

Exercise 4 Volcanic Hazards

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Student Name _____

Section _____

In this lab you will:

examine various volcanic hazards and some of the techniques that can be used to help minimize the loss of life and property damage.

Background Reading and Needed Supplies

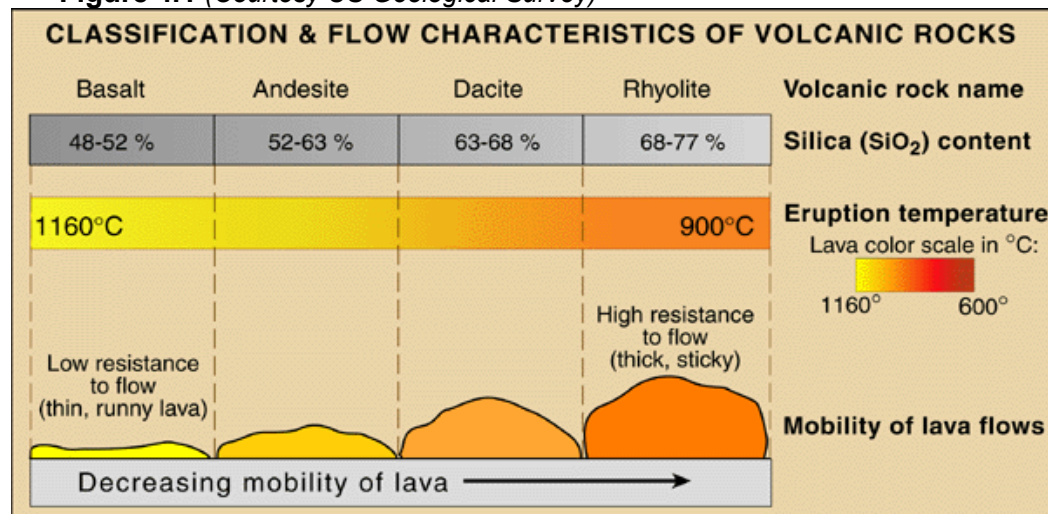
Prior to doing this exercise you should read Chapter 8 in the textbook.
With respect to supplies, you will need a calculator, ruler, and colored pencils.

Part I – Magma Chemistry and Lava Flows

In general, basaltic magmas originate from the upper mantle and are relatively hot, rich in iron and magnesium, but poor with respect to silica (SiO_2). Andesitic and rhyolitic magmas, on the hand, are relatively cool, poor in iron and magnesium, but rich in SiO_2 . These so-called SiO_2 rich magmas form in a variety of ways. One is when basaltic rock (oceanic crust) undergoes partial melting in a subduction zone. Another is when granitic rock (continental crust) melts, or is incorporated into a basaltic magma. Finally, SiO_2 -rich magmas can form when iron and magnesium rich crystals within a basaltic melt become separated from the magma.

The SiO_2 content of magmas is important because it helps control the fluid property known as **viscosity**. As illustrated in Figure 4.1, magmas that are relatively rich SiO_2 have more resistance to flow, hence are more viscous. Temperature is also important because as magmas become cooler their viscosity increases. Consequently, relatively hot, SiO_2 -poor basaltic magmas are much less viscous than the cooler, SiO_2 -rich andesitic and rhyolitic magmas.

Figure 4.1 (Courtesy US Geological Survey)



<http://volcanoes.usgs.gov/images/pglossary/VolRocks.php#flow>

1) Lava flows are one of the more obvious types of volcanic hazard. Which magma, basaltic or rhyolitic, would likely pose the greatest threat to communities in the area surrounding a volcano? Explain why.

2) Shown below are topographic profiles of the two basic types of volcanoes, shield and composite cone.



