EXERCISE 5

Hazards of Mount St. Helens

INTRODUCTION

The goals of this exercise are, first, to look at the well-documented events associated with the May 18, 1980, and subsequent eruptions of Mount St. Helens; and second, to investigate the impact that these volcanic events had on the surrounding area. Mount St. Helens is located in southwestern Washington. Figure 5.1 illustrates the locations of and different eruption histories that characterize Cascade volcanoes in the United States. Mount St. Helens, as can be seen from its eruption history over the past 4,000 years, is very active. Events that occurred on and hazards generated by Mount St. Helens are typical of those that could be expected if other Cascade volcanoes were to erupt. Mount Rainier is close to the Seattle–Tacoma area of Washington, and Mount Hood is close to the Portland area of Oregon. Eruptions of either of these volcanoes might have major impacts on nearby metropolitan areas.

PART A. ERUPTION OF 1980

The eruption of May 18, 1980, was preceded by increasing seismic activity at the volcano, small phreatic eruptions (steam-driven eruptions created as the mountain warmed up and heated groundwater within the volcano), tilting of the volcano's slopes, and noticeable bulging on the north side of the volcano.

There were several distinct events on the morning of May 18, 1980. These chronologically were (1) an earthquake of Richter magnitude 5.1, (2) a landslide on the north side of the mountain, (3) a lateral blast to the north, (4) an eruption column that soon became vertical, with pyroclastic flows to the north, (5) lahars down many river valleys that lead from the volcano, and (6) extensive tephra deposits, carried by the wind to eastern Washington and beyond. In this exercise we investigate a few of these events and processes. Refer to your text or to reference materials suggested by your instructor if you need additional information.

QUESTIONS 5, PART A

Mount St. Helens: Topography Before and After

1. Figure 5.3a is a topographic map of Mount St. Helens prior to the eruption, and Figure 5.3b is a map of the mountain after the eruption. Compare these maps with both the oblique photographs (Figure 5.2) and with the stereo photographs (Figure 5.4). Use a Stereoscope, if available, to study Figure 5.4.

Draw topographic profiles of the mountain from point A to point B on Figure 5.3a and from point C to point D on Figure 5.3b. Draw both profiles on the same sheet of your own graph paper; you need use only the heavy contours in your profiles. Each profile begins at 4,800 ft on the west end and ends at 4,400 ft on the east end.

2. Describe the main differences in these profiles. How are these differences reflected in the stereo photographs? Why does it help (or not) to have the oblique photos for reference in drawing these profiles?

3. What were the peak elevations of Mt. St. Helens before and after the eruption? How much elevation was lost from the old peak to the new crater floor? (Hint: Use the average elevation between the two contours that define the 1980 crater floor.)

4. From the shape of the mountain prior to eruption, is Mount St. Helens closer in profile to Hawaiian volcanoes or to composite volcanoes? (See Introduction, Exercise 4.)

