VOLCANIC EVENT

DEFINITIONS:

Composite Volcano – typically steep-sided, symmetrical cones of large dimension built of alternating layers of lava flows, volcanic ash and tephra. Typical features include a crater at the summit, which contains a central vent or a clustered group of vents connected to a conduit system through which magma from a reservoir deep in the Earth's crust rises to the surface; sometimes called stratovolcanoes.

Debris Flow – fast-moving slurry of rock, mud, and water that looks and behaves like flowing wet concrete; similar to but coarser and less cohesive than a mudflow.

Lahar – an Indonesian word describing mudflows and debris flows that originate from the slope of a volcano; pyroclastic flows can generate lahars by rapidly melting snow and ice.

Lava – molten rock or magma that erupts, or oozes onto the Earth's surface.

Lava Dome – a mound of hardened lava that forms when viscous lava is erupted slowly and plies up over the vent rather than moving away as a lava flow.

Lava Flow – streams of molten rock or magma that erupt relatively non-explosively from a volcano and move slowly downslope.

Magma – molten rock located below the surface of the Earth.

Mudflow – a fast-moving slurry of rock, mud, and water that looks and behaves like flowing wet concrete; similar to but less coarse and more cohesive than a debris flow.

Pyroclastic Flow – a hot, fast-moving avalanche of ash, rock fragments and gas that moves down the sides of a volcano during explosive eruptions or when the steep edge of a dome breaks apart and collapses.

Tephra – large fragments of rock and natural glass that is blasted from a volcano during a violent eruption and then falls to Earth.

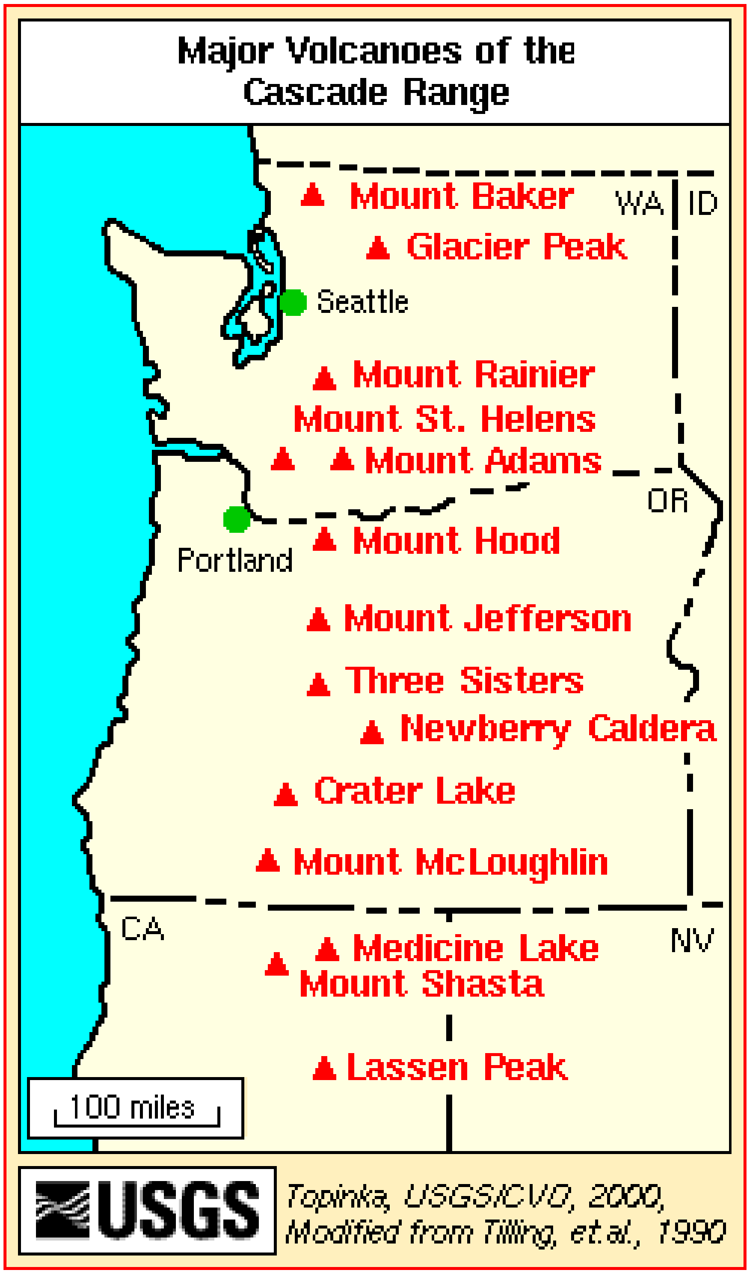
USGS – United States Geological Survey

Volcanic Ash – small fragments of rock and natural glass that is blasted from a volcano during a violent eruption and then falls to Earth. During large events, volcanic ash can travel hundreds of miles.

Volcano – a vent in the earth's crust through which magma (molten rock), rock fragments, gases, and ashes are ejected from the earth's interior. A volcanic mountain is created over time by the accumulation of these erupted products on the earth's surface.

BACKGROUND INFORMATION:

The Cascade Range extends more than 1,000 miles forming an arc-shaped band extending from Southern British Columbia to Northern California lying roughly parallel to the Pacific coastline and includes 14 major volcanic centers. The Cascade Range is made up of a band of thousands of very small, short-lived volcanoes that have built a platform of lava and volcanic debris. Rising above this volcanic platform are a few strikingly large volcanoes that dominate the landscape. The Cascades volcanoes define the Pacific Northwest section of the "Ring of Fire", a fiery array of volcanoes that rim the Pacific Ocean.