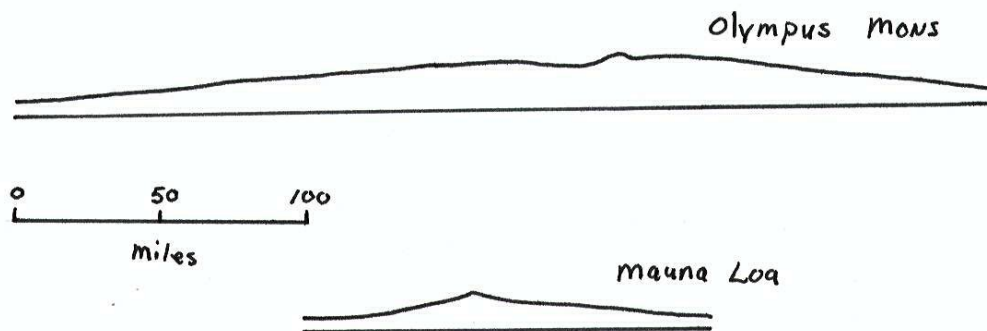
a) Label which profile corresponds to a shield volcano and which is a composite cone.

b) Label which volcano would contain mostly basaltic flows, and which would have mostly andesitic/ rhyolitic flows.

c) Explain how the topographic profiles of the volcanoes above are related to the viscosity of their respective magma types. In other words, how does magma viscosity affect a volcano's topographic profile?

3) When an oceanic (basaltic) crustal plate collides with a continental (granitic) plate at a convergent plate boundary, the oceanic plate almost always undergoes subduction. Describe how the difference in chemical composition between basalt and granite (rhyolite) determines which plate undergoes subduction.

- 4) Volcanism has taken place on all of the rocky planets of the inner solar system in the geologic past. Olympus Mons (now extinct) is the largest volcano on Mars, and on Earth, Mauna Loa is the largest. Their topographic profiles are shown below.



- a) Based on its topographic profile, what type of volcano is Olympus Mons?
- b) What does the topographic profile of Olympus Mons indicate about the chemical composition of its lava flows. Explain how you know.
- 5) As measured from its base on the sea floor, Mauna Loa is 5.1 miles high and has radius of 68 miles. Olympus Mons is 15.5 miles high and its radius is 171 miles. Because the volcanoes are cone shaped, we can use the following formula to estimate the volume rock making up each volcano:

$$V = \frac{1}{3} \pi r^2 h$$

where r = the radius at its base, and h = the height.

- a) Using the equation above, estimate the volume of rock (in miles³) making up Mauna Loa.
- b) Estimate the volume of rock (in miles³) in Olympus Mons.
- c) In terms of volume, how many times larger is Olympus Mons than Mauna Loa?
- 6) Convert the heights of Mauna Loa and Olympus Mons from miles to feet.

Mauna Loa = 5.1 miles high x _____ = _____ feet

Olympus Mons = 15.5 miles high x _____ = _____ feet

For comparison, Mt. Everest is about 29,000 feet above sea level. Note that because Mauna Loa here is measured from its base on the sea floor, approximately 14,000 feet of its total height lies below sea level.

Part II – Composite Cone Hazards

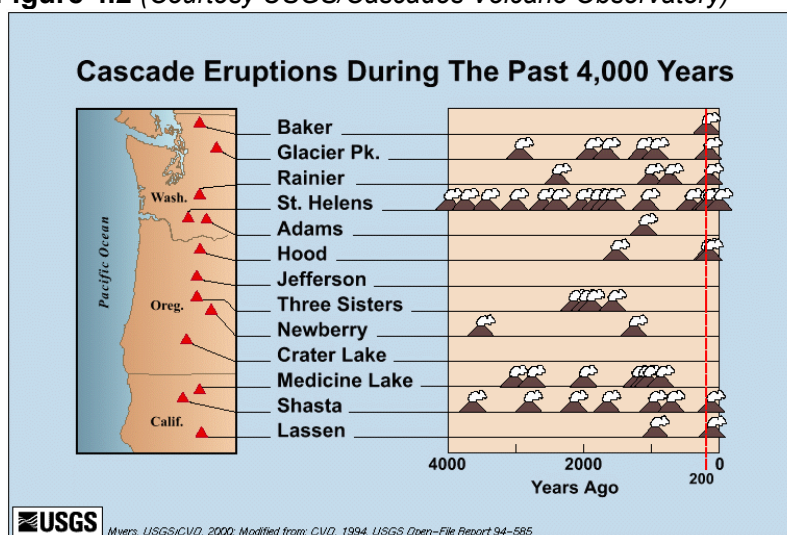
In addition to being more viscous, andesitic and rhyolitic magmas typically contain much higher levels of dissolved gases than do basaltic magmas. The dominant gas in andesitic/rhyolitic magmas is water vapor, which originates from sedimentary material that is pulled down into subduction zones. Deep within the Earth, confining or overburden pressure keeps the gases in a dissolved state, producing a highly pressurized magma (similar to how dissolved carbon dioxide creates pressurized soft drinks). When a gas-rich magma rises through the crust and breaches the surface, the dissolved gases can rapidly decompress, creating a violent explosion. This explosive effect creates a number of volcanic hazards, including lateral blasts, ash fall, and pyroclastic flows.