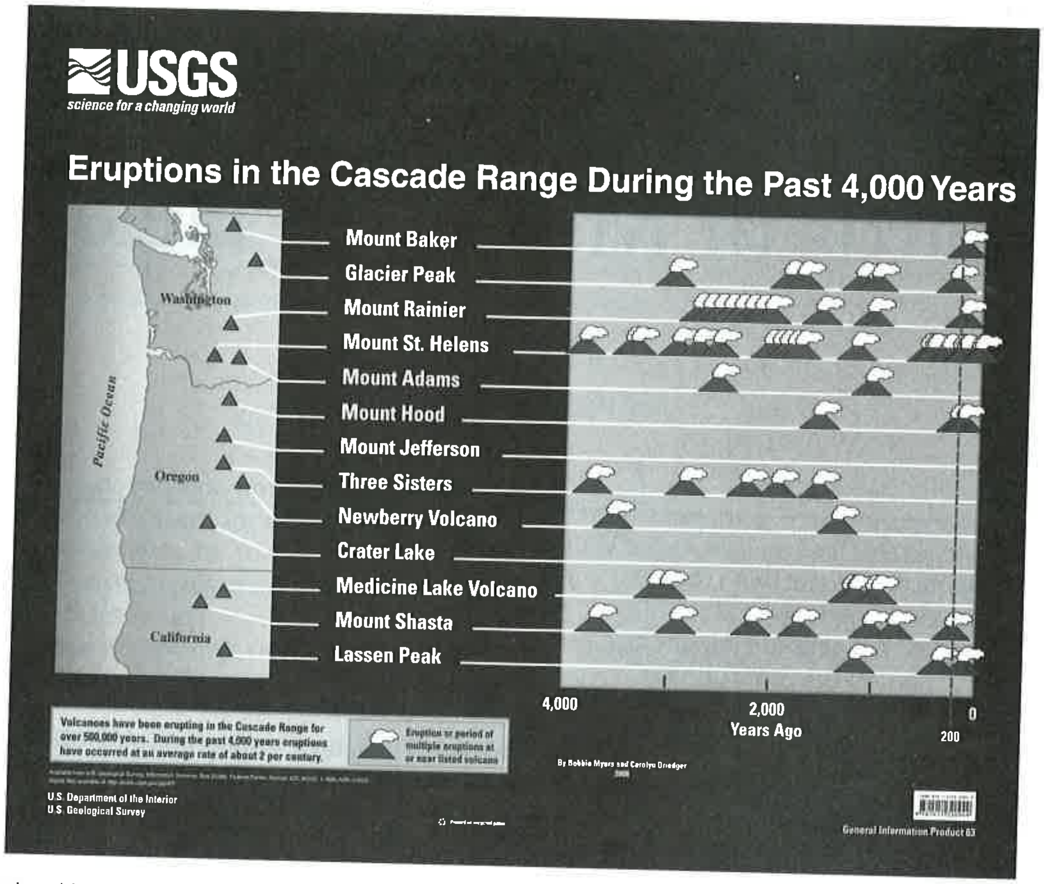


FIGURE 5.1 Regional location map of Cascade volcanoes, eruption histories of the volcanoes over the past 4,000 years, and nearby metropolitan areas. Courtesy of Bobbie Myers and Carolyn Driedger, U.S. Geological Survey Cascade Volcano Observatory. http://Pubs.usgs.gov/gip/63/, downloaded August 2008.

5. What does the shape of Mount St. Helens suggest about the composition of rock that you would expect to find here?

6. After the eruption, much of the volcano was missing. Where did the material go?

a. Compare the elevation of Spirit Lake on Figures 5.3a and 5.3b. What is the elevation before the eruption? _____ What is the elevation after the eruption? _____ Explain how the changes occurred.

b. Follow the channel of the North Fork of the Toutle River west from Spirit Lake. On Figure 5.3a, in section 18, just east of where Studebaker Creek enters the Toutle River, what is the elevation of the bench mark?

c. After the eruption (Figure 5.3b), how much elevation change occurred in the elevation of the northern third of section 18?

d. What geologic deposit occurs in this area southwest of Johnston Ridge (refer to Figure 5.5 in the colored maps section)? What is the origin of this deposit? What other eruption impacts occurred in this area?

7. Examine Figures 5.3 and 5.5 (and photos 5.2 and 5.4) to determine the distribution of glaciers near the top of Mt. St. Helens both before and after the eruption.

a. What changes took place?

b. Where did the ice go?

c. What river channel(s) was (were) heavily impacted by waters from the melting ice?

Volcanic Deposits Near the Mountain

8. Figure 5.5 (in maps section at back of book) is a map of proximal deposits and features of 1980 eruptions of Mount St. Helens published by the U.S. Forest Service. What are the major types of volcanic deposits and eruption-related features depicted on this map?

9. What are the relative geographic and topographic positions of these deposits and features in relation to the main cone of the mountain (i.e., which are nearby and which are farther away)? Which are confined to valleys and which are found on hills?

FIGURE 5.2 Oblique aerial photographs of Mount St. Helens before (top) and after (bottom) the May 18, 1980 eruption. View looking south. Compare these photographs with the topographic maps in Figures 5.3a and 5.3b.

