

Chapter 4

Mt. St. Helens: A Case Study

Introduction

Mt. St. Helens is part of the Cascades volcanic arc, a continental-margin island arc system extending from Lassen Peak in northern California through Oregon and Washington before terminating in southwestern Canada where Mount Meager represents the northernmost volcano within the arc system (Figure 1). Stratovolcanoes within the Cascades arc are the result of the subduction of the Juan de Fuca microplate beneath the North America plate along the Cascadia subduction zone (Figure 2). They include Lassen Peak and Mt. Shasta in northern California, Crater Lake and Mt. Hood in Oregon, and Mt. St. Helens, Mt. Rainier, and Mt. Baker in Washington.

The Cascades volcanic arc forms a small segment of the Pacific Rim of Fire, and occurs within a region with a human population in excess of 10 million. Most of the present-day volcanoes within the arc are generally less than 2 million years old. Mt. Lassen erupted in 1912 and 1920, but the most recent eruption within the arc was at Mt. St. Helens in 1980. Let's review the events that lead up to the VEI 6 eruption of Mt. St. Helens on May 18, 1980 using

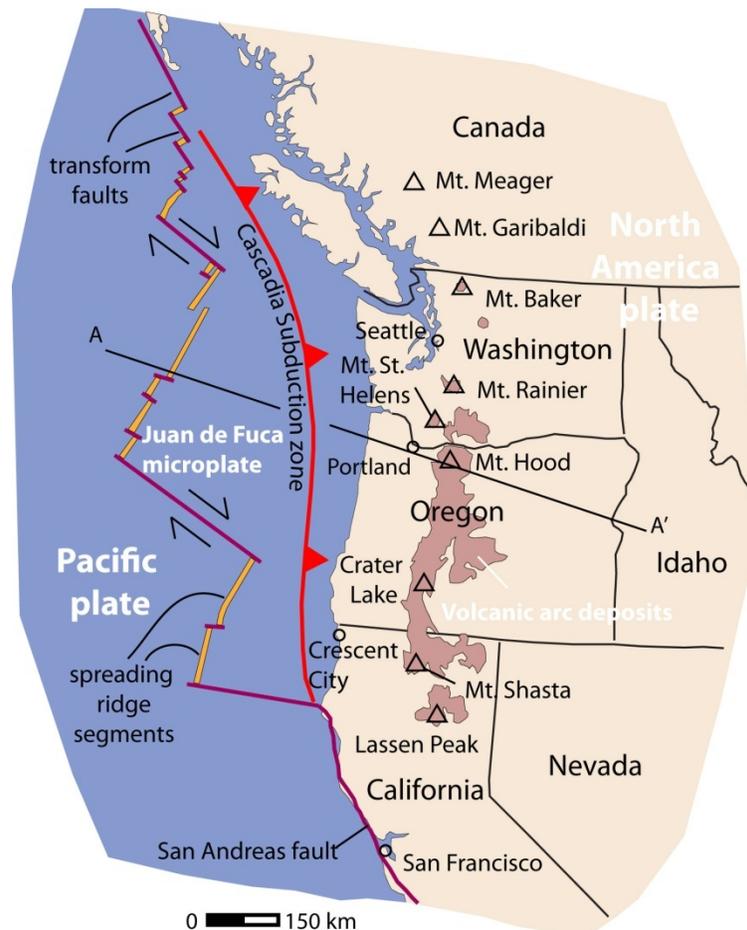


Figure 1. Generalized map showing major tectonic elements of the NW United States and the location of Figure 2.

