Names: **ESS 315**

Lab # 3 Volcanic Hazards along the Cascadia Subduction Zone

Introduction

In the Pacific Northwest, the Juan de Fuca Plate is being subducted beneath the North American Plate. As the denser oceanic lithosphere is subducted beneath the continental lithosphere, it encounters high temperatures and pressures that partially melt solid rock. Some of this newly formed magma rises toward the Earth's surface to erupt forming an arcuate chain of volcanoes, known as the Cascade Range. The Cascade Range has been an active volcanic arc for about 36 million years as a result of plate convergence between the Juan de Fuca and North American Plates at about 3-4 centimeters per year. According to most interpretations, volcanism in the Cascades has been discontinuous in time and space, with the most recent activity commencing about 5 million years ago and resulting in more than 3000 vents that extend from Mount Garibaldi in British Columbia Canada, to Lassen Peak in northern California. Thirteen volcanic centers in Washington, Oregon, and California are considered potential geologic hazards and are capable of further eruptions **(NOTE: Figures are in separate, laminated set).**

The map in Fig. 3-1 shows the major volcanic centers in the Cascade Range and surrounding population centers. Which volcano(es) pose(s) the greatest geologic hazard to the following population centers listed in the Table 3-1 below?

TABLE 3-1

Population Center	**Volcanoes**
Seattle-Tacoma, WA	
Bellingham, WA	
Mount Vernon, WA	
Portland, OR	
Eugene, OR	
Bend, OR	
Weed, CA	

Volcanic Hazards

Volcanoes generate a wide variety of phenomena that can alter the Earth's surface and atmosphere and endanger people and property **(See Fig. 3-2).** While most volcanic hazards are associated with eruptions, some, like landslides, can occur when a volcano is quiescent. Small volcanic events may pose a hazard only within a few miles of the volcano, while large event can directly or indirectly endanger people and property tens to hundreds of miles away.

Eruption Columns and Clouds

An explosive eruption blasts molten and solid rock fragments (tephra) into the air with tremendous force. The largest fragments (bombs) fall back to the ground near the vent, usually within 2 miles. The smallest rock fragments (ash) continue rising into the air, forming a huge, billowing eruption column. Volcanic ash is composed of fragments of rock, minerals, and glass that are less than 2 millimeters (0.08 inch) in diameter.

Eruption columns can be enormous in size and grow rapidly, reaching more than 12 miles above a volcano in less than 30 minutes. Once in the air, the volcanic ash and gas form an eruption cloud. Eruption clouds pose a serious hazard to aviation. During the past 15 years about 80 commercial jets have been damaged by inadvertently flying into ash, and several have nearly crashed. Large eruption clouds can travel hundreds of miles downwind from a volcano, resulting in ash fall over enormous areas. Ash from the May 18, 1980, eruption of Mount St. Helens was deposited over 22,000 square miles of the western United States. With increasing distance downwind from a volcano, the ash particles become smaller and the thickness of the resulting layer decreases. Minor ashfall can be a nuisance to people and damage crops, electronics, and machinery; heavy ashfall can collapse buildings.

Although the 1980 eruption of Mt. St. Helens eruption was impressive, the volume of material ejected from the volcano was actually small in comparison to other historic eruptions at subduction-related volcanoes. Table 3-2 lists the estimated volumes of ejecta thrown out during selected historic eruptions.

TABLE 3-2.

Year	**Eruption**	**Volume of Ejecta (Km^3)**
5000 BC	Mt. Mazama, Oregon	41
79 AD	Vesuvius, Italy	2.5
1707	Mt. Fuji, Japan	2
1815	Tambora, Indonesia	30
1842-57	Mt. St. Helens	1
1883	Krakatau, Indonesia	18
1912	Mt. Katmai, Alaska	12
1956	Bezymianny, Kamchatka, USSR	1
1980	Mt. St. Helens	0.5
1991	Mt. Pinatubo, Phillipines	5

Which do you think has the potential to be more destructive: A convergent margin volcano like Mt. St. Helens that erupts about once every century, or one that erupts at much longer intervals? Why do you think this is so?