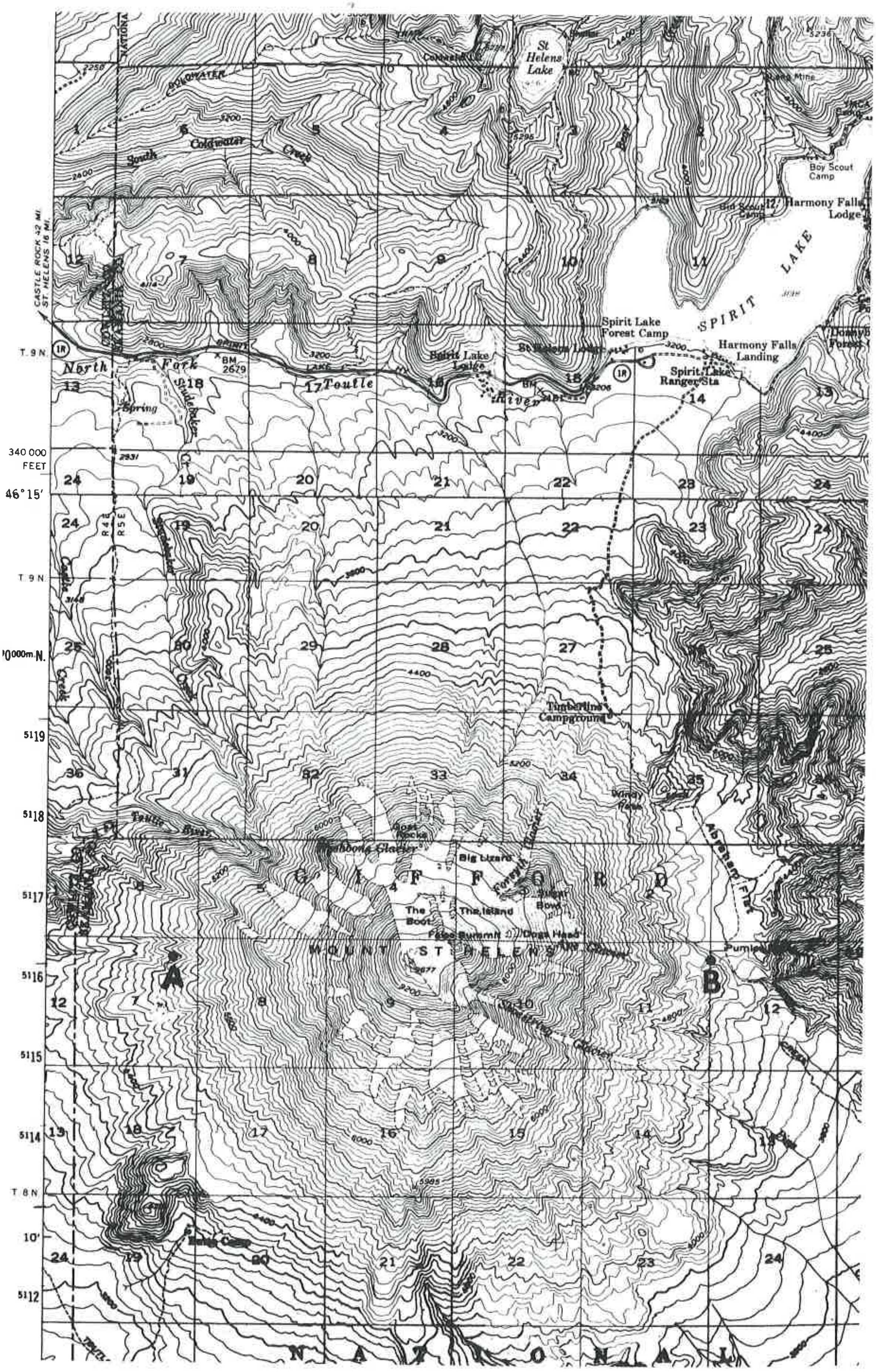


FIGURE 5.3(A) Topographic map of Mount St. Helens prior to May 18, 1980 eruption (USGS). Sections for Scale.