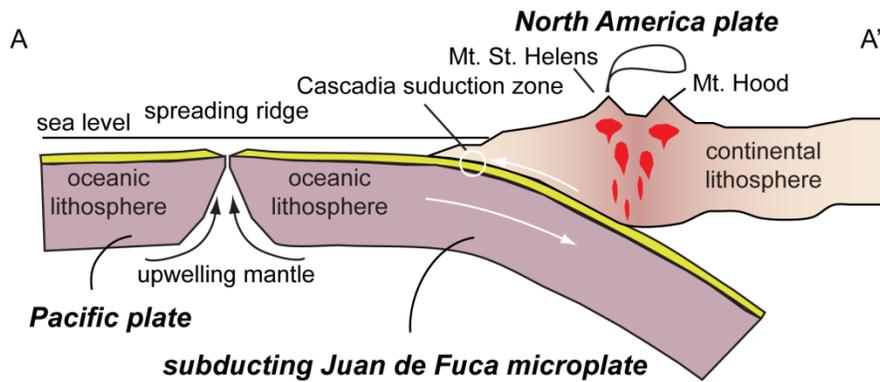


Figure 2. Cross section showing the position of Mt. St. Helens above the subducting Juan de Fuca microplate.

the timeline outlined by R.I. Tilling, L. Topinka, and D.A. Swanson of the United States Geological Survey. Perhaps from such a review we might learn something about how the other now sleeping and dormant volcanoes lying within the Cascades volcanic arc might behave prior to an eruption.

The Timeline of Mt. St. Helens Eruption

Prior to the May 18, 1980 eruption, Mt. St. Helens formed a relatively calm and classical looking snow and glacier capped stratovolcanic edifice in southwestern Washington (Figure 3).



Figure 3. Mt. St. Helens, May 17, 1980. The following day the volcano erupted. USGS photograph by Harry Glicken. Inset is an Earth Explorer 5.0 DEM showing the location of Mt. St. Helens in SW Washington.

Its relatively steep little eroded slopes merged symmetrically upward encircling a central vent area.

The visible cone shape of Mt. St. Helens had formed in the last ~2,200 years making it one of the youngest in the Cascades volcanic arc. Though concerned geologist such as D.R. Crandell, D.R. Mullineaux, and M. Rubin as early as 1975 and 1978 recognized the potential danger of Mt. St. Helens, as late as May 17, no one expected an imminent eruption.

Beginning about March 16, 1980 and continuing until about March 26 significant **earthquake activity**, that is a shaking and vibration of the land surface, was recorded at Mt. St. Helens. Richter earthquake magnitudes varied from about 2.6 to 4.2. Between March 26 and March 27 over 174 earthquakes with magnitudes greater than 2.6 were recorded.

On March 27 at 12:36 PST Mt. St. Helens began to spew steam and ash into the atmosphere. The eruption column rose to about 829 meters (~6000 feet). An ~76 meter (~250 feet) wide crater formed as a result of the initial eruption. In addition, noticeable new cracks formed across the summit.

The observed March 27 eruption of steam and ash, and others that followed in the coming days, were likely produced by hot intruding magma encountering ground water, which then explosively flashed to generate and sustain the observed **steam-blast eruptions**.

The activity that began on March 27 continued intermittently through April 21 with explosive bursts of steam and ash lasting from a few seconds to tens of minutes. During this activity a second crater formed and then merged with the first.

Earthquakes and intermittent volcanic activity continued at Mt. St. Helens, and on March 31 **volcanic tremors** were recorded on seismographs. Volcanic tremors are different from the distinct relative short jolts characteristic of earthquakes, as they are represented by a more continuous rhythmic ground shaking. At Mt. St. Helens, they were interpreted to signify the movement of magma or gases beneath the volcano.

Eruptive activity ceased in late April and early May, but resumed on May 7 and then continued intermittently through May 16. About 10,000 earthquakes were recorded through mid-May with the greatest concentration of activity occurring in a small area less than ~2.57 km (~1.6 miles) directly beneath a bulge on the north flank of the volcano. Such intense seismic activity and the visible swelling and cracking of the volcano signified that magma was being forced into the sub-volcanic magma chamber, and, as result, the bulge near the summit of the volcano was more than ~137 meters (~450 feet) higher than it was in the summer of 1979. Laser-beam measurements indicated that the bulge was growing predominantly horizontally in a northward direction at a rate of ~1.5 meters/day (~5 feet/day). As the bulge moved northward, the summit area in back of it (to the south) sank, forming a graben (Figure 4A).