The subduction zone along the northwest Pacific coast of the United States generates explosive magma that has formed the chain of composite cone volcanoes known as the Cascade Range. Note in Figure 4.2 that of all the Cascade volcanoes, Mount St. Helens's has been the most active over the past 4,000 years. The most recent eruption was the 1980 eruption of Mount St. Helens. We will make use of the extensive data collected by the U.S. Geological Survey (USGS) since this eruption to help illustrate some of the hazards associated with composite cone volcanoes. For more details on Mount St. Helens, see:

<http://vulcan.wr.usgs.gov/Volcanoes/MSH/framework.html>

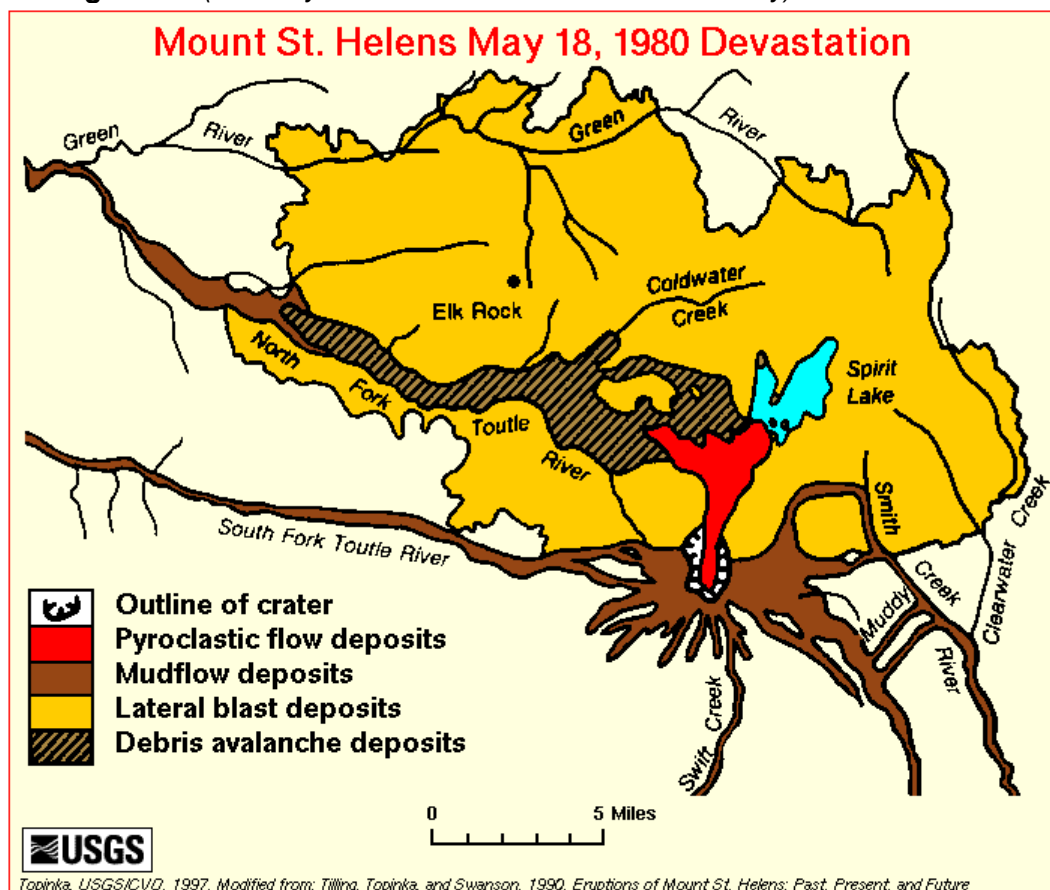
<http://vulcan.wr.usgs.gov/Volcanoes/MSH/Hazards/OFR95-497/OFR95-497.html>