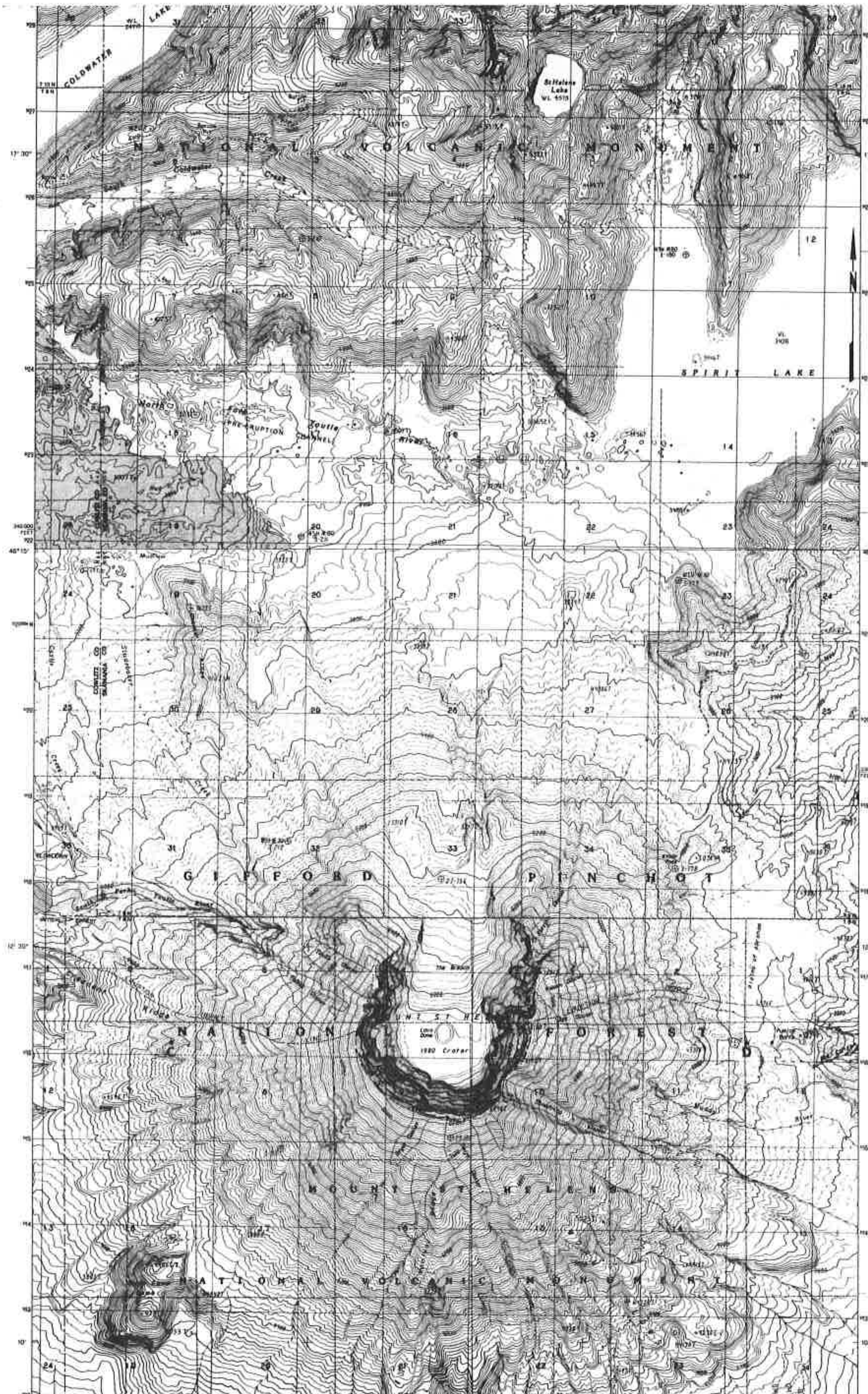


FIGURE 5.3(B) Topographic map of Mount St. Helens after the May 18, 1980, eruption (USGS). Sections for Scale.

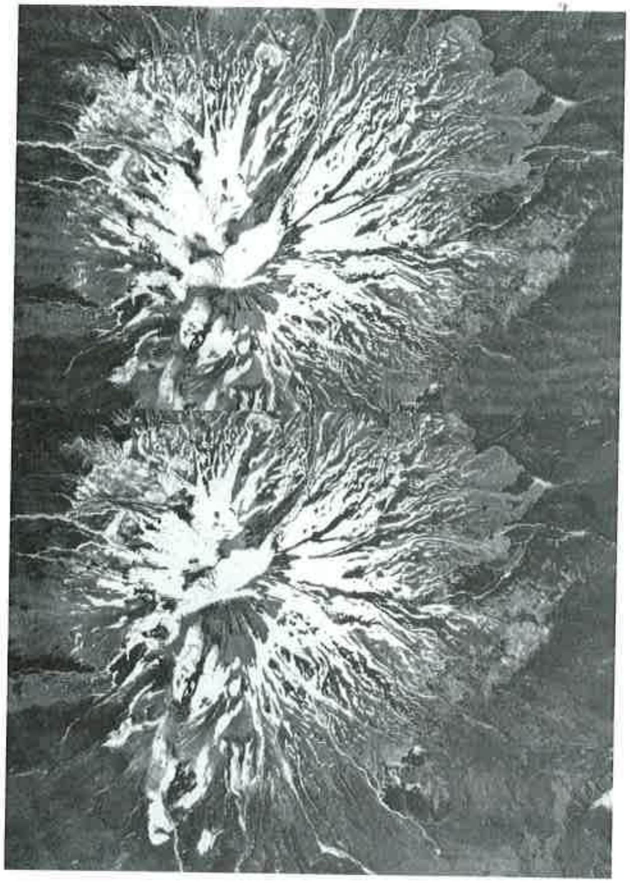


FIGURE 5.4(A) Vertical aerial stereographic photos of Mount St. Helens prior to May 18, 1980 (USGS).

FIGURE 5.4(B) Vertical aerial stereographic photos of Mount St. Helens after the May 18, 1980, eruption (USGS).

Eruption-Related Problems Away From the Volcano

10. Figure 5.6 shows the general area impacted by lahars (mudflows). Since the major direction of the first volcanic burst was to the north, what geologic processes caused lahars to form on all sides of the volcano?

11. The lahars transported tremendous amounts of sediment far from the volcano. Figure 5.7 shows the configuration of the Columbia River bed before and after the eruption. What differences in configuration are evident?

12. How thick did sediment deposited in 1980 in the Columbia River get?

Tephra

Figure 5.8 is a wind rose, which shows the percent of time that the wind blows in a particular direction. Imagine that you are standing in the center of the circle. The letters on the outside of the circle represent compass directions, and the numbers inside the circle represent the percent of time that the wind is blowing from you toward that particular direction. It can be seen, for instance, that the wind blows 16% of the time toward the east (E), and only 1% of the time toward the west (W). Note that this convention is opposite what you might expect, in that a westerly wind (one coming out of the west) is plotted toward the east, in the direction the wind is going.

13. Based on the wind rose data, what percent of time would winds blow toward the ENE and E? ________ Are Olympia (NNW) or Portland (SSW) at much risk of tephra from Mount St. Helens, based on the data in the wind rose? ________ Explain.