On Sunday, May 18, 1980, Mt. St. Helens explosively and dramatically erupted at about 8:32 am PDT. As illustrated in the following description of this event by R.I. Tilling, L. Topinka, and D.A. Swanson, the eruption came unexpectedly.

“May 18, a Sunday, dawned bright and clear. At 7 a.m. Pacific Daylight Time (PDT), USGS volcanologist David A. Johnston, who had Saturday-night duty at an observation post about 6 miles north of the volcano, radioed in the results of some laser-beam measurements he had made moments earlier that morning. Even

considering these measurements, the status of Mount St. Helens' activity that day showed no change from the pattern of the preceding month. Volcano-monitoring data--seismic, rate of bulge movement, sulfur-dioxide gas emission, and ground temperature--revealed no unusual changes that could be taken as warning signals for the catastrophe that would strike about an hour and a half later. About 20 seconds after 8:32 a.m. PDT, apparently in response to a magnitude 5.1 earthquake about 1 mile beneath the volcano, the bulged, unstable north flank of Mount St. Helens suddenly began to collapse, triggering a rapid and tragic train of events that resulted in widespread devastation and the loss of 57 people, including volcanologist Johnston."

Shown in Figure 4 are a series of cross-sections depicting the collapse of the north flank of Mt. St. Helens. This collapse produced the largest landslide-debris avalanche recorded in historic time. During the collapse first one block began to move, and then another, and then another (Figure 4B). This series of moving blocks then merged down slope into a single gigantic

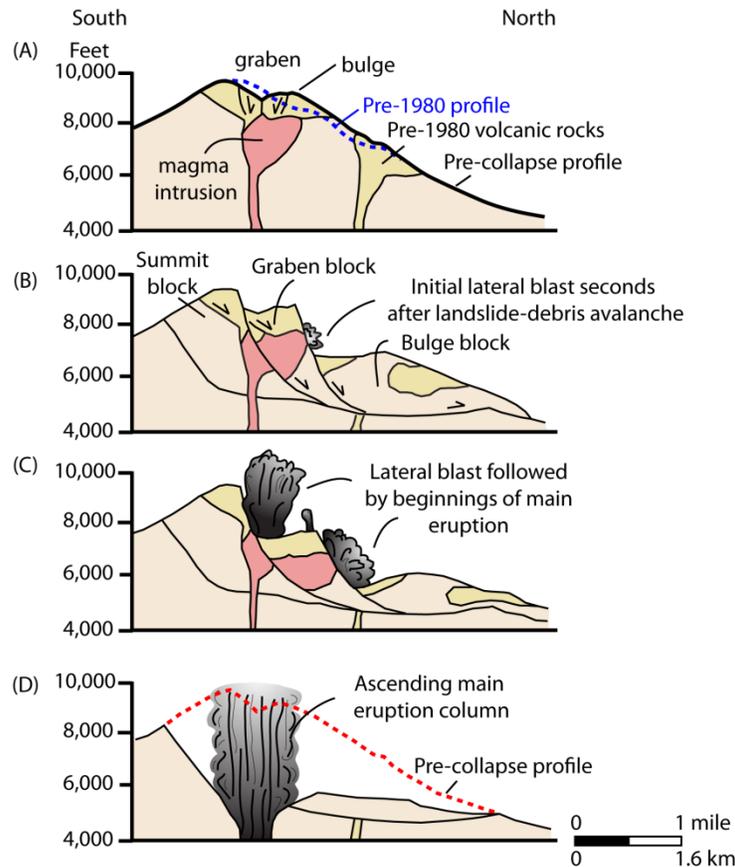


Figure 4. Series of schematic illustrations showing development of debris avalanche during early stage of development of May 18, 1980 eruption at Mt. St Helens. Modified after Tilling et al. (1993).