Study **Figure 3-3** (Cascade Eruptions During the Last 4000 Years) and **3-4** (Annual Probability of Tephra Accumulation).

Where is the main area of concentration of tephra accumulation?

What are the main factors that control the spatial pattern of the annual probability of 10 cm or more of tephra accumulation in the Pacific Northwest from Cascade volcanoes?

PYROCLASTIC FLOWS

High-speed avalanches of hot ash, rock fragments, and gas move down the sides of a volcano during explosive eruptions or when the steep edge of a dome breaks apart and collapses. These pyroclastic flows, which can reach 1500 degrees F and move at 100-150 miles per hour, are capable of knocking down and burning everything in their paths. A more energetic and dilute mixture of searing gas and rock fragments is called a pyroclastic surge. Surges move easily up and over ridges; flows tend to follow valleys.

The May 18, 1980 eruption of Mount St. Helens generated a horizontally directed series of explosions that formed a lateral blast. This blast destroyed an area of 230 square miles. Trees 6 feet in diameter were mowed down like blades of grass as far as 15 miles from the volcano. The blast exhibited characteristics of both pyroclastic flows and surges.

On the day of the main Mt. St. Helens eruption, seismometers 3.5 miles from the blast origin stopped transmitting 77 seconds after the eruption, when they were overridden by a dense pyroclastic blast cloud. Based on this information, how fast (in miles per hour) was the blast cloud moving? Show your math.

LAVA FLOWS AND DOMES

Molten rock (magma) that pours or oozes onto the Earth's surface is called lava. The higher a lava's silica content, the more viscous it becomes. For example, low- silica basalt lava can form fast-moving (10-30 miles per hour), narrow lava streams or spread out in broad sheets up to several miles wide. Between 1983 and 1993, basalt lava flows erupted at Kilauea Volcano in Hawaii destroyed nearly 200 houses and severed the coast highway along the volcano's south flank.

In contrast, higher-silica andesite and dacite lava flows tend to be thick, move slowly, and travel short distances from a vent. Dacite and rhyolite lava flows often form mound-shaped features called domes. Between 1980 and 1986, Mount St. Helens built a lava dome about 1,000 feet high and 3,500 feet in diameter. Renewed activity since October, 2004 has built a second new dome that continues to grow:
(see http://vulcan.wr.usgs.gov/Volcanoes/MSH/Eruption04/LIDAR/framework.html for recent laser altimetry data of the growth of the new dome)

LAHARS (DEBRIS FLOWS OR MUDFLOWS)

Lahars are mixtures of water, rock, sand, and mud that rush down valleys leading away from a volcano. They can travel over 50 miles downstream, commonly reaching speeds between 20 and 40 miles per hour. Sometimes they contain so much rock debris (60-90% by weight) that they look like fast-moving rivers of wet concrete. Close to the volcano they have the strength to rip huge boulders, trees, and houses from the ground and carry them downvalley. Further downstream they simply entomb everything in mud. Historically, lahars have been one of the most deadly volcanic hazards.

Lahars can form in a variety of ways, either during an eruption or when a volcano is quiet. Some examples include the following: (1) rapid release of water from the breakout of a summit crater lake; (2) generation of water by melting snow and ice, especially when a pyroclastic flow erodes a glacier; (3) flooding following intense rainfall; and (4) transformation of a volcanic landslide into a lahar as it travels downstream.

Study the USGS map HA-729 Sheet 1, “Debris Flow, Debris Avalanche and Flood Hazards at and Downstream from Mt. Rainier, Washington.” The Osceola Mudflow (~5000 years ago) is the maximum lahar at Mt. Rainier and is believed to have a recurrence interval ~10,000 years. The inundation area of the actual flow is easily discernible on the Puget Sound Lowland.

What population centers are built on top of the Osceola Mudflow?