Figures 5.9 and 5.10 are maps of tephra deposits from two Mount St. Helens eruptions. Note the little circles in the corner of each figure. These are wind directions, toward which winds are blowing at the times of eruption, given for different elevations in the atmosphere. Remember that the posteruption elevation of the top of Mount St. Helens is about 2,550 meters.

14. Compare the distributions of tephra, the wind directions at the times of the eruptions, and the wind rose. Did the eruptions occur at times of common or uncommon wind directions? Explain.

Assessing the Likely Hazard

Figure 5.11 shows potential hazard areas of Mount St. Helens; the map was published about 2 years before the major eruption. Compare it with Figure 5.5 in the map section at the back of the book, which depicts deposits from the 1980 eruptions.

15. List the predicted events for each flowage–hazard zone shown in Figure 5.11.

16. a. Was a preferred direction predicted for events in flowage zone 1? _____ Zone 2? _____ Zone 3? _____

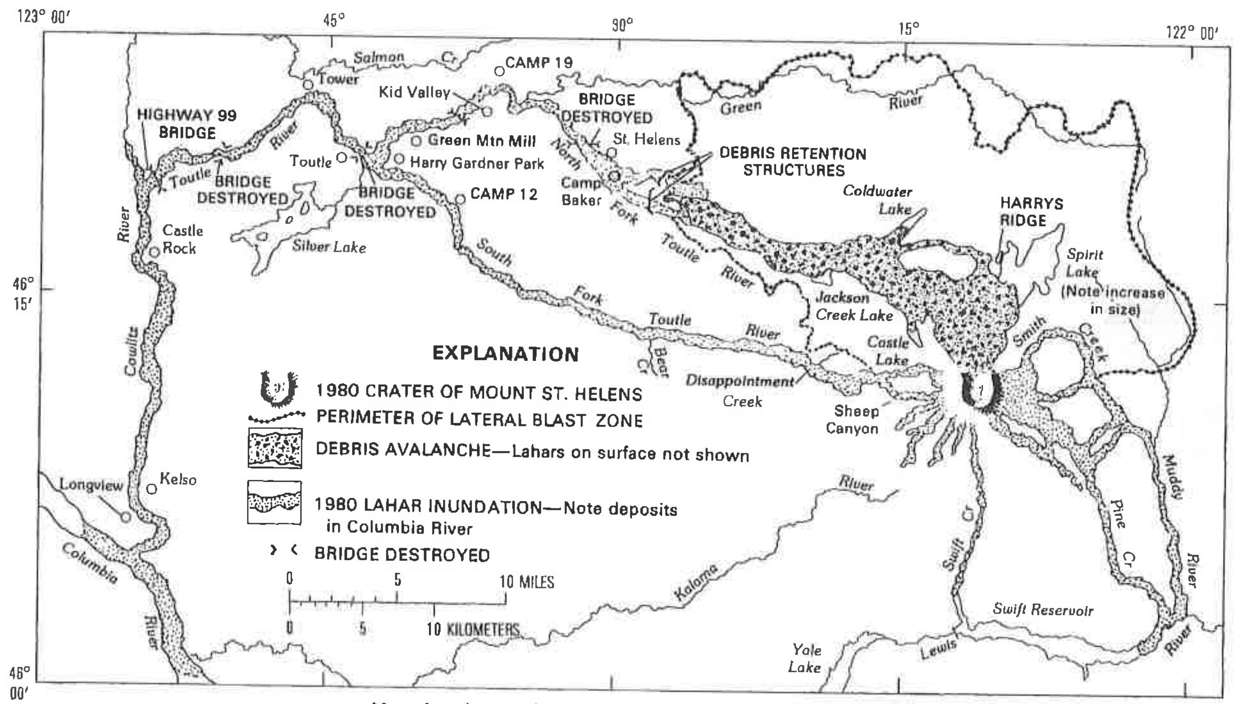
b. What eruption processes and products that occurred, if any, were not included in the predictions?

17. a. How closely do the predictions in Figure 5.11 match the locations of actual mudflows or lahars in the southern half of zone 1 at end of the following valleys (see Figure 5.5 and 5.6).