debris avalanche that traveled at speeds of 177 to 249 kilometers/ hour (110 to 155 miles/hour). At one point in its downward movement it retained sufficient momentum to travel up and over a ridge ~350 meters high (1150 feet). Over all, the debris avalanche advanced more than ~20.9 kilometers (13 miles) down the North Fork of the Toutle River filling the valley to an average depth of about ~45.7 meters (~150 feet) (Figure 5). The total volume of the resulting deposit is estimated to be about 2.9 cubic kilometers (~0.7 cubic miles).

The unloading of the summit of the volcano by the debris avalanche triggered the expansion of high temperature-high pressure steam trapped in the cracks and voids in the volcano and the vesiculation of gases dissolved in the dacitic magma that had created the northward bulge noted earlier. The end result was a northward-directed **lateral blast** that formed a **pyroclastic flow** composed of rock, ash, and hot gases. The movement of the pyroclastic flow devastated a fan-shaped sector, 597.7 square kilometers in area (~230 square miles) north of the volcano, while to the south the affected area was only near the summit (Figure 5). Though the lateral blast occurred only seconds after the debris avalanche (Figure 4B), the resulting pyroclastic flow traveled at such a high velocity that it overtook the debris avalanche. The pyroclastic flow is estimated to have traveled initially at ~354 kilometers/hour (~220 mile/hour), but this speed quickly increased to ~1078 kilometers/hour (~670 mph). The blast was heard in parts of British Columbia, Montana, Idaho, and northern California.

The movement of the pyroclastic flow produced by the lateral blast caused widespread devastation as far as ~30.6 kilometers (~19 miles) from the volcano. The area affected can be subdivided into three roughly concentric areas referred to as the **direct blast**, **channelized blast**, and **seared** zones (Figure 5). Within the direct blast zone virtually everything was

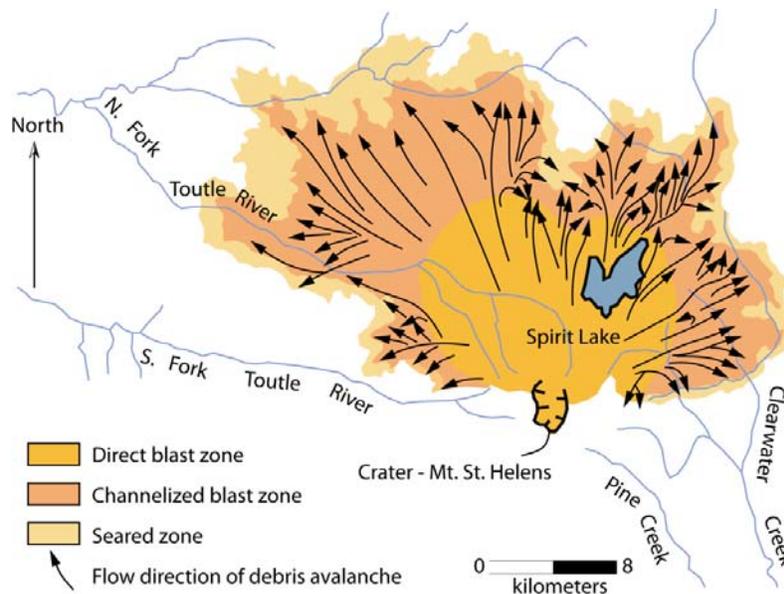


Figure 5. Map showing the spatial distribution of the direct blast, channelized blast, and seared zones derived from the May 18, 1980 eruption at Mt. St. Helens. Modified after Tilling et al. (1993).

obliterated or carried away by the pyroclastic flow. The pyroclastic flow within the channelized blast zone flattened everything that it encountered. For example, large trees were toppled, broken off at the base of their trunks. The outermost zone affected by the pyroclastic flow is the seared zone (Figure 5). In this zone, trees remained standing, but were singed brown by the hot gases from the blast.