Figure 4.2 (Courtesy USGS/Cascades Volcano Observatory)



- 7) Figure 4.3 is a USGS map showing the distribution of volcanic deposits associated with the 1980 explosive eruption of Mount St. Helens. The photo in Figure 4.4 illustrates the power of the initial lateral blast, whereas the space shuttle image in Figure 4.5 provides an overview. Note that the shuttle image is oriented such that north is to the right. Also note that the lake which formed on Coldwater Creek is not shown on the hazard map.

Figure 4.3 (Courtesy USGS/Cascades Volcano Observatory)



- Locate the island-shaped blast deposit (gold) in Figure 4.3 that lays within the debris avalanche material (striped pattern) filling the North Fork of the Toutle River valley. Use an orange-colored pencil or marker to outline this isolated blast deposit on the photo in Figure 4.5.
- The area you just outlined is a ridge (i.e., topographic high) where the USGS operated one of its monitoring stations prior to the 1980 eruption. This ridge has been named Johnston Ridge in honor of the USGS geologist named David Johnston, who lost his life in the eruption. Using the graphical scale on Figure 4.3, determine the distance in miles between Johnston Ridge and the volcano's vent within the crater.

- 8) The photo in Figure 4.4 shows some of the large fir trees that were blown down by the lateral blast along Smith Creek, located just east of Mount St. Helens.
- Using the graphical scale on the map in Figure 4.3, estimate the distance in miles between Smith Creek and the crater.
 - Compare the distances from Smith Creek and Johnston Ridge to the crater. Are they much different or about the same?
 - Based on what you see in Figure 4.4, describe the specific types of blast hazards that would have been present at both Smith Creek and Johnston Ridge.

Figure 4.4 – Smith Creek, located east of Mount St. Helens. For scale, note the arrow pointing to two geologists standing along the river bank. (Courtesy USGS/Cascades Volcano Observatory, Lyn Topinka.)



- 10) Using the map in Figure 4.3 as a guide, outline the volcanic deposits listed below on the space shuttle image in Figure 4.5. Use the colors as indicated:
- pyroclastic flow (red)
 - mudflow (brown)
 - debris avalanche (black)

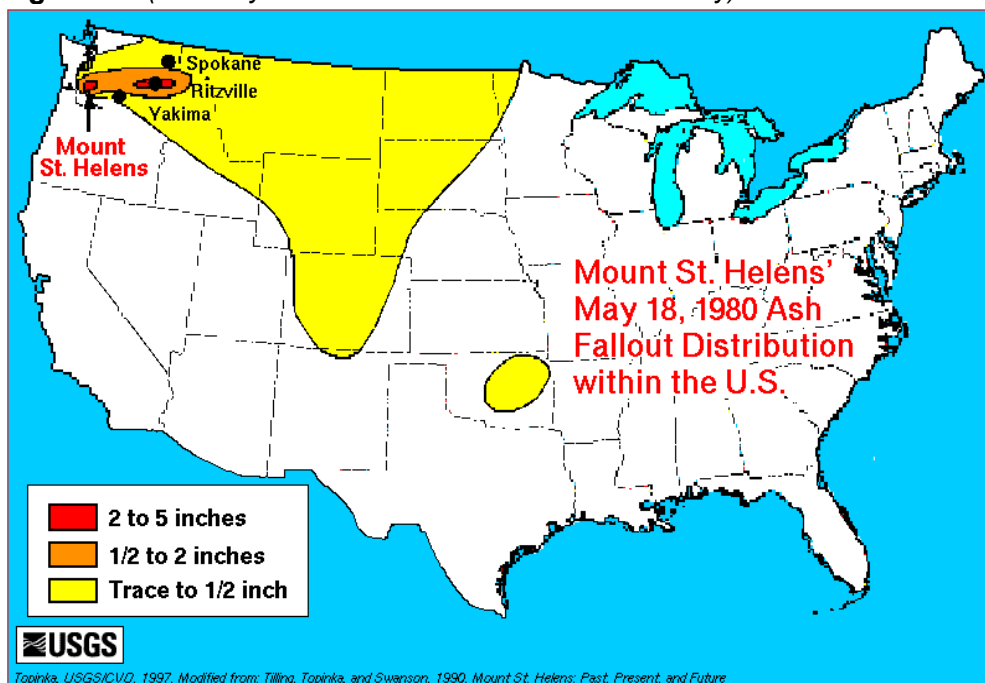
Figure 4.5 - 1994 view of Mount St. Helen's from space; north is to the right. (*Courtesy NASA*)