Muddy River _____

Pine Creek _____

Swift Creek _____



Map of study area showing locations and extent of 1980 lahars

FIGURE 5.6 The general area impacted by lahars (mudflows) from Mount St. Helens. (Scott, 1988)

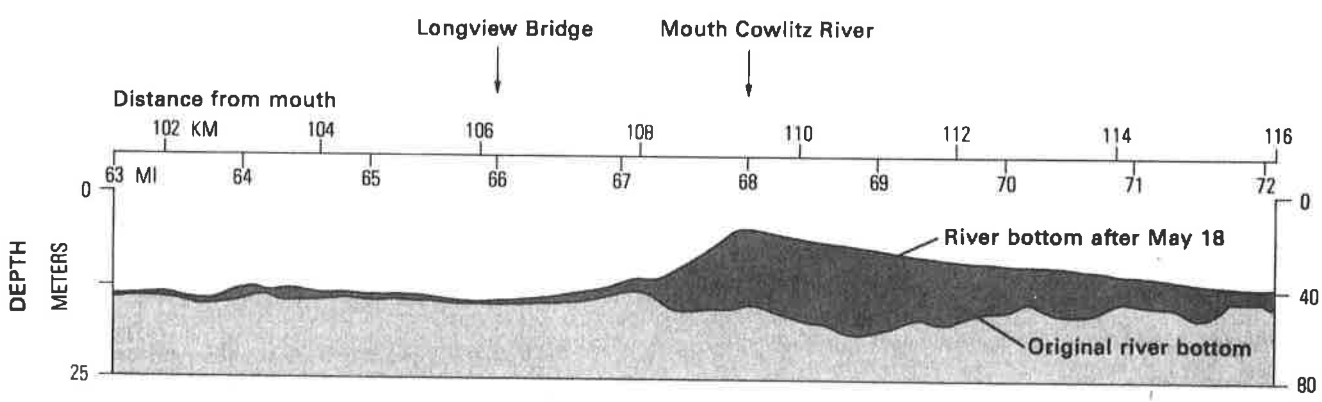


FIGURE 5.7 Longitudinal profile (along the river channel) of the Columbia River bed before and after the 1980 eruption of Mount St. Helens. Dark shaded area represents the thickness of sediment deposited as a result of the May 18, 1980, eruption (Schuster, 1981).

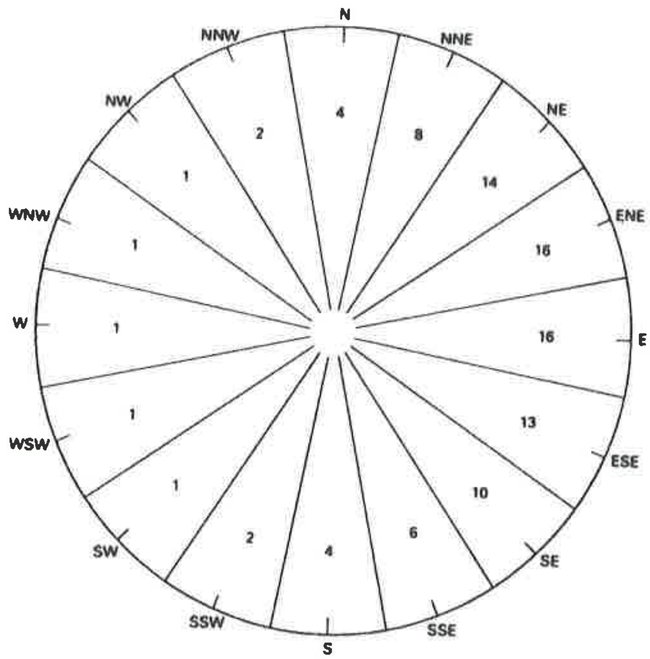


FIGURE 5.8 Approximate percentage of time, annually, that the wind blows toward various sectors in western Washington. Frequencies determined between 3,000m and 16,000m at Salem, OR, and Quillayute, WA (Crandell and Mullineaux, 1978).