Many of these volcanoes have erupted in the recent past and will most likely be active again in the future. Given an average rate of two eruptions per century during the past 12,000 years, these disasters are not part of our everyday experience.

Skagit County's Eastern boundary follows the crest of the Cascade Range. While there are no volcanic peaks within Skagit County, Mount Baker lies just to the North in Whatcom County and Glacier Peak lies just to the South in Snohomish County. Geologic evidence indicates that both Mount Baker and Glacier Peak have erupted in the past and will no doubt erupt again in the foreseeable future. Due to the topography of the region and the location of drainage basins and river systems, eruption events on either Mount Baker or Glacier Peak resulting in lahar's, pyroclastic flows, tephra or ash fall, and lava flows could severely impact portions of Skagit County.

Mount Baker

Mount Baker is an ice-clad composite volcano located just North of Skagit County in the North Cascades. USGS research in the last decade shows Mount Baker to be one of the youngest volcanoes in the Cascade Range. At 10,775 feet it is the third highest volcano in Washington State. After Mount Rainier, Mount Baker is the most heavily glaciated of the Cascade volcanoes: the volume of snow and ice on Mount Baker (about 0.43 cubic miles) is greater than that of all the other Cascades volcanoes (except Rainier) combined. Isolated ridges of lava and hydrothermally altered rock, especially in the area of Sherman Crater, are exposed between glaciers on the upper flanks of the volcano; the lower flanks are steep and heavily vegetated. The volcano rests on a foundation of non-volcanic rocks in a region that is largely non-volcanic in origin.

PHOTO COURTESY OF WHATCOM COUNTY DIVISION OF EMERGENCY MANAGEMENT

Glacier Peak

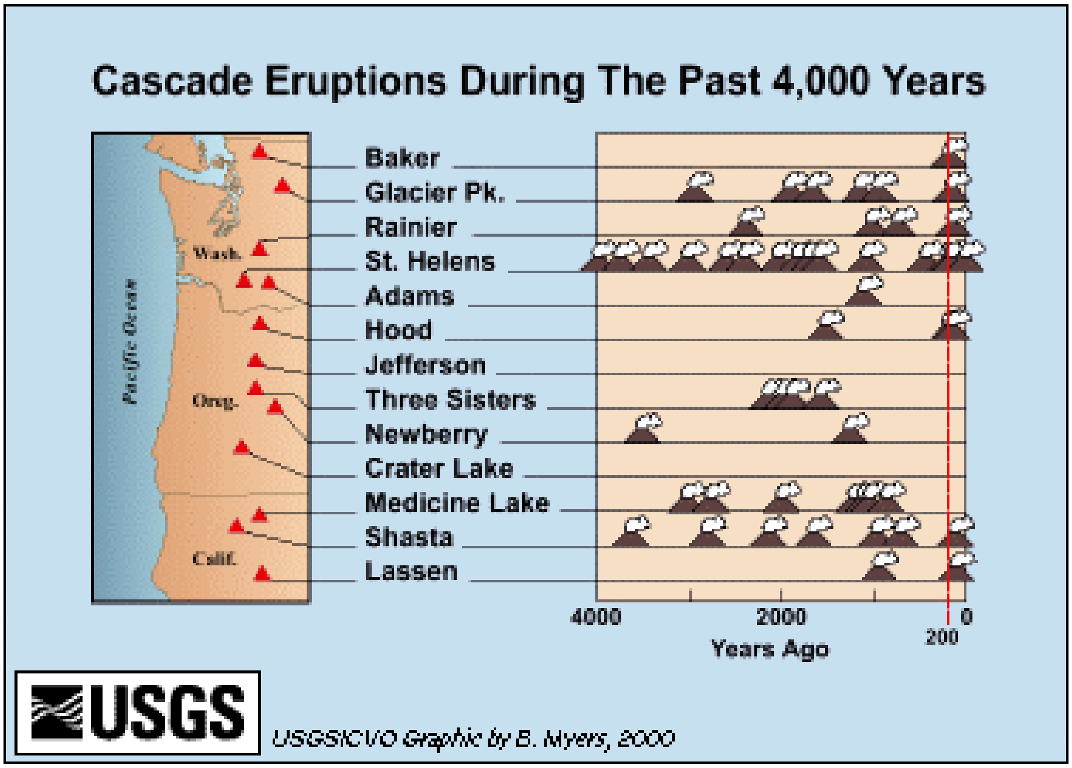
Glacier Peak is a small composite volcano and is the most remote of the five active volcanoes in Washington State. At 10,541 feet elevation, it is, next to Mount Saint Helens, the shortest of the major Washington volcanoes. Glacier Peak is not prominently visible from any major population center, and so its hazards tend to be over-looked.