(*NASA Earth from Space photo STS064-51-25, September 1994*)

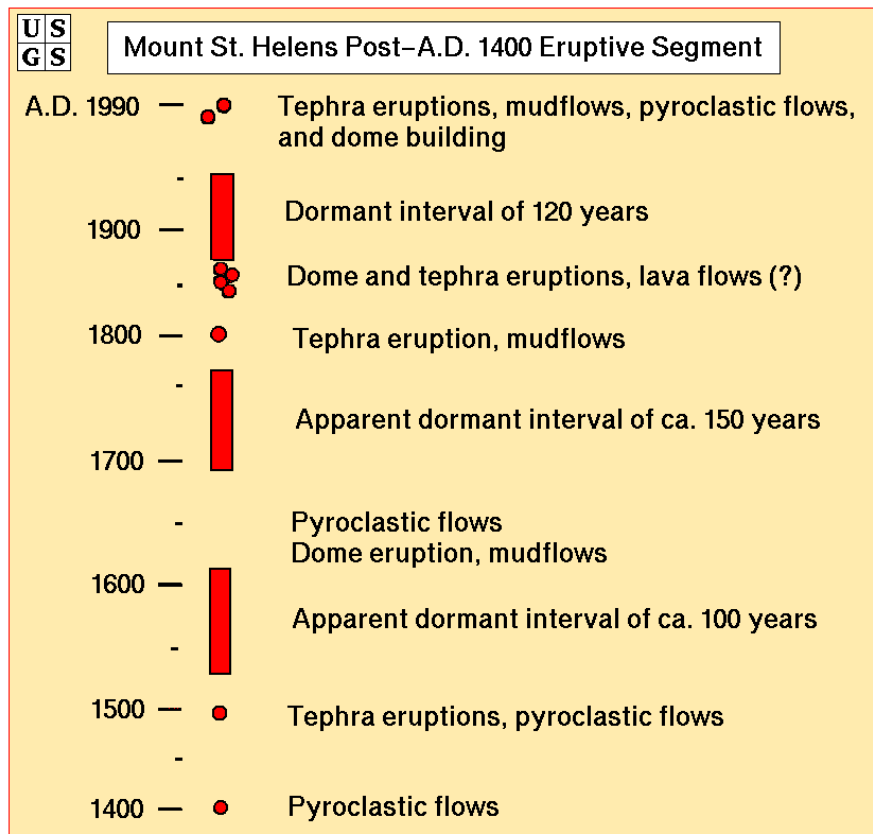
- 11) The original valley of the North Fork of the Toutle River is now filled with as much as 1,000 feet (305 m) of pyroclastic flow deposits from the 1980 eruption. What are pyroclastic flows and explain why they are so hazardous?
- 12) From the map in Figure 3.5 one can see that mudflows travel much farther from a volcano than do pyroclastic flow. Explain why this is so.
- 13) The map in Figure 4.6 shows the distribution of volcanic ash fallout over the United States from the 1980 eruption of Mount St. Helens. List and describe four (4) types of problems that volcanic ash can pose for a modern society.

Figure 4.6 (Courtesy USGS/Cascades Volcano Observatory)