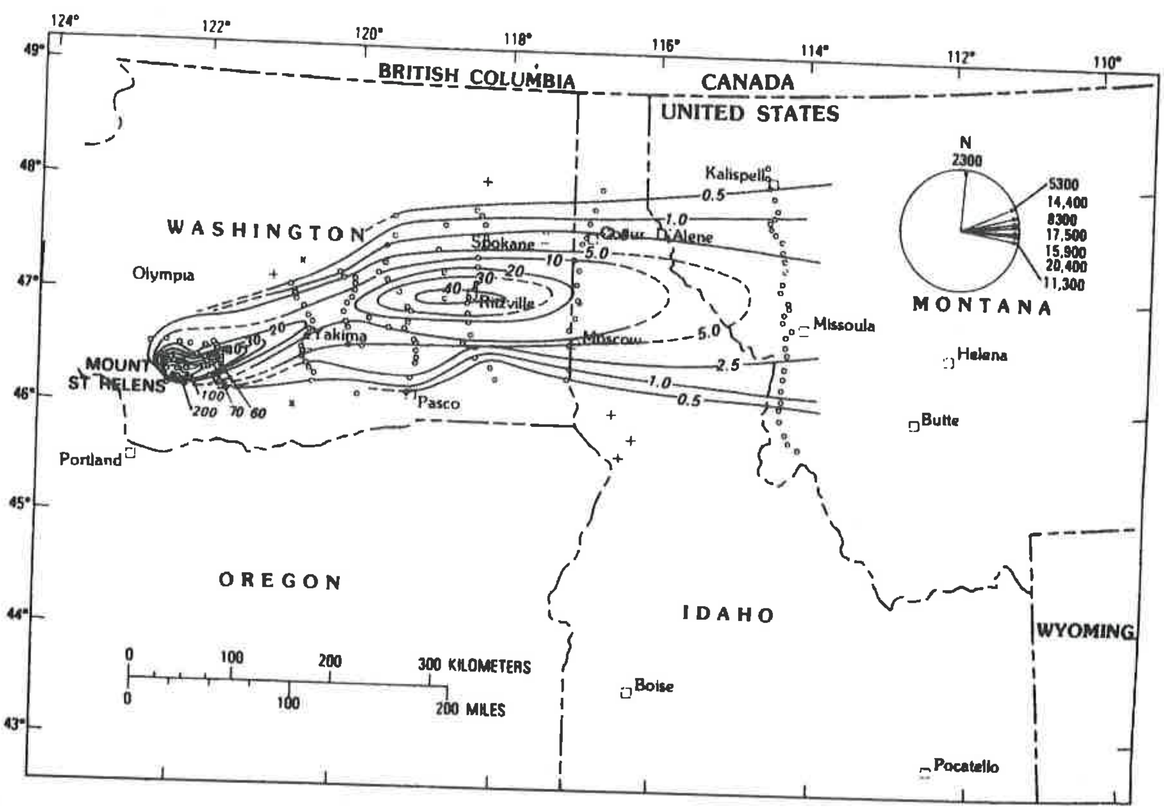


FIGURE 5.9 Map of tephra thickness in mm from May 18, 1980, eruption. + = light dusting of ash, x = no ash observed, and o = observation sites. Wind circle shows directions toward which wind is blowing, which were measured at selected altitudes (in meters) at 10:20 PDT on May 18 at Spokane, WA. Data from U.S. National Meteorological Service (Sarna-Wojcicki, and others, 1981).

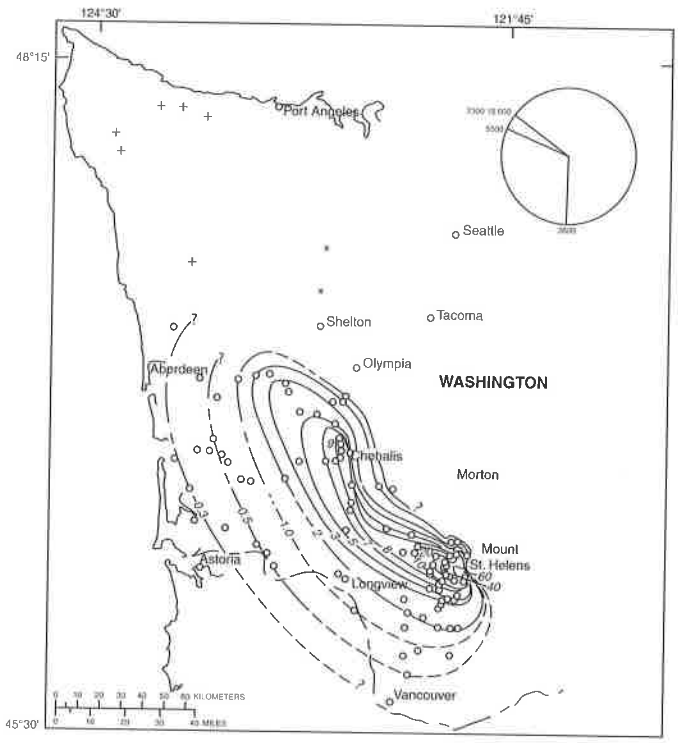


FIGURE 5.10 Distribution of tephra from the May 25, 1980, eruption. Ash thickness in mm. Circle represents measureable thickness, t = trace, and x = no ash. Wind circle shows directions toward which wind is blowing which were measured at selected altitudes (in meters). (Sarna-Wojcicki et al., 1981).

b. How closely do the predictions in Figure 5.11 match the locations of pyroclastic flows in the northern half of zone 1? (see Figure 5.5.)

18. a. How closely do the predictions for lahars in Figure 5.11 match the actual distribution of lahars as shown in Figure 5.6 for each of the following valleys?

Toutle River (North) _____

Toutle River (South) _____

Cowlitz River _____

Kalama River _____

Lewis River _____

b. Do you think that future lahars will follow the patterns of May 18, 1980? Why or why not?

PART B. THE VOLCANO WAKES UP

After 18 years of no new magma, Mount St. Helens awoke again on September 23, 2004. A series of small earthquakes heralded the start of a new eruption sequence, which so far has largely consisted of growth of a new dome. This new dome, however, will have one of two fates. Either it will become, like the previous 1986 dome, a building block for constructing a new mountain, or it will be blown to bits in a new violent eruption.