Shortly after the lateral blast, a vertical column of ash and steam rose from the summit of the volcano (Figure 4D). In less than 10 minutes, the **eruption column** had rose ~19.3 kilometers (~12 miles) into the atmosphere and had begun to spread out to form the classical mushroom shape of the **umbrella region**. Near the volcano vegetation and forests were set afire by **lightening** generated within the swirling cloud of ash. During this time, parts of the mushroom-shaped eruption column collapsed, sending additional pyroclastic flows speeding



Figure 6. A dramatic and surrealistic image of Mt. St. Helens, May 18, 1980. Photograph from US Geological Survey (<http://pubs.usgs.gov/gip/monitor/studies.html>)

down the flanks of Mt. St. Helens. As the eruption continued, the high part of the eruption column (the umbrella region) was blown by the prevailing winds and drifted to the east – northeast (Figure 6). The **ash cloud** traveled at about 96.6 kilometers per hour (~60 miles per hour) and was dense enough to block out nearly all sun light in Yakima and Spokane, Washington.

During the 9 hours of vigorous eruption activity, an extensive **ash fall** deposit composed of about 540 million tons of ash was produced. It covered an area of about 56,980 square kilometers (~22,000 square miles). However, by late afternoon on May 18 the eruptive column had subsided, and by May 19 the eruption had ceased. By this time, the ash cloud had reached the central United States and several days later, though now very diffuse, it was detected in distant parts of the NE United States. After about 2 weeks some of the ash had drifted around the globe.

The eruption of so much ash enlarged the depression at the summit that had formed from the initial debris avalanche and lateral blast. Today it forms an amphitheater-shaped crater that opens to the north (Figure 7). The eruption on May 18 lowered the highest point on the summit of Mt. St. Helens by about 400 meters (1,313 feet).

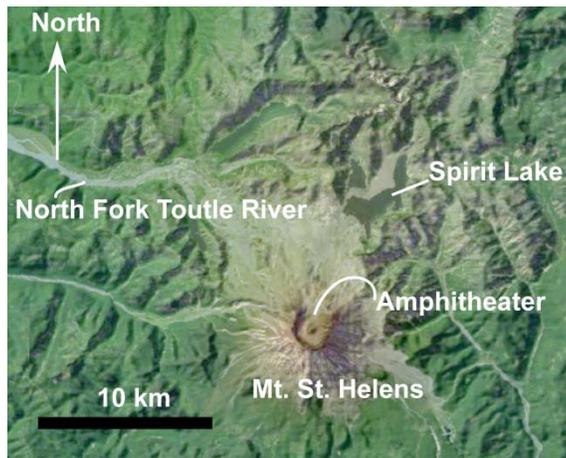


Figure 7. Earth Explorer 5.0 DEM of Mt. St. Helens showing the amphitheater-like depression at the summit produced by the lateral blast.

According to R.J. Janda, K.M. Scott, K.M. Nolan, and H.A. Martinson of the United States Geological Survey as hot pyroclastic debris melted snow and ice on the upper slopes of Mt. St. Helens destructive **lahars** developed minutes after the May 18 eruption. Such lahars flowed down the Muddy River, Pine Creek, and the South Fork Toutle River (Figure 8). These early