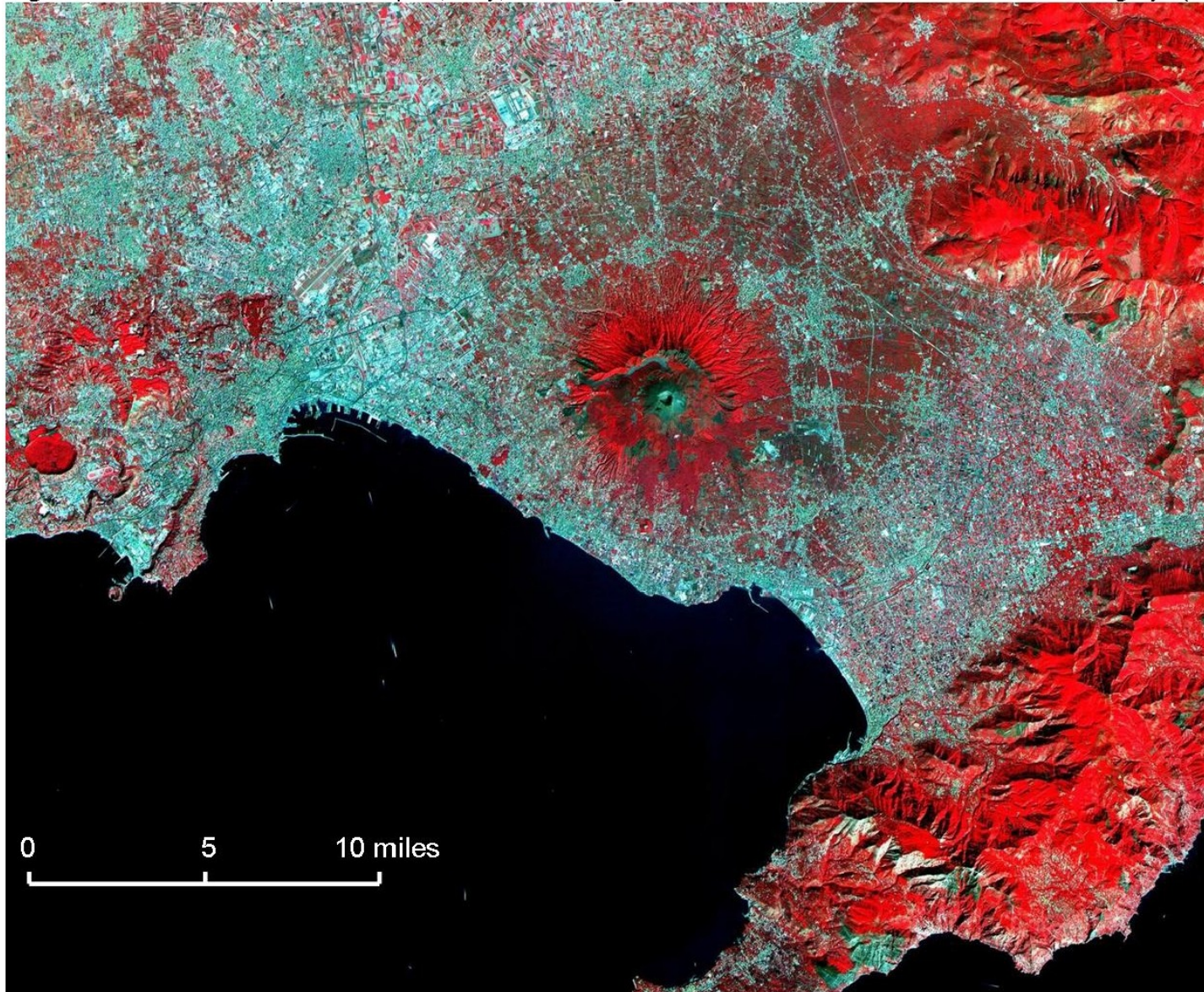
- 14) The eruptive history of Mount St. Helens since 1400 A.D. is shown in Figure 4.7.
- What is the average number of years that the volcano has remained dormant between eruptions during this period?
 - Give a geologic explanation as to why the eruption cycle appears to be somewhat regular.
 - Based on the average dormant interval, and the fact that Mount St. Helens last eruption was around 1990, estimate the year in which another major eruption is likely to occur.
 - How accurate do think such a prediction might be? Explain.

Figure 4.7 (Courtesy USGS/Cascades Volcano Observatory)



Robert I. Tilling, Lyn Topinka, and Donald A. Swanson, 1990, *Eruptions of Mount St. Helens: Past, Present, and Future*, U.S. Geological Survey Special Interest Publication, 56p.