The Osceola Mudflow would have had a mean flow velocity of ~40 meters per second at the base of the volcano, ~20 m/s at the Lowland boundary, and 10 m/s on the Lowland.

Calculate the response times that the following communities would have to move their citizens to higher ground in the event of a comparative lahar with a similar magnitude as the Osceola Mudflow.

Table 3-3

Community	**Response Time (minutes)**
Enumclaw	
Auburn	
Kent	
Tukwila	

The inundation area of modern cohesive lahar of the same magnitude of the Osceola Mudflow could extend to the Puget Sound, through Tacoma along the Puyallup River and through Seattle by way of the Green River system and the Duwamish Waterway.

What physical (and ecological) changes have affected many of the river valleys (lahar flow paths) since the arrival of European settlers in the 19th and 20th centuries?

What impact might such changes have on the potential distance and flow velocity of a recurrent flow?

Assuming an average recurrence interval of 10,000 years for an Osceola-sized lahar event, how would you advise city planners in Enumclaw, WA, regarding site location within city limits for:

A. An elementary school

B. A nuclear power plant

(There isn't a right or wrong answer to the above questions, but please explain your recommendations)

Case I lahars (e.g., Electron Mudflow) have a recurrence interval of 500-1000 years. Even one event equal to or greater than a flow with a 1000-year recurrence interval has a 9.5% probability of occurring at least once in the next century.

Study the USGS map HA-729 Sheet 1 again. Find the inundation area of the Electron Mudflow (~500 years ago) on the map.

How would the response times differ between the communities of Orting and Tacoma in order to evacuate the potential inundation area of a lahar with the same characteristics as the Electron Mudflow?

Orting:

Tacoma:

What would you recommend to Orting city planners regarding the site location for an elementary school within city limits? Would it differ from your advice to Enumclaw regarding their elementary school? Explain.

Study Figures 3-5 (Glacier Peak Eruption History) and 3-6 (Areas Inundated by Glacier Peak Debris Flows). What relationship do you see between the recurrence interval of volcanic eruptions and the size of the debris flow?

You will notice that a large debris flow inundated the Stillaguamish River valley between 12,500 and 13,100 years ago. What factor(s) might account for the subsequent large debris flow event to inundate the Sauk and Skagit River valleys 6300-5900 years ago and no longer flow into the Stillaguamish River valley?

VOLCANIC LANDSLIDES (DEBRIS AVALANCHES)

A landslide is a rapid downslope movement of rock and/or soil. In glaciated regions, landslides can also include snow and ice. Landslides range in size from small movements of loose debris on the surface of a volcano to massive failures of the entire summit or flanks of a volcano. Volcanic landslides are not always associated with eruptions; heavy rainfall or a large regional earthquake can trigger a landslide on steep slopes. Volcanoes are susceptible to landslides because they are composed of layers of weak, fragmented, volcanic rocks that tower above the surrounding terrane. Furthermore, some of these rocks have been altered to soft, slippery, clay minerals by hot, acidic ground water inside the volcano. At least five large landslides swept down the slopes of Mount Rainier during the past 6,000 years. The largest volcanic landslide in historical time occurred at Mount St. Helens on May 18, 1980.

Study the USGS map HA-729 Sheet 2, "Modern Debris Avalanches and Debris Flows at Mt. Rainier, Washington." What are the three most common factors causing debris avalanches on Mt. Rainier?

1.

2.

3.

Based on information provided to you from the above volcanic hazard map, do you think that debris avalanches pose a threat to any of the URBAN areas of the Puget Sound region?

An outburst flood from which glacier system would pose the greatest risk to the town of Longmire (Review Figure 3-7)?

A velocity of about 50 meters per second, which was increasing at the point of measurement, was reported for the 1980 debris avalanche at Mt. St. Helens. If these data can be extrapolated to a potential Mt. Rainier debris avalanche, how long would the citizens of Longmire have to react to a debris avalanche generated at the terminus of the Nisqually Glacier?