronic circuit boards. This four engine jumbo jet was essentially a glider for several minutes until the crew was able to individually re-start engines. Three of the engines eventually re-started but delivered reduced performance. The fourth engine eventually came on line when the aircraft was on final approach to Anchorage. Although the crew landed safely, the encounter caused $80 million dollars damage to the airplane. Under only slightly different circumstances, 240 plus fatalities and a total hull loss could have been the result.

KLM 867 was only one of several commercial aircraft exposed to varying amounts of damage during several days of volcanic activity from Mt. Redoubt. Anchorage is one of the world's busiest airports for both passengers and cargo. The eventual economic impact of aircraft damages, cargo delays, passenger flight delays and cancellations, and general disruption to the Alaskan economy was staggering. Every commercial aviation operation in or through that territory suffered economic consequences.

The USGS works with the Federal Aviation Association to provide information about volcanic unrest and potential eruptions. The information is used to reroute flights and reduce the risk of future ash encounters. For more information, please see the Volcanic Ash Site.

Q: Why is monitoring important for reducing risk from ground-based volcanic hazards?

A: U.S. communities on or near volcanoes are at risk from ground-based volcanic hazards that can quickly destroy towns, disrupt communication, and shut off transportation routes. By monitoring volcanoes, the people who live, work, and play, near the volcano slopes can be notified when the volcano awakens and take proper precautions that will minimize the volcano's disruption to their lives.

Volcanic eruptions commonly begin with the explosion of gases that force billions of pieces of rock (ash) high into the sky. Ash in the atmosphere is a hazard to aviation (see Why is monitoring volcanoes important to aviation?). Once it falls to the ground, ash can interfere with systems for telecommunications, transportation, water, sewer and power, and can have a detrimental effect on agriculture and human health, even at great distances from the volcano (see the Volcanic Ash Site). Ground-based ash hazards can persist for months or years when resuspended by wind or human activity. More than one billion dollars (1980 dollars) in losses resulted from the 1980 eruption of Mount St. Helens, and much of the loss was from volcanic ash.

Volcanic eruptions often continue with the eruption of lava. As the lava flows down the steep slopes it often breaks apart into a billowing avalanche of hot rock and gas, called a pyroclastic flow. Pyroclastic flows destroy anything in their path. In 1902 a pyroclastic flow from Mount Pelee in the West Indies killed 30,000 people in the nearby town of St. Pierre in a matter of minutes.

On snow-covered volcanoes, a pyroclastic flow churns and melts snow and glacier ice which forms a slurry of boulders, mud, and water called a lahar. Lahars can sweep down valleys to great distances from the volcano. In 1985, lahars formed during the eruption of Nevado del Ruiz in Colombia killed 23,000 people within four hours of the beginning of the eruption. The use of real-time lahar-detection systems in valleys where large populations are at risk, such as near Mount Rainier, can provide warning of the occurrence of a lahar, and valuable extra minutes for evacuation. For more information, please see the Volcano Hazards page.

Q: How does the USGS monitor volcanoes in the United States?

A: In cooperation with universities and state agencies, the USGS monitors seismic activity, ground deformation, volcanic gases, thermal emissions, and changes in water levels and chemistry. When unusual activity is detected, a response team may do more ground surveys and install more instruments, if possible, to better determine if an eruption is likely.

Q: How are volcanic thermal features measured?

A: USGS scientists use instruments in the field and mounted on aircraft and satellites to measure surface temperatures and geothermal heat flux and look for thermal anomalies that may be precursor to an eruption or indicative of significant changes during an on-going eruption. Satellite-based thermal measurements can be made on a regular basis for near-real time thermal monitoring of any volcano in the world. Higher-resolution field-based and aircraft-based thermal measurements can be made episodically to understand the spatial details of thermal features.

Q: Does the USGS have a team of volcanologists that can respond to volcanic unrest on short notice?

A: Yes. The USGS Volcano Hazards Team includes experts in all aspects of volcano hazard assessment, monitoring, information dissemination, and volcano-emergency response.

Q: Does the USGS have a team for rapid response to volcano emergencies abroad?

A: Yes. Such a team is operated by the U.S. Geological Survey as part of the Volcano Disaster Assistance Program (VDAP). The team was formed in cooperation with the Office of U.S. Foreign Disaster Assistance (OFDA) of the U.S. Agency of International Development (USAID) following the 1985 eruption of Nevado del Ruiz Volcano, Colombia, in which over 23,000 people lost their lives. At the request of host countries and working through OFDA, VDAP scientists quickly determine the nature of volcanic unrest and assess its possible consequences. VDAP has responded to volcano emergencies in more than a dozen countries during the past decade.