USGS Photo by D. Mullineaux

<u>HISTORY</u>:

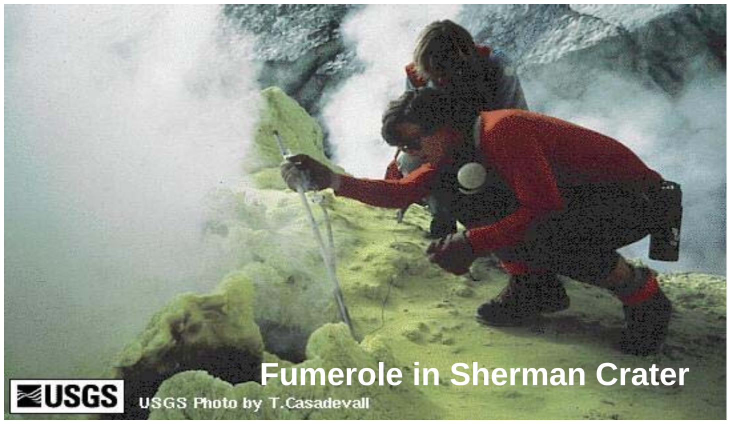
Eruptions in the Cascades have occurred at an average rate of 1-2 per century during the past 4,000 years, and future eruptions are certain. Seven volcanoes in the Cascades have erupted within the past 225 years. Four of those eruptions would have caused considerable property damage and loss of life if they had occurred today without warning – the next eruption in the Cascades could affect hundreds of thousands of people.

The most recent volcanic eruption events within the Cascade Range occurred at Mount Saint Helens in Washington (1980-1986) and at Lassen Peak in California (1914-1917).



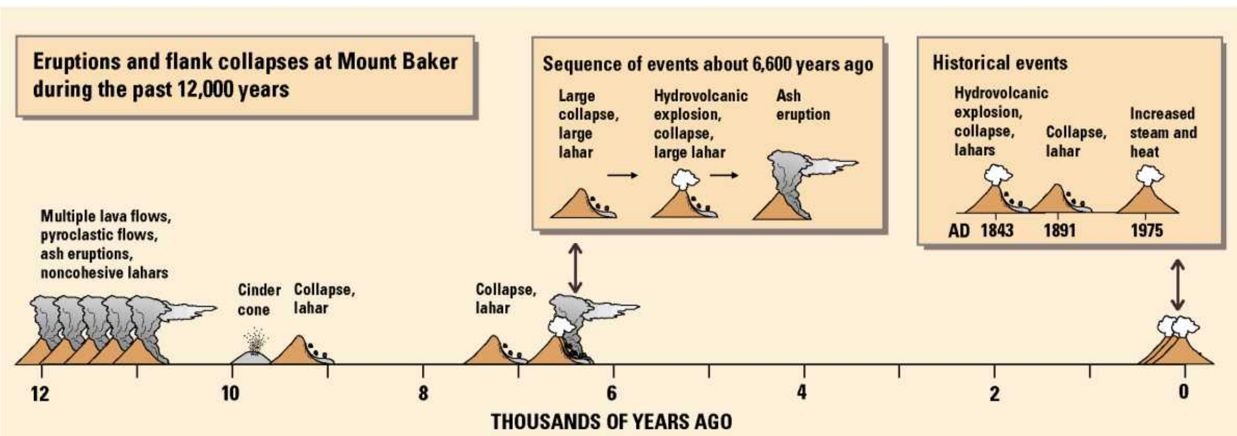
Mount Baker

Geologic evidence in the Mount Baker area reveals a flank collapse near the summit on the West flank of the mountain that transformed into a lahar that is estimated to have been approximately 300 feet deep in the upper reaches of the Middle Fork of the Nooksack River and could have been up to 25 feet deep 30 miles downstream and may have reached Bellingham Bay. A huge hydrovolcanic (water mixed with magma) explosion occurred near the site of present day Sherman Crater, triggering a second collapse of the flank just East of the Roman Wall. This collapse also became a lahar that spilled into tributaries of the Baker River. Finally, an eruption cloud deposited several inches of ash as far as 20 miles downwind to the northeast. Geologic evidence shows lahars large enough to reach Baker Lake have occurred at various times in the past.



Historical activity at Mount Baker includes several explosions during the mid-19th century, which were witnessed from the Bellingham area. Sherman Crater (located just South of the summit) probably originated with a large hydrovolcanic explosion. In 1843, explorers reported a widespread layer of newly fallen rock fragments and several rivers south of the volcano were clogged with ash. A short time later, two collapses of the East side of Sherman Crater produced two lahars, the first and larger of which flowed into the natural Baker Lake, raising its water level at least 10 feet.

In 1975, increased fumarolic activity in the Sherman Crater area caused concern that an eruption might be imminent. Additional monitoring equipment was installed and several geophysical surveys were conducted to try to detect the movement of magma. The level of the present day Baker Lake reservoir (located to the East and south of the mountain) was lowered and people were restricted from the area due to concerns that an eruption-induced debris avalanche or debris flow might enter Baker Lake and displace enough water to either cause a wave to overtop the Upper Baker Dam or cause complete failure of the dam. However, few anomalies other than the increased heat flow were recorded during the surveys nor were any other precursory activities observed to indicate that magma was moving up into the volcano. This volcanic activity gradually declined over the next two years but stabilized at a higher level than before 1975. Several small lahars formed from material ejected onto the surrounding glaciers and acidic water was discharged into Baker Lake for many months.



