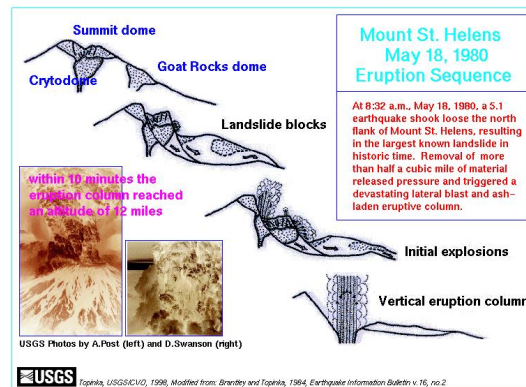
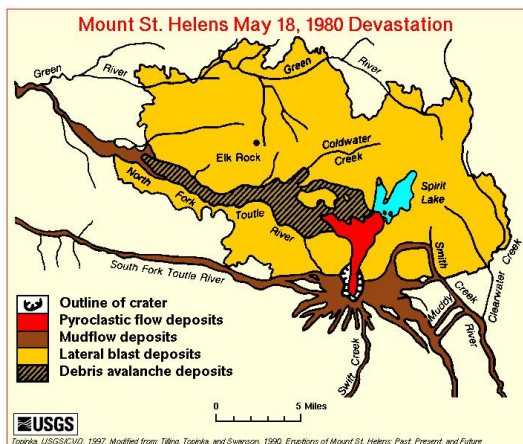


Volcano Case History: Mount St Helens

The Cascade Range is a volcanic chain stretching from northern California to British Columbia. The volcanoes are generated by melting above a subduction zone. The smallest of five major volcanic peaks in Washington State is Mount St Helens, which had an elevation of 2950 m before the eruption of 18 May 1980. On 20 March 1980, after a quiet period of 123 yr, earthquake activity resumed. Small phreatic (steam) explosions began 7 days later. A bulge developed on the northern flank as magma pushed up within the peak. It grew at up to 1.5 m/day and by 17 May it had inflated by 135 m.

On 18 May 1980, at 8:32am Pacific Daylight Time, a magnitude 5.1 earthquake shook loose the north flank of Mt St Helens, resulting in the largest known landslide in the region. The bulge and surrounding area slid away in a gigantic rockslide and debris avalanche, releasing pressure, and triggering a major pumice and ash eruption of the volcano. 400 m of the peak collapsed or blew outwards. As a result, 62 km² of valley was filled by a debris avalanche, 650 km² of recreation, timber and private lands were damaged by a lateral blast, and an estimated 150×10^6 m² of material was deposited directly by lahars (volcanic mudflows) into the river channels. 57 people were killed or are still missing. Within 10 minutes the eruption column reached an altitude of 20–25 km and a vigorous plume of ash erupted for more than 9 hr. The plume moved eastward at an average speed of 95 km hr⁻¹, with ash reaching Idaho by noon. By early 19 May the devastating eruption was over.



Features of the 18 May 1980 eruption

Crater After the May 18, 1980 eruption, Mt St Helens' elevation was only 2550 m and the peak was scarred by a horseshoe-shaped crater 1.5 km wide.

Ash fall For weeks volcanic ash covered the landscape around the volcano and for several hundred miles downwind to the east. Noticeable ash fell in 11 states (ash fall deposits are also called *tephra*). The total volume of ash (before its compaction by rainfall) was ~ 1.01 km³, enough ash to cover a football field to a depth of 240 km. Migration of the ash plume was mapped using satellite photos.

Lateral blast The lateral blast flattened forests for miles around. Over four billion board feet of usable timber, enough to build 150,000 homes, was damaged or destroyed.

Debris avalanche The debris avalanche travelled 24 km downstream at > 250 km hr⁻¹. It left behind 2.3 km³ of a hummocky deposit of average thickness of 45 m and maximum thickness 180 m. This is enough material to cover Washington, D.C. to a depth of 14 feet (4 meters).