In addition to helping people in other countries to get out of harm's way, VDAP's international work directly benefits volcano-hazard mitigation in the United States. Through VDAP, we gain experience at active volcanoes that will help during future crises in the western United States, and we collect important scientific data on eruption precursors that are used to better understand how U.S. volcanoes work.

Q: How are earthquakes monitored?

A: By installing seismometers that send information continuously via radio to a central recording site (observatory), scientists can determine the sizes and locations of earthquakes near a volcano. They look for specific types of earthquakes that are often associated with volcanic activity, including long- period volcanic earthquakes and volcanic tremor. For more information, please see Monitoring Volcano Seismicity.

Q: How are ground movements measured?

A: Ground deformation (swelling, subsidence, or cracking) is measured with a variety of techniques, including Electronic Distance Meters (EDM), the Global Positioning System (GPS), precise leveling surveys, strainmeters, and tiltmeters. EDMs use lasers to accurately measure changes in distance between benchmarks (fixed points) with repeated measurements. GPS makes use of satellites orbiting the Earth to determine and track the locations of points. Strainmeters and tiltmeters are used to monitor subtle changes in shape of the ground surface. For more information, please see Monitoring Volcano Ground Deformation.

Q: How are volcanic gases measured?

A: Instruments to measure sulfur dioxide and carbon dioxide can be mounted in aircraft to determine the quantity of gas being emitted on a daily basis. Such instruments can also be used in a ground-based mode. An instrument that detects carbon dioxide can be installed on a volcano and configured to send data continuously via radio to an observatory. Sulfur dioxide in volcanic clouds can also be measured from space with instruments aboard satellites. For more information, please see Monitoring Volcanic Gases.

Q: What else do scientists measure at volcanoes?

A: Field observations by experienced volcanologists go hand in hand with more sophisticated equipment and techniques to form a complete system for monitoring volcanoes. Field observations may include water temperature and pH (acidity) measurements, or observations of ground cracking and new areas of avalanching rocks. An experienced observer can integrate many different types of data on the spot and design simple measurements to further assess the significance of volcanic unrest. There is no substitute for well-trained, experienced observers when trying to figure out how a volcano will behave. For additional information, please see Hydrologic Monitoring of Volcanoes.

Frequently Asked Questions About Volcanic Hazards

A restless volcano endangers any nearby residents with clouds of ash, falling blocks of rock, pyroclastic flows or ash hurricanes, lava flows, and floods of debris or lahars. These hazards are typical of snow- and ice-covered stratovolcanoes like those in the Pacific Northwest and Alaska. Since 1980, volcanic activity has killed more than 29,000 people worldwide. Most of the deaths were caused by lahars and pyroclastic flows; a few hundred people were killed by ash falls, which collapsed the roofs of buildings.

Q: What kinds of hazards are associated with volcanic eruptions?

A: Debris flows, or lahars, are slurries of muddy debris and water caused by mixing of solid debris with water, melted snow, or ice. Lahars destroyed houses, bridges, and logging trucks during the May 1980 eruption of Mount St. Helens, and have inundated other valleys around Cascade volcanoes during prehistoric eruptions. Lahars at Nevado del Ruiz volcano, Colombia, in 1985, killed more than 23,000 people. At Mount Rainier, lahars have also been produced by major landslides that apparently were neither triggered nor accompanied by eruptive activity. Lahars can travel many tens of miles in a period of hours, destroying everything in their paths.

Tephra (ash and coarser debris) is composed of fragments of magma or rock blown apart by gas expansion. Tephra can cause roofs to collapse, endanger people with respiratory problems, and damage machinery. Tephra can clog machinery, severely damage aircraft, cause respiratory problems, and short out power lines up to hundreds of miles downwind of eruptions. Explosions may also throw large rocks up to a few miles. Falling blocks killed people at Galeras Volcano in Colombia in 1992, and at Mount Etna, Italy, in 1979.

Pyroclastic surges and flows are hot, turbulent clouds of tephra (known as surges), or dense, turbulent mixtures of tephra and gas (known as flows). Pyroclastic flows and surges can travel more than a hundred miles per hour and incinerate or crush most objects in their path. Though most extend only a few miles, a pyroclastic surge at Mount St. Helens in 1980 extended 18 miles (28 km) and killed 57 people. Pyroclastic surges at El Chichón volcano in Mexico in 1982 killed 2000 people, and pyroclastic flows at Mount Unzen, Japan, in June, 1991, killed 43 people. Speeding vehicles cannot outrun a pyroclastic flow or surge.