Figure 4.8 - False color photo of Naples, Italy, where vegetation is shown in red and the urban area in grey. (Courtesy NASA)



15) The false-color satellite image in Figure 4.8 shows Mount Vesuvius and the surrounding urban area of Naples, Italy. This composite cone erupted in 79 AD, burying 3,600 residents of the Roman City of Pompeii and surrounding settlements in ash and pyroclastic flow material. Today, nearly 4 million people now live in the Naples metro area.

a) The lateral blast from Mount St. Helen's 1980 eruption extended outward approximately 15 miles from the crater. Using the graphical scale on the Naples image in Figure 4.9, outline a 15-mile blast radius around Mt. Vesuvius.

b) Based on your blast zone, what percentage of Naples metro area do you think should be evacuated if Mt. Vesuvius were to become active and a major eruption was eminent?

c) In addition to the blast itself, describe two other volcanic hazards that would threaten the developed area of Naples.

d) If a major eruption were to occur, what do you think would happen to the millions of residents who presumably had safely evacuated in time?

Part III – Mudflow Hazards around Mount Rainier

As described in the textbook, Mount Rainier is the largest composite cone in the Cascade Range. This volcano has extensive glaciers covering its summit, and has a history of producing exceptionally large debris avalanches and mudflows. About 5,000 years ago, a large portion of the volcano collapsed, creating a debris avalanche and mudflow that raced down the stream valleys leading away from the volcano. Some of the mudflows reached as far as present day Tacoma and Seattle. A smaller, but still significant mudflow took place about 550 years ago. Today, many of the communities surrounding Mount Rainier are built on ancient mudflow deposits in these same river valleys.

In a future eruption, Mount Rainier could be expected to generate pyroclastic flows that quickly melt the glacial ice cap, creating mudflows that go crashing down the surrounding river valleys. Mudflows could even form in absence of volcanic activity. Geologists believe that hydrothermal activity can slowly weaken the rocks within the volcano to the point where a major slope failure occurs. The result would be an avalanche of rock and glacial ice in which the ice rapidly melts to form a massive mudflow.

16) From Figures 4.9 and 4.10 one can see that ancient mudflow deposits are found in all the river valleys whose headwaters are located near the summit of Mount Rainier. Notice how the town of Kent is on the edge of an ancient mudflow deposit, but yet the headwaters of the Green River are located far from the volcano. Explain how mudflows from Mount Rainier could have entered the Green River (Hint: examine the drainage map and think about the topography).

17) Should Mount Rainier become active and threaten to erupt, seismic monitoring would likely provide sufficient early warning to allow for the safe evacuation of communities in the surrounding river valleys. Explain how seismic monitoring could also be used to alert residents of a mudflow caused not by volcanic activity, but by a massive slope failure.

18) The continued expansion of communities in the river valleys surrounding Mount Rainier is obviously creating the potential for a large loss of life and property. Do you think that zoning laws should be passed to discourage future development in such high-risk areas, or should people rely on early warning systems and take the chance that a mudflow will not occur in their lifetime?

Figure 4.9

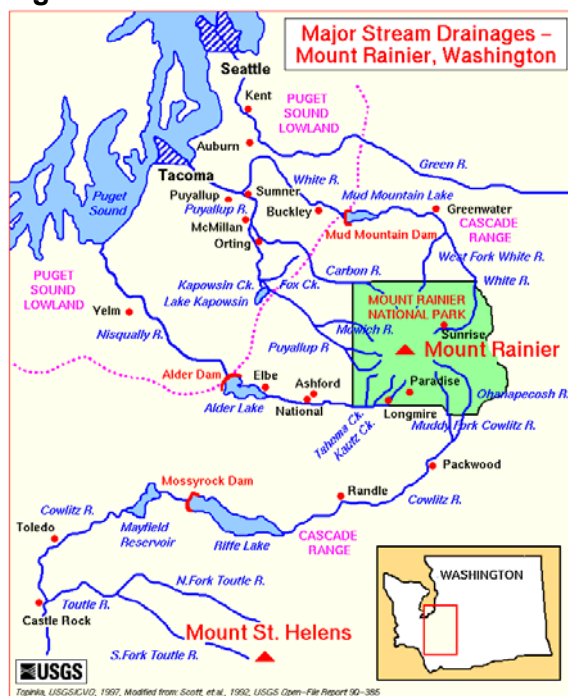


Figure 4.10