Volcanic mudflow (Lahar) Nearly 220 km of river channels surrounding the volcano were affected by the lahars of 18 May. More than 200 homes and over 300 km of roads were destroyed.

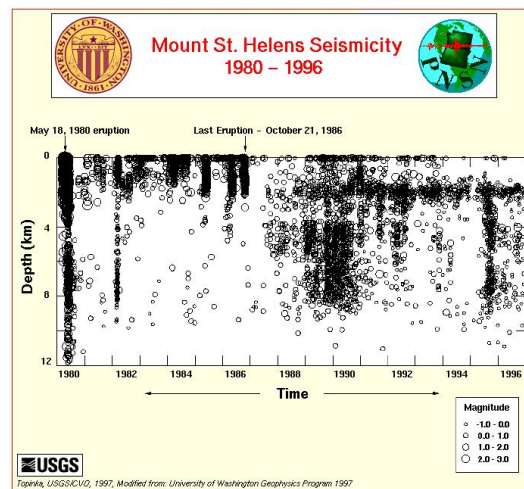
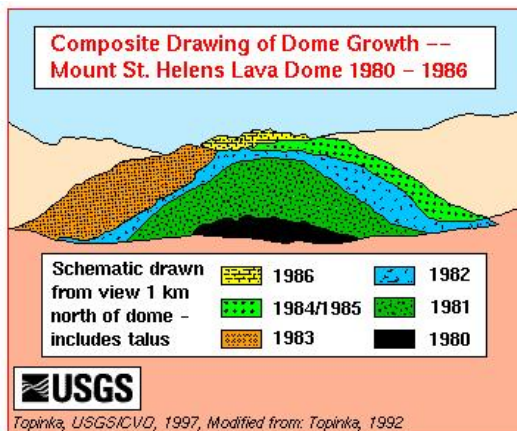
Pyroclastic flows At least 17 separate pyroclastic flows descended the flanks of Mt St Helens during

the 18 May 1980 eruption. The flows typically travelled at speeds of over 100 km hr^{-1} and reached temperatures of over 400°C .

Later eruption history

Mt St Helens has continued to erupt since the 18 May 1980 eruption. 5 more explosive eruptions occurred during 1980. For example, an explosive eruption on 19 March 1982 sent pumice and ash 14 km into the air and generated a lahar. Plumes of steam, gas and ash often occur at Mt St Helens and on clear days they can be seen from Portland, Oregon, 81 km to the south.

Domes Since December 1980, eruptions of Mt St Helens have added material to a dacitic lava dome with the crater. This dome was not the first dome to grow in the crater; in June and August 1980 two domes formed, only to be blasted away by the explosive events of 22 July and 16 October. The present Mt St Helens dome grows in different ways. From 1980 through 1982 it grew in periodic extrusions of stubby lava flows, called lobes. This pattern changed in February 1983, when growth became continuous and mostly internal. Periodic lobe growth, along with internal growth, resumed in early 1984. Mt St Helens' lobes grow at a rate of $1\text{--}3 \text{ m hr}^{-1}$. Continuous monitoring has revealed how individual domes grow and how many domes coalesce. By 1990, the dome had replaced 3% of the volume removed by the 18 May 1980 eruption. At this rate it will take over 200 years to rebuild Mt St Helens to its pre-1980 size.



Monitoring Programs

The U.S. Geological Survey has established both periodic and continuous 24-hour monitoring programs of Mt St Helens in order to study and predict eruptions.

Deformation Widening of cracks in the crater floor is an indication that magma is rising and deforming the area, leading to an eruption; these cracks are generally radial to the dome. The rate of deformation of the lava dome is determined by periodic surveying using theodolites and electronic distance meters. Deformation rates often reach 10 m hr^{-1} as magma rises and the dome expands before extrusion starts. Precise levelling of the crater floor is done using tiltmeters, in order to monitor magma movement. Deformation of the entire volcano is monitored by angle and distance measurements at a network of stations around the base of Mt St Helens; scientists are on the alert for deformation similar to the 1980 pre-eruption bulge. In addition, deformation of the volcano can be measured using synthetic aperture radar interferometry, which measures tiny differences between elevation maps derived from satellite radar data over two different time periods.