(THE ABOVE INFORMATION WAS OBTAINED FROM THE UNITED STATES GEOLOGICAL SURVEY, CASCADES VOLCANO OBSERVATORY)

Glacier Peak

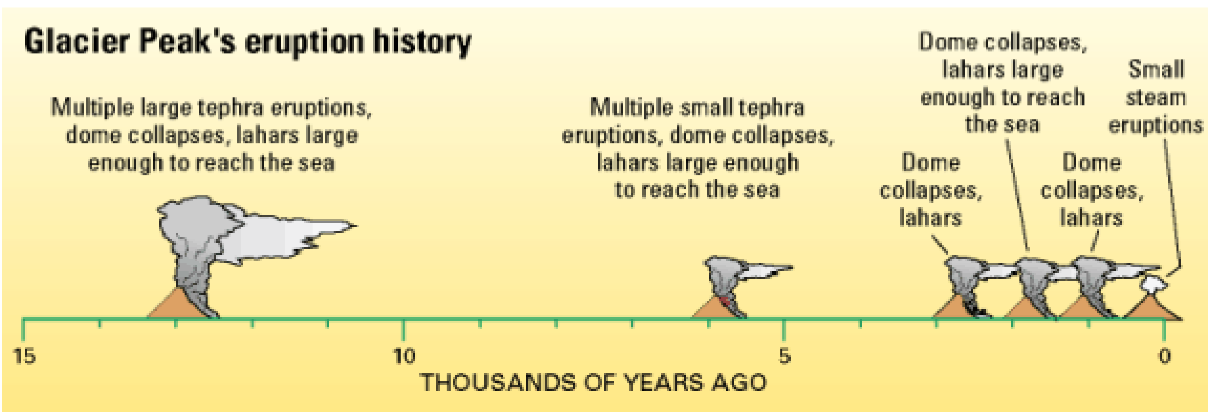
Unlike Mount Baker, Glacier Peak is not prominently visible from any major city. At 10,541 feet elevation, it is, next to Mount St. Helens, the shortest of the major Washington volcanoes. Its small size belies a violent past. Glacier Peak has produced larger and more explosive eruptions in post-glacial time than any other Washington volcano with the exception of Mount St. Helens. During this time period, Glacier Peak has erupted multiple times during at least six separate episodes, most recently about 300 years ago.

Glacier Peak and Mount Saint Helens are the only volcanoes in Washington State that have generated large, explosive eruptions in the past 15,000 years. Their violent behavior results from the type of magma they produce which is too viscous to flow easily out of the eruptive vent and must be pushed out under high pressure. As the magma approaches the surface, expanding gas bubbles within the magma burst and break into countless fragments of tephra and ash. The largest of these eruptions occurred about 13,000 years ago and ejected more than five times as much tephra as the May 18, 1980, eruption of Mount Saint Helens.

During most of Glacier Peak's eruptive episodes, lava domes have extruded onto the volcano's summit or steep flanks. Parts of these domes collapsed repeatedly to produce pyroclastic flows and ash clouds. The remnants of prehistoric lava domes make up Glacier Peak's main summit as well as its "false summit" known as Disappointment Peak. Pyroclastic flow deposits cover the valley floors east and west of the volcano. Deposits from ash clouds mantle ridges East of the summit.

There is definite evidence that pyroclastic flows have mixed with melted snow and glacial ice to form lahars that have severely affected river valleys that head on Glacier Peak. Approximately 13,000 years ago, dozens of eruption-generated lahars descended down the White Chuck, Suiattle, and Sauk Rivers, inundating valley floors.

Geologic evidence indicates that lahars flowed down both the North Fork Stillaguamish (then an outlet of the upper Sauk River) and the Skagit River to Puget Sound. These lahars deposited more than seven feet of material as far away as 60 miles from Glacier Peak. The Sauk River's course via the Stillaguamish was abandoned and the Sauk River began to drain only into the Skagit River as it still does today.



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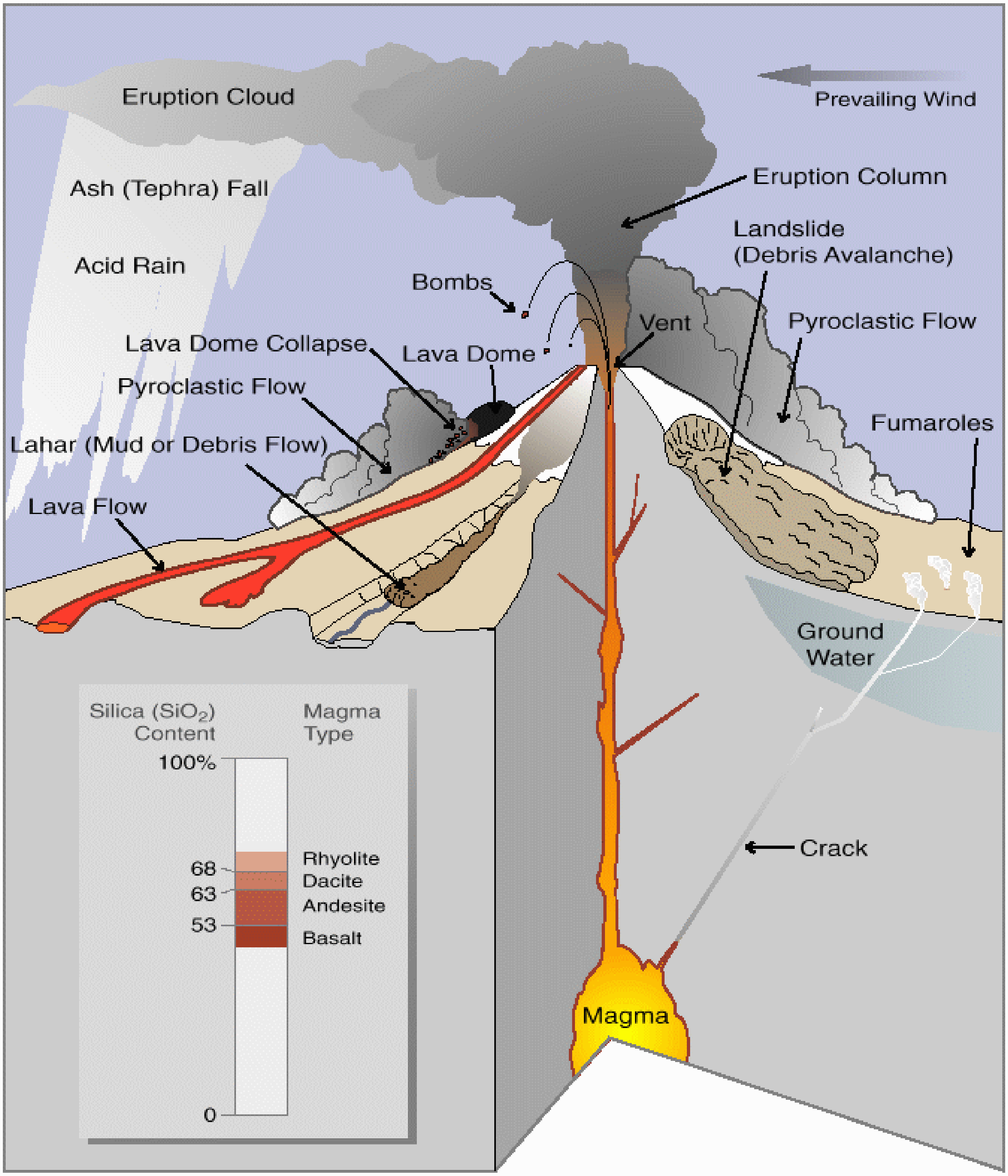
<u>HAZARD IDENTIFICATION</u>:

We know from geological evidence that Mount Baker and Glacier Peak have produced numerous volcanic events in the past. Several of these events, if they took place today, would place Skagit County communities at risk. Volcanic hazards from Mount Baker and Glacier Peak result from a variety of different eruptive phenomena such as lahars, ash fall, tephra fall, and pryroclastic flows.

The diagram on the following page (obtained from the United States Geological Survey, Cascades Volcano Observatory) provides basic information regarding the inner workings and hazards associated with volcanoes.



Volcanoes produce a wide variety of natural hazards that can kill people and destroy property. This simplified sketch shows a volcano typical of those found in the Western United States and Alaska, but many of these hazards also pose risks at other volcanoes, such as those in Hawaii. Some hazards, such as lahars and landslides, can occur even when a volcano is not erupting. (Hazards and terms in this diagram are highlighted in bold where they are discussed in the text below.)

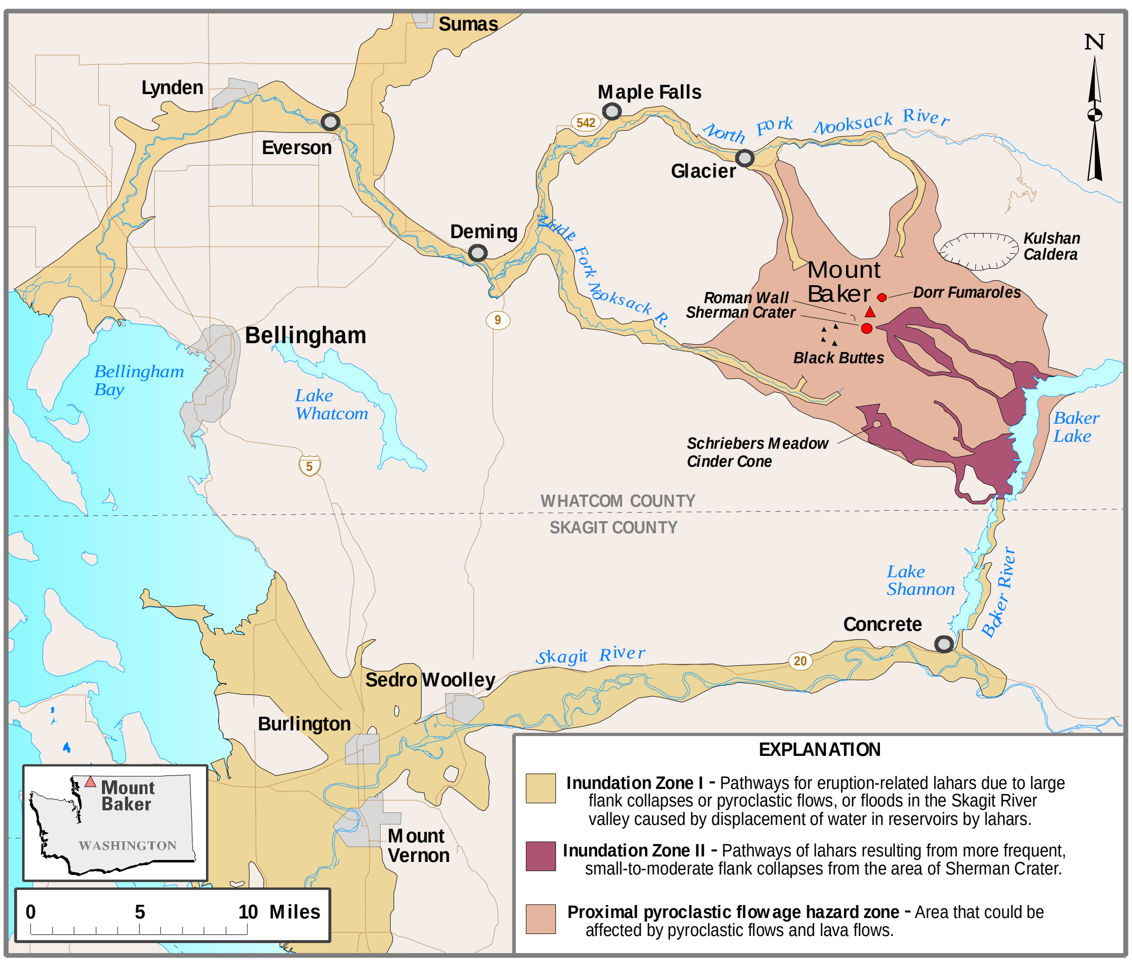
Lahars

Lahars are the primary threat and present the greatest hazard to Skagit County resulting from volcanic activity at either Mount Baker or Glacier Peak.

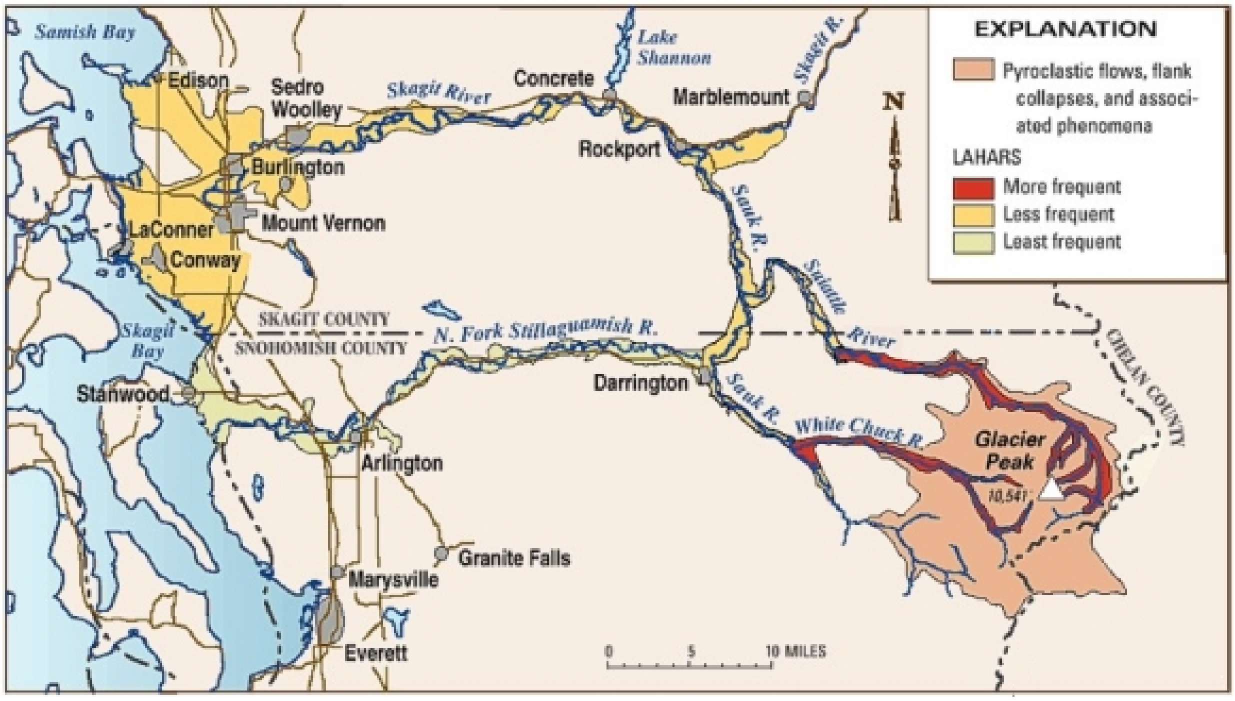