Lava flows erupted at explosive stratovolcanoes like those in the Pacific Northwest and Alaska are typically slow-moving, thick, viscous flows. Kilauea volcano on the Island of Hawaii has produced thin, fluid lava flows throughout its history, and almost continuously since 1983. Lava flows destroyed a visitor center at Kilauea in 1989 and overran the village of Kalapana on the volcano's southeast flank in 1991.

Q: Can volcanoes be dangerous even when they don't erupt?

A: Definitely. Many stratovolcanoes have a plumbing system of hot acid water that progressively breaks down hard rock to soft, clay-rich material. The volcano is gradually weakened, and large parts may suddenly fail. Resulting water-rich landslides are especially dangerous because they can occur without any volcanic or seismic warning.

The risk of mudflows formed this way is especially high along rivers downstream from Mount Rainier, because of the large population on floodplains, the huge weakened edifice of the volcano, and a long history of large flows that occurred when the volcano was otherwise dormant.

Q: How can residents who live near volcanoes prepare for future eruptions?

A: Residents can obtain copies of USGS volcano-hazard reports to determine whether they live or work in areas at risk from volcanic activity. Everyone should plan how they and their family will respond to a natural disaster, including unrest or eruptive activity at nearby volcanoes. Preparation might include knowing where to go when family members are separated, where to go for emergency housing, what emergency supplies to keep on hand, and how to be self sufficient for several days, as recommended by local emergency management agencies. Residents who live within 100 miles of a volcano should also find out what their local officials are doing to prepare their community for the possibility of renewed volcanic activity. Lastly, enjoy the scenic, recreational, and inspirational benefits of living near an active volcano!

Q: How does the USGS provide eruption warnings?

A: The USGS volcano observatories post updates about volcanic activity on our web site. Information about our alert system is available online.

If activity at a volcano increases, we provide hazards-zone maps and other information about the frequency of eruptions and extent of specific hazards to public officials, land-use planners, and emergency-management agencies. The assessments we've already completed are available online in our hazard assessments section. The USGS works with the Federal Aviation Administration and National Weather Service to provide airline pilots with timely information about hazardous volcanic ash clouds.

When communities are at risk, scientists give hazards information directly to public officials to help them make decisions about land-use or evacuations. Unlike what is often portrayed in movies, warnings are delivered only after a thorough analysis of all existing information and careful consultation among members of the USGS response team. Our goal is always to keep natural processes from becoming natural disasters.

Q: How many active volcanoes are there in the United States?

A: There are about 169 volcanoes in the United States that scientists consider active. Most of these are located in Alaska, where eruptions occur virtually every year. Others are located throughout the west and in Hawaii (see our Volcano Activity Map for their locations). Kilauea

volcano in Hawaii is one of the most active volcanoes on Earth. It has been erupting almost continuously since 1983!

Q: How many active volcanoes are there on Earth?

A: There are about 1500 potentially active volcanoes worldwide, aside from the continuous belt of volcanoes on the ocean floor. About 500 of these have erupted in historical time. Many of these are located along the Pacific Rim in what is known as the "Ring of Fire." In the U.S., volcanoes in the Cascade Range and Alaska (Aleutian volcanic chain) are part of the Ring, while Hawaiian volcanoes form over a "hot spot" near the center of the Ring.

Frequently Asked Questions About Volcanoes in Movies

Movies Fact or Fiction

Dante's Peak, a volcano-disaster thriller from Universal Studios, dramatizes some real-world concerns faced by communities located near active volcanoes in the United States. Set in the northern Cascade Range of Washington State, the movie portrays the roles of U.S. Geological Survey (USGS) scientists and local public officials during the reawakening and eruption of a fictional volcano - one that resembles dozens of real volcanoes in Alaska, British Columbia, Washington, Oregon, and northern California. To separate fact from fiction, here are answers to some frequently asked questions about the movie and the USGS mission to reduce the risk from dangerous volcanoes.

Q: Is the eruption depicted in Dante's Peak realistic?