Seismicity (earthquakes) The U.S. Geological Survey, in conjunction with the University of Wash-

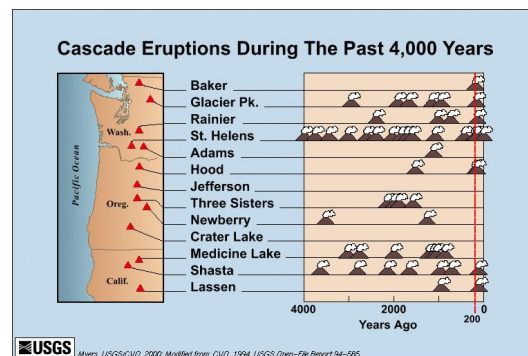
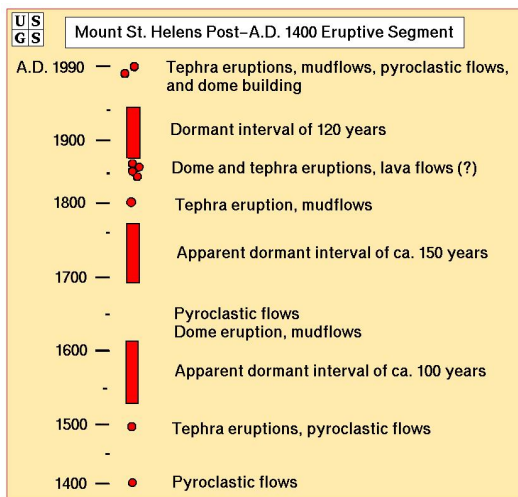
ington, maintains seismic stations at Mt St Helens. An increase in seismicity is often the first precursor to an approaching eruption. The spatial pattern of the earthquakes can also be used to track movement of magma within the volcano's internal plumbing system.

Gas emissions Gas is sampled periodically at vents on the dome and crater floor. Additionally, SO_2 gas is measured from aircraft before, during, and after eruptions. During eruptions, emission rates typically increase by 5–10 times.

Magnetism The magnetic field strength is measured periodically around the crater. The field strength increases as the dome cools and magnetic minerals form. During eruptions, the magnetic field strength usually changes rapidly as magma heats and deforms the dome.

24-hour monitoring In addition to periodic manual measurements, constant measurements are taken using automatic displacement meters, tiltmeters, gas sensors and magnetometers. The 24-hour data stream is relayed to the Cascade Volcano Observatory via satellite.

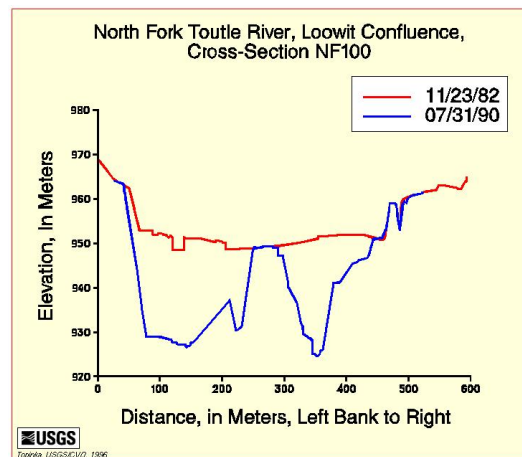
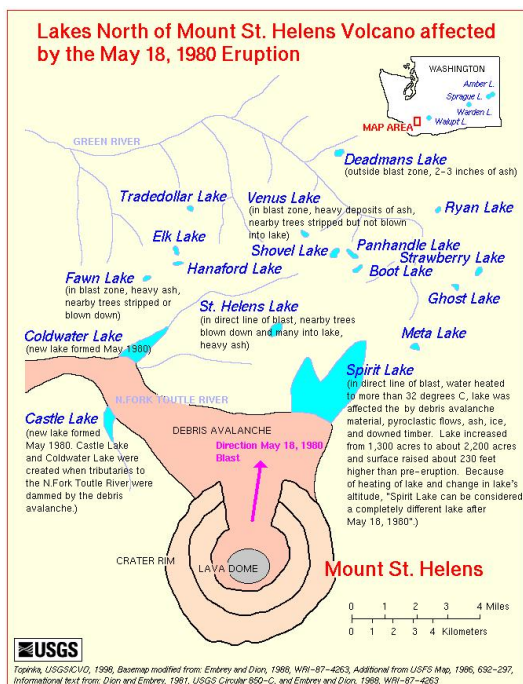
Historical eruptions Knowledge of the history of eruptions in the Cascade range is helpful when assessing hazards. The number and size of eruptions can be pieced together by careful analysis of stratigraphic sections through the pyroclastic deposits, and the age of eruptions can be found from historical records and radiometric dating of minerals. Mt St Helens is one of the most active volcanoes in the Cascade range.