Lahars, also called volcanic mudflows or debris flows, are slurries of volcanic rock, sediment, and ash mixed with water that rush down stream and river valleys leading away from a volcano. They can travel more than 60 miles downstream, commonly reaching speeds between 20 and 35 miles per hour (the fastest lahars on Mount Saint Helens traveled over 70 miles per hour). Lahars may obtain depths of several hundred feet in canyons near their point of origin but spread out over valleys and low ridges downstream. Close to the volcano, lahars have the power to destroy entire forests and demolish large buildings and bridges. Further downstream, they simply entomb everything in mud. A very large lahar could overtop or destroy a dam.

Lahars damaged or destroyed 200 homes, 27 bridges, 185 miles of roads, and 15 miles of railways during the 1980 eruption of Mount Saint Helens.

The diagram shown below (obtained from the United States Geological Survey, Cascades Volcano Observatory) shows areas that have been affected by past lahars and pyroclastic flows originating from Mount Baker.



The diagram shown below (obtained from the United States Geological Survey, Cascades Volcano Observatory) shows areas that have been affected by past lahars and pyroclastic flows originating from Glacier Peak. This diagram has been modified from R.B. Waitt and others, U.S. Geological Survey.



In addition to damaging or destroying transportation routes, homes, and farmland, lahars can restrict or block river channels, and increase the occurrence and/or severity of flood events for years or decades due to filled in stream channels. In some cases, very large lahars may cause river courses to be significantly altered.