A: In many but not all respects, the movie's depiction of eruptive hazards hits close to the mark, especially as regards the enormous power unleashed during an eruption. Stratovolcanoes in the Cascade Range and Alaska erupt explosively and produce pyroclastic flows, clouds of volcanic ash, and debris flows (lahars) that behave much as shown in the movie. Lava flows at these volcanoes, though, are usually thick and slow moving, unlike the fluid flows in the movie. Fast-flowing flows of basalt lava are common in Hawaii, though. Real eruptions may be considerably larger or smaller, and affect larger or smaller areas, than those shown in the film.

Q: Can eruptions really threaten helicopters, as in the movie, and other aircraft?

A: Yes. Encounters between aircraft and clouds of volcanic ash are a serious concern. Jet engines and other aircraft components are vulnerable to damage by fine, abrasive volcanic ash, which can drift in dangerous concentrations hundreds of miles downwind from an erupting volcano.

In the past, many aircraft have accidentally encountered volcanic ash clouds, and in some cases jet engines have temporarily lost power. An international consortium of government agencies, including the U.S. Geological Survey, Federal Aviation Administration, and National Weather Service, now monitors ash-producing volcanoes and tracking volcanic ash clouds to reduce the likelihood of future encounters.

Q: Do earthquakes large enough to collapse buildings and roads accompany volcanic eruptions?

A: Not usually. Earthquakes associated with eruptions rarely exceed magnitude 5, and these moderate earthquakes are not big enough to destroy the kinds of buildings, houses, and roads that were demolished in the movie. The largest earthquakes at Mount St. Helens in 1980 were magnitude 5, large enough to sway trees and damage buildings, but not destroy them.

During the huge eruption of Mount Pinatubo in the Philippines in 1991, dozens of light to moderate earthquakes (magnitude 3 to 5) were felt by several hundred thousand people. Many houses collapsed, but not primarily because of the shaking. Heavy, wet ash from the eruption and a hurricane accumulated on roofs and crushed them.

Stronger earthquakes sometimes DO occur near volcanoes as a result of tectonic faulting. For example, four magnitude 6 earthquakes struck Long Valley caldera, California, in 1980, and a magnitude 7.2 earthquake struck Kilauea Volcano, Hawaii, in 1975. Both volcanoes were quiet at the time. The Hawaii earthquake triggered a small eruption at the summit of Kilauea. No eruption has yet occurred at Long Valley, but the area has been restless since the 1980 earthquakes.

Q: Can a town's water supply become contaminated when a volcano is restless?

A: Yes, but probably not as quickly as shown in the movie. If a town's water supply originates directly from a volcano's groundwater system or from a stream that has been covered with volcanic ash, the water could become contaminated with foul-smelling gases or fine ash and other sediment. Some volcanic gases such as sulfur dioxide dissolve in groundwater, making the water acidic. Sulfurous odors, however, are caused by hydrogen sulfide gas, which smells like rotten eggs.

Q: Do scientists drive across moving lava flows?

A: No. Any attempt to drive across an active lava flow, even one that has partly solidified to form a thin crust, is likely to lead to disaster. With a temperature of 1,700 degrees Fahrenheit or higher, fresh lava will quickly melt rubber tires and ignite gas tanks. And if a vehicle gets stuck in moving lava, well, you know the rest of the story.

Q: Can carbon dioxide gas from volcanoes kill trees and wildlife?

A: Yes. At several volcanoes around the world, carbon dioxide gas released from magma has accumulated in the soil in sufficient concentrations to kill vegetation or has collected in low areas and suffocated animals. At Mammoth Mountain in California, carbon dioxide has killed about 100 acres of trees since 1989, and visitors to this area have occasionally suffered symptoms of asphyxiation when entering cabins or below-ground excavations. USGS scientists have concluded that the gas is escaping from a magma body beneath Mammoth Mountain. The magma itself is not currently moving toward the surface, but the USGS is monitoring the situation carefully.

Q: Can volcanoes suddenly become restless and erupt within one week of the first signs of activity?

A: Yes. The first steam eruption at Mount St. Helens on March 27, 1980, was preceded by only 7 days of intense earthquake activity. The climactic eruption, on May 18, followed seven weeks later. An eruption of Redoubt Volcano in Alaska on December 13, 1989, was preceded by only 24 hours of intense earthquake activity. But other volcanoes have been restless for

months or years before an eruption occurred, and sometimes a period of unrest doesn't produce an eruption at all.

Q: Are robots used by the USGS to monitor volcanoes?

A: No. We rely on observations and measurements made by experienced scientists and on critical data sent by radio or satellite relay from monitoring instruments installed around a volcano. These instruments include seismometers, tiltmeters, Global Positioning System (GPS) receivers, gas sensors, mudflow (lahar or debris flow) sensors, and temperature probes.