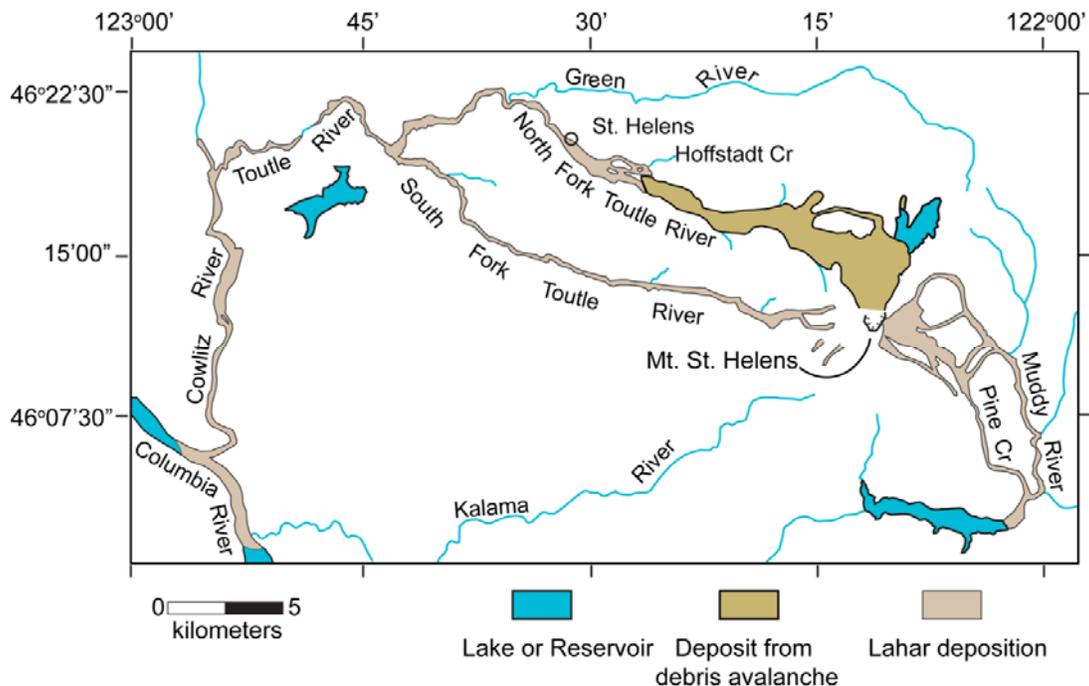


Figure 8. Map showing lahar deposits from May 18. Modified from Janda et al. (1981).

lahars may have originated as **wet rock avalanches** traveling initially at velocities as high as 45 meters per second (~148 feet per second). However, as they moved down valley, their velocities decreased and they turned into **mudflows**, i.e., in a volcanic setting, a lahar composed mostly of material finer grained than about 0.06 mm (e.g., of a mixture of sand, silt, and clay between about 20% to 80% will be silt sized or smaller).

Slumping and flowage of water-saturated parts of the deposit resulting from the initial debris avalanche in the North Fork Toutle River produced a lahar that had the greatest volume, lowest velocity, most sustained flow, and the greatest length of flow than any other lahar that formed on May 18. In addition, deposits from this lahar are the coarsest and most poorly sorted. As shown in Figure 8, the lahar flowing from the deposit derived from the debris avalanche followed two routes, one down the channel of Hoffstadt Creek and the other down the main channel of the North Fork Toutle River. These two flows converged just above the small town of St. Helens (Figure 8). From this point on, the lahar swept away bridge decks and girders as it moved downstream reaching a velocity of 12 meters per second (~39 feet per second) below the mouth of Green River (Figure 8). However, throughout most of its reach, the lahar probably traveled at velocities in the range of 6 to 8 meters per second (~20 to ~26 feet per second), and upon reaching the main Toutle River continued for another 120 kilometers (~74.5 miles) down the Cowlitz and Columbia rivers where it caused widespread channel filling, flooding, and damage to roads, bridges, and other structures.

Aftermath

By the time the initial pyroclastic flow from the lateral blast encountered its first human victims it was still very hot and composed of suffocating amounts of gas and ash. Most of the overtaken victims died from asphyxiation but several individuals died from burns, while one was buried under hundreds of feet of avalanche material. In addition to the loss of human life, 200 homes, 27 bridges, 24 kilometers (15 miles) of railways and 300 kilometers (185 miles) of highway were destroyed. In short, by the time the eruption was over, 57 people had lost their lives and \$2.74 billion (2007 dollars) in damage had occurred.

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