Lava Flows

Lava flows from Cascade Range volcanoes tend to be small and slow moving due to the viscosity of the magma. Lava flows may issue from the main volcanic vent or from nearby cinder cones formed at or near the base of the mountain. The heat of the lava may start forest fires or grass fires. Flows may bock roads and escape routes.

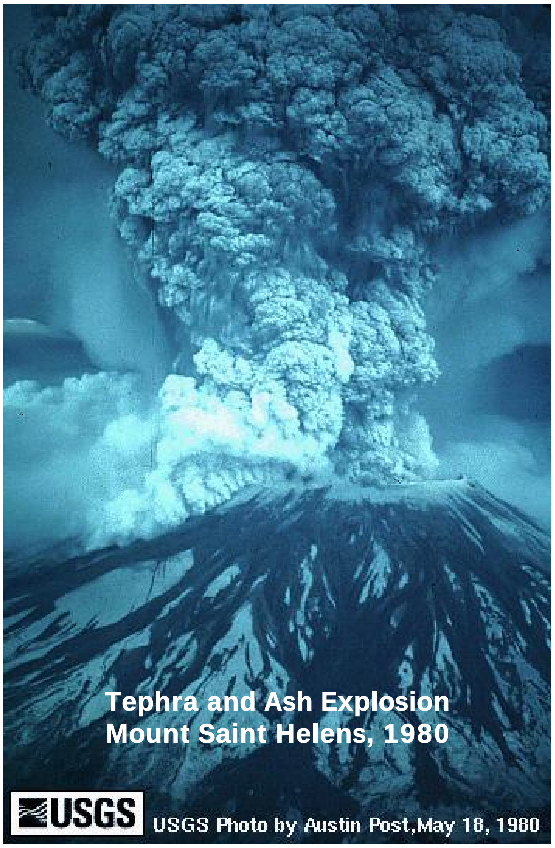
Pyroclastic Flows

High-speed avalanches of hot ash, rock fragments, and gas can move down the slopes of volcanoes during an explosive eruption or when the dome breaks apart and collapses. Pyroclastic flows can reach temperatures up to 1,000 degrees Celsius and travel at speeds up to 100 miles per hour and are capable of capable of knocking down and burring everything in their path. The May 18, 1980 eruption of Mount Saint Helens generated a lateral pyroclastic blast that destroyed an area of approximately 450 square miles with an estimated initial velocity in excess of 500 miles per hour.

Steam and Gas Explosions

Explosions of steam and other gases, containing suspended, pulverized fragments of older rocks as well as newly erupted lava bombs or blocks may occur at any time hot magma or other material comes in contact with water, glacial ice, or snow.

Tephra and Ash



Tephra and Ash Explosion
Mount Saint Helens, 1980

Not all volcanic eruptions involve the extrusion of large amount of magma. In some cases (as with Glacier Peak and Mount Saint Helens) eruption events may be preceded by an extreme build-up of pressure within the volcano and conclude with such a violent and explosive release of tephra and ash particles into the air. Particles may range in size from microscopic ash to boulders 36 inches in diameter. As the ash falls to Earth, it forms a layer that covers broad areas downwind from the volcano, generally decreasing in thickness and particle size as distance from the source increases. Heavy ashfall can blot out sunlight.

Most injuries and fatalities from tephra occur miles away where ash-sized fallout from the eruption accumulates thickly on roofs and other human-made structures - especially when the ash is wet. On average, a one-inch layer of ash weighs approximately ten pounds per square inch. In addition, ash may clog watercourses, cause electrical short circuits, and make driving hazardous or impossible; aircraft are particularly vulnerable to ash. Because winds and air currents easily carry it, ash deposits usually remain a hazard to all types of machinery and transportation for many months following an eruption.

Ash can clog and/or restrict breathing passages and may cause death; however, a short period of exposure has not been found to be harmful to persons in normal health. When an ash cloud mixes with rain, sulfur dioxide combines with water to form diluted sulfuric acid that may cause minor (but painful) burns to skin, eyes, nose, throat, and mucous membranes. In addition, acid rains may also affect water supplies.

Volcanic Earthquakes

Volcanic earthquakes are usually centered within or beneath the volcano and are generally categorized as: **pre-eruption earthquakes** caused by explosions of steam or underground magma movements; **eruption earthquakes** caused by explosions and/or collapse of interior crater walls; **post-eruption earthquakes** caused by magma retreat and interior structural collapse of the volcano.

Volcanic Landslides

Avalanches of glacial ice or rock debris may be set in motion without warning by volcanic explosions, earthquakes, flank collapses, or heat-induced melting snow and ice. These landslides may not become a full-fledged mudflow but can cause considerable damage in valleys and drainages close to the slopes of the mountain.

The following list is a compilation of comments and suggestions made by various stakeholders and the public regarding possible problems that could result from a volcanic event.

In addition to damaging homes, businesses, property, and the environment, a volcanic event in Skagit County could potentially result in the following:

- An event on the southeast slopes of Mount Baker could cause a large debris flow that may enter Baker Lake and cause damage to or overtopping of the Upper Baker Dam. Damage to or overtopping of the Upper Baker Dam could result in damage to or overtopping of the Lower Baker Dam thereby causing severe damage and possible loss of life in the Town of Concrete and nearby low-lying areas.

- A severe lahar event from either Mount Baker of Glacier Peak could cover most of the Skagit River Floodplain resulting in a catastrophic disaster and long-term economic impacts throughout the entire county and possibly the region.