NASA has tested a robot named Dante at Mount Erebus volcano in Antarctica and Mount Spurr volcano in Alaska. The USGS believes that, on Earth, experienced volcanologists are a better and more cost-effective alternative for monitoring dangerous volcanoes.

Q: Can volcanoes produce large explosive eruptions and rivers of fluid lava at the same time?

A: Not usually. During a single eruption, a volcano CAN produce both lava flows and ash, sometimes simultaneously. The red, glowing lava fountains and lava flows in Dante's Peak (including the active flow across which Harry Dalton drives) are characteristic of a fluid magma, called basalt. In contrast, explosive gray ash columns and pyroclastic flows shown in other scenes are characteristic of more viscous magmas, called andesite, dacite, or rhyolite. It's uncommon for a volcano to erupt magmas of widely different composition at the same time.

Q: Can lakes near volcanoes become acidic enough to be dangerous to people?

A: Yes. Crater lakes atop volcanoes are typically the most acid, with pH values as low as 0.1 (very strong acid). Normal lake waters, in contrast, have relatively neutral pH values near 7.0. The crater lake at El Chichon volcano in Mexico had a pH of 0.5 in 1983 and Mount Pinatubo's crater lake had a pH of 1.9 in 1992. The acid waters of these lakes are capable of causing burns to human skin but are unlikely to dissolve metal quickly. Gases from magma that dissolve in lake water to form such acidic brews include carbon dioxide, sulfur dioxide, hydrogen sulfide, hydrogen chloride, and hydrogen fluoride. However, the movie's rapidly formed acidic lake capable of dissolving an aluminum boat in a matter of minutes is unrealistic.

FAQs About Studying and Working on Volcanoes

Q: Are you "scared" when working on an active volcano?

A: "Excited" is the first word that comes to mind when most of us think about our work at active volcanoes. Safety is always our primary concern, because volcanoes can be dangerous places. But we manage personal risk in the same way as other professionals in hazardous occupations, such as police officers or astronauts. We try hard to understand the risk inherent in any situation, then train and equip ourselves with the tools and support necessary to provide a comfortable margin of safety. Such training involves learning the past and current activity of the volcano, first aid, helicopter safety procedures, and wilderness survival techniques.

In the words of one scientist, "maybe because of these precautions, I've never felt scared while working near an active volcano. Instead, I'm usually terribly excited by the puzzle that every eruption poses to volcanologists: what is the volcano doing right now and what might happen next?"

Some of us, however, have experienced situations that were more than exciting. In the words of another scientist, "Scared? Oh sure. When a little steam explosion occurred from the dome at Mount St. Helens in 1982, three of us were surveying the dome from less than 100 meters away. As soon as we saw the basket-ball size rocks streaming through the air, we ran for cover beneath a huge block of ice on the crater floor. Until the rocks stopped landing all around us, I was absolutely terrified."

Q: Are you scared when the volcano is showing signs of restless activity and you've concluded the volcano is likely to erupt soon?

A: This is the most anxious time, because generally there is nothing more to be done than wait, watch, and hope your team is right in its assessment of the situation. With modern monitoring instruments, the level of unrest can seem almost overwhelming at this stage -- earthquakes happening virtually non-stop for hours or days, swelling or cracking of the ground at rates that keep going up and up, changes in the kinds and amounts of volcanic gases being released. But even so there are always uncertainties, including the very real possibility that the process will simply stop before magma reaches the surface and you'll be asked to explain why there was so much fuss over a "failed eruption."

A: The difference between a major eruption and a period of unrest that quickly fades from most people's memories can be very slight, and we haven't yet learned how to identify the point of no return. A restless volcano is a mind-boggling collection of complicated processes interacting with each other at ever increasing rates and under conditions that are often extreme, rushing toward an outcome that can't be known for sure until it happens. The uncertainty can be exciting, frightening, confusing, frustrating, and incredibly rewarding all at the same time. Many of us feel such emotions when working on a volcano that's threatening to erupt.

Q: Is it dangerous to work on volcanoes and what precautions do scientists take?

A: Restless volcanoes can be very dangerous places, but it's possible to work safely around them if you're properly prepared. First and foremost, scientists protect themselves by working as a team to create a "safety net" in which all the important bases are covered. Like a professional driving team, a

volcano-response team includes key staff who know the monitoring equipment extremely well, experts in several scientific disciplines who can interpret data coming back from the field, a spokesperson to communicate warnings and other information to public officials and the media, and a scientist-in-charge, or "driver," who assumes overall responsibility for team performance. As part of an experienced scientific team capable of quickly assessing the past behavior of a restless volcano, installing instruments to take its pulse, and analyzing all available information to understand what the volcano is doing, a modern volcanologist is prepared to work safely even in the hazardous environment of a restless volcano.