Engineering Challenges

Lake overflow The 18 May 1980 debris avalanche flowed down the Toutle River valley and blocked tributaries of the North Fork Toutle River. This damming caused Spirit Lake to increase in area from 1300 to 2200 acres and its surface was raised 70 m. New lakes such as Castle Lake and Coldwater Lake were created. One major concern to people living downstream of Mt St Helens is a breakout of any of these impounded lakes due to instability of the debris dams blocking them. Flood waters from a breakout could be more catastrophic than the lahars of 18 May 1980. *Water level gauges* have been installed at lakes and streams surrounding the volcano to continuously monitor changes in water levels. Major increases or decreases in lake levels trigger warnings which are telemetered to the U.S. Geological Survey in Vancouver. *Outlet channels* have been built at Castle Lake and Coldwater Lake to stabilize water levels and prevent overtopping of the debris dams. From late 1982 through the spring of 1985, a *pump station* operated at Spirit Lake to maintain the water at a safe level. Without pumping, it was estimated that Spirit Lake would have overtopped its debris dam within a year. In the spring of 1985 a *permanent tunnel* 3.4 m in diameter and more than 2.5 km in length was opened, allowing water to drain out of the lake safely. The water level of Spirit Lake is now maintained around 30 m below the estimated overtopping level.

Sediment clogging Another major problem is the high sedimentation rate resulting from stream erosion of the relatively unconsolidated volcanic avalanche and lahar deposits. The eroded material is transported downstream and deposited on the streambeds, decreasing the carrying capacity of the channels and increasing the chances of floods. In order to remove the 18 May 1980 sediment deposits, and to keep up with new sedimentation, the U.S. Army Corps of Engineers began a dredging program on the Toutle, Cowlitz and Columbia Rivers. By 1987, nearly $110 \times 10^6 \text{ m}^3$ of material had been removed from the channels, enough material to build twelve lanes of highway, one-foot-thick, from New York to San Francisco. In the spring of 1987, construction of a sediment retention dam on the North Fork Toutle River began. The dam was designed to help stop downstream movement of sediment from its source on the debris avalanche. Sedimentation and erosion rates are monitored by periodic surveying of the cross-sections of stream channels cut through the 18 May 1980 pyroclastic deposits. Hydrologists also measure stream discharge and take water samples to determine how much sediment is suspended in the stream and how much sediment is moving along the streambed.



Environmental matters

Vegetation began reappearing as early as the summer of 1980 as many small trees and plants were protected by the snowpack on 18 May 1980. Seeds, carried by the wind or by animals, also entered the area and grew. By 1985, the ridges surrounding the volcano were covered with new growth. Many smaller animals, such as gophers, mice, frogs, fish, and insects were hibernating below ground or under water on 18 May 1980, and they survived the blast. Larger animals such as bear, elk, deer and coyotes have been moving back into the area as their food supplies increase.

Data Sources

These notes and the slides in the lecture were mostly gathered from <http://volcan.wr.usgs.gov/Volcanoes/>, which has links to pages detailing hundreds of volcanoes and eruptions.