- Glaciers could melt resulting in mudflows and flooding of the Baker River, Sauk River, and Skagit River.

- An ash fall event could cause numerous transportation-related problems and delay first response agencies in responding to emergency situations.

<u>VULNERABILITY ASSESSMENT</u>:

The degree of volcanic hazard from the volcanoes of the Cascade Range depends upon the type, size, and origin of the eruption. While the possibility of a large volcanic eruption exists, these types of events are typically separated by several hundred to a few thousand years and it is unlikely that we will see such an event in our lifetimes. Clearly, persons, property, and infrastructure closest to the volcano at the time of the eruption are most vulnerable.

Lahar

The river valleys and associated floodplains of the Baker River, Skagit River, Sauk River, and Suiattle River along with their associated tributaries are all especially vulnerable to the effects of large-scale lahars and associated flooding that will no doubt result from a large lahar.

Lahars traveling down the Baker River drainage could rapidly raise the level of Baker Lake leading to overtopping and/or damaging the Upper Baker Dam thereby leading to possible overtopping and/or damage to the Lower Baker Dam resulting in severe flooding of portions of the Town of Concrete and surrounding upriver areas of the Skagit River floodplain.

As demonstrated during the 1980 Mount Saint Helens eruption, the hydraulic power of fast-moving lahars and debris flows is astonishing. Sandbags and other "normal" flood fight measures will not be effective to provide any type of protection for such an event.

Furthermore, problems related to lahar debris could last for years and even decades because of the tremendous volume of loose rock and ash that has could potentially have been added to the ground surface near the volcano. This debris could provide a source of material that would no doubt flow downstream during flood events for many years following the eruption event.

Tephra and Ash Fall

Because of the location of Mount Baker and Glacier Peak and the flow direction of prevailing winds, the majority of airborne ash would most likely be carried to the Northeast or East and away from population centers in Skagit County should an ash eruption occur. Regardless of wind direction, there would still be considerable amount of ash fall in the immediate vicinity of the volcano during and immediately flowing an explosive tephra and ash eruption.

The 1980 eruption of Mount Saint Helens produced enough ash fall to reduce the maximum flow capacity of the Cowlitz River from 76,000 cubic feet per second to less than 15,000 cubic feet per second and also reduced the channel depth of portions of the Columbia River from 40 feet to 14 feet. **Should a Saint Helens-type event occur from either Mount Baker or Glacier Peak, large portions of the Skagit River floodplain could be severely impacted by flooding in addition to the direct effects of the ash eruption.**

PROBABLIITY AND RISK:

Because of the historical infrequency of such events, it is unlikely that we will see a volcanic eruption in our lifetimes. However, due to the topography and river drainage basins within Skagit County, the impacts of a major eruption from either Mount Baker or Glacier Peak to persons, property, infrastructure, and the environment in Skagit County would be catastrophic. As previously stated lahars are the primary threat and present the greatest hazard to Skagit County resulting from volcanic activity at either Mount Baker or Glacier Peak. Therefore, there is a **Low Probability** of such an event occurring but a **Moderate to High Risk** to persons, property, and the environment in Skagit County should an eruption occur from either Mount Baker or Glacier Peak.

CONCLUSION:

Although the probability of a volcanic eruption is low, if an eruption were to occur, the greatest threat to life, property, infrastructure, and the environment in Skagit County would most likely be from lahars or debris avalanches originating from either Mount Baker or Glacier Peak.

Based on past events and especially the 1980 eruption of Mount Saint Helens, future eruptions from either Mount Baker or Glacier Peak will almost certainly be preceded by an increase in seismic (earthquake) activity, and possibly by measured swelling of the volcano and emission of volcanic gases. The University of Washington Geophysics Program, in cooperation with the USGS, monitors seismic activity at Mount Baker and other Cascade Range volcanoes that could signal a possible future eruption. In addition, the USGS monitors gas emissions from Sherman Crater on Mount Baker to detect possible changes in the volcano's interior "plumbing system" that may be a warning of impending magma activity or an increase in hydro-volcanic activity in an effort to predict the likelihood of an eruption event. This ability to monitor seismic and other types of activity at Mount Baker and Glacier Peak provides a warning system of sorts for volcanic eruptions that could impact Skagit County.

Furthermore, the 1980 Mount Saint Helens eruption made it clear that preparing for and responding to a large-scale volcanic eruption must involve a wide variety of agencies and jurisdictions. For this reason, emergency managers from Skagit, Snohomish, and Whatcom Counties, the State of Washington, and the Province of British Columbia, as well as personnel from the United States Forest Service developed the **Mount Baker-Glacier Peak Coordination Plan**. The plan was adopted in April 2001, and provides a tool to coordinate the actions that various agencies must take to minimize loss of life and damage to property before, during, and after a hazardous geologic event occurring at either volcano. The plan also includes the necessary legal authorities in addition to statements of responsibilities of County, State, and Federal agencies in the United States as well as Provincial and Federal agencies in Canada.

Mount Saint Helens
Photo Courtesy of Washington State Military Department, Emergency Management Division

Further information regarding the volcanoes of the Cascade Range and the hazards associated with volcanic events can be obtained via the Internet from:

- USGS Cascades Volcano Observatory at http://vulcan.wr.usgs.gov/
- USGS Volcano Hazards Program at http://vocanoes.usgs.gov/