Q: What's it like to work on volcanoes?

A: Volcanoes are inherently beautiful places where forces of nature combine to produce awesome events and spectacular landscapes. For most of us, they're FUN to work on! Most people are fascinated by volcanoes, and many may feel a strong connection to them in the same way we sometimes feel a connection or familiarity to a place, like a favorite coastline, a river valley, or forest. In the words of a scientist, "for me, there's something fundamental and moving about the idea of magma rising from deep inside our restless planet to flow gracefully onto its surface, as in Hawaii, or explode violently into its atmosphere, as at Mount St. Helens. I'm fascinated by the knowledge that some of the gases I breathe were once miles deep in the Earth, and arrived in my lungs by way of a volcano." Perhaps no spot on Earth is untouched by the effects of volcanoes. In fact, more than half of the Earth's surface is covered by volcanic flows, especially the sea floor. All forms of life on Earth are linked in some way to volcanic activity. With this perspective, what could be more exciting or rewarding than to work on an active volcano?

Q: What kind of school training do you need to become a volcanologist?

A: There are many paths to becoming a volcanologist. Most share a college or graduate school education in a scientific or technical field, but the range of specialties is very large. Training in geology, geophysics, geochemistry, biology, biochemistry, mathematics, statistics, engineering, atmospheric science, remote sensing, and related fields can be applied to the study of volcanoes and the interactions between volcanoes and the environment. The key ingredients are a strong fascination and boundless curiosity about volcanoes and how they work. From there, the possibilities are almost endless. Learn more about volcano training and schools.

Q: What instruments, tools, and methods do you use to study volcanoes?

A: The type of equipment and techniques we use to study volcanoes depends on the particular volcano topic we are investigating and on the experiment we are conducting. When specialized instruments are not available for a special study or for monitoring a specific type of activity, we design and build our own; for example the acoustic flow monitor (AFM) for detecting lahars and an experimental flume for studying flowing mixtures of water and rock debris under controlled conditions.

For studying and monitoring restless and erupting volcanoes, several onsite and remote methods are used to gather data that also help us answer four critical questions during a volcano emergency.

For reconstructing a volcano's eruptive history so that we can identify the type of activity most likely to occur in the future as well as the areas around a volcano that are likely to be effected by future eruptions, we use many geologic mapping and dating strategies. These include:

1. Identifying rock outcrops, formations, and features on the ground and identifying their exact location on detailed aerial photographs and topographic maps or in computerized geographic information systems (GIS).
2. Collecting dozens to hundreds of volcanic rock and ash samples from sites located on or near the volcano and also tens of kilometers downwind or downstream, and then using laboratory techniques for determining their chemistry and mineral compositions.
3. Determining the ages of as many rock deposits formed by past activity of the volcano by using several common methods:
    - Carbon-14 dating when a volcanic deposit either incorporated or came to rest on top of vegetation or organic-rich soil and sufficient carbon-bearing material can be found. It's based on the fact that living trees and other organic matter contain small amounts of carbon's radioactive isotope (atomic weight of 14). When a tree is killed by a volcanic deposit, its radioactive carbon begins to decrease by radioactive decay at a known rate. By measuring the 14C/12C ratio in the wood sample, its age can be calculated. This technique can adequately date deposits that are as old as about 50,000 years, and each date may have an error range of between a few tens to several hundred years. The most common technique for dating recent volcanic deposits, only a few scientific laboratories in the United States can perform the carbon analysis.
    - Tree-ring dating when a volcanic deposit caused an unusual growth pattern of annual rings among trees growing at the time the deposits were emplaced. This technique can sometimes date deposits to an actual calendar year or to within a few years when used to on deposits of the past few hundred years.
    - Paleomagnetism in some volcanic areas where scientists have determined the yearly changes in the position of the Earth's magnetic pole over the past several hundreds or thousands of years and when the Earth's magnetic direction is preserved in volcanic rocks (usually lava flows and individual large rocks in pyroclastic flows); this technique usually yields ages with a range of between a few tens and several hundred years.
4. Representing the types and ages of volcanic rock deposits and/or identifying volcanic hazard areas around the volcano on a paper map or computerized geographic information system.