Before we examine the rejuvenated eruption more closely, let's put the eruptions of Mount St. Helens into their context in the overall volcanic activity of the Cascade Range. Over its relatively short geological history (less than 50,000 years) Mount St. Helens has had several stages of eruptive activity, which have lasted several thousand years, separated by periods of inactivity (Mullineaux, 1996). The last 4,000 years have been a time of increased eruptive activity (Pringle, 1993).

QUESTIONS 5, PART B

1. Figure 5.1 shows larger eruptions of Cascade volcanoes, including Mount St. Helens, for the past 4,000 years.

a. How many eruptions are shown for Mount St. Helens?

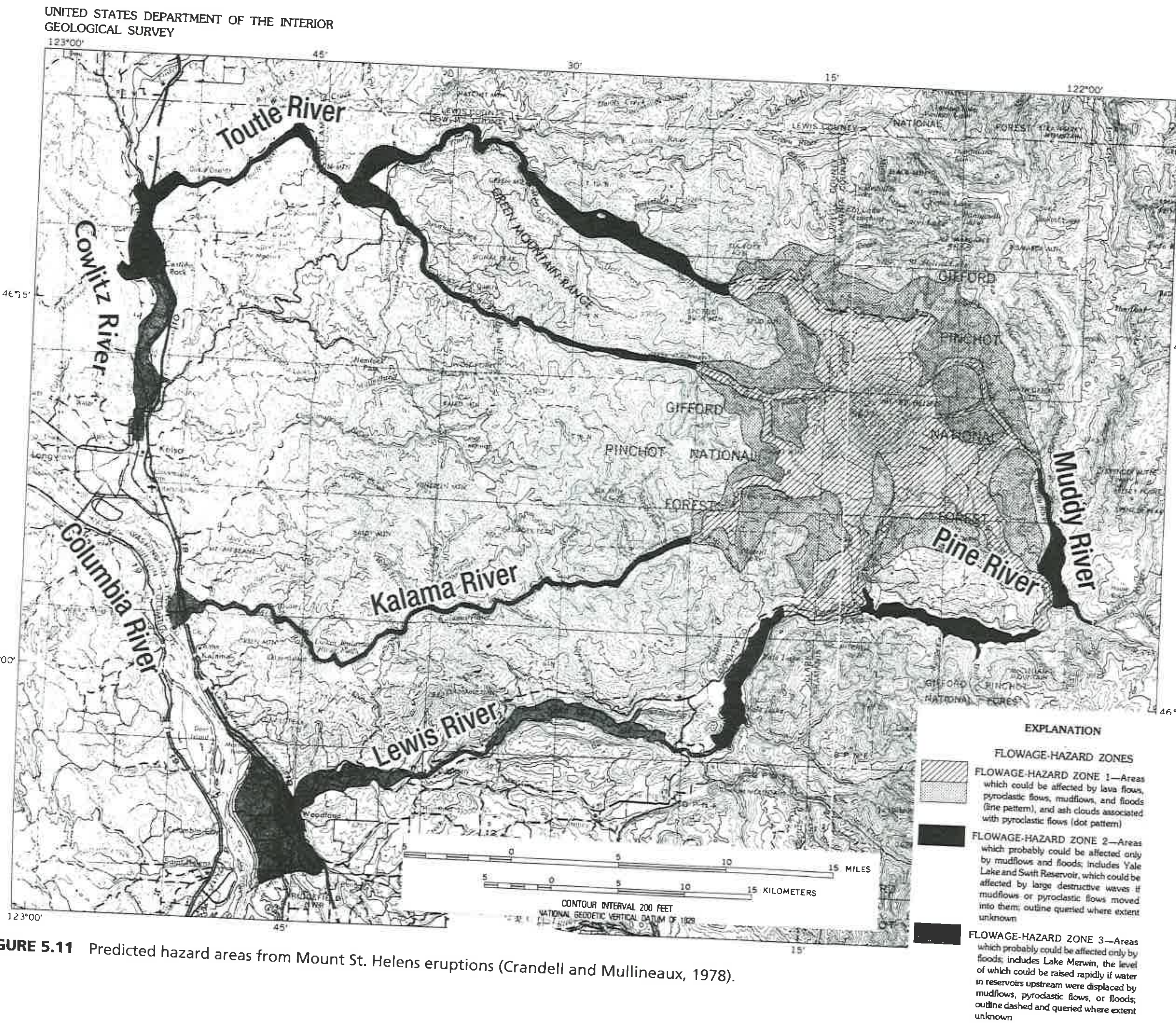


FIGURE 5.11 Predicted hazard areas from Mount St. Helens eruptions (Crandell and Mullineaux, 1978).

b. Which is the second most active volcano? _______
How many eruptions does it have? _______

c. What is the average interval between eruptions of Mount St. Helens for the past 4,000 years?

d. Prior to the 1980 eruption (shown at the present on Figure 5.1), approximately how many years before was the previous eruption?

e. Does the interval between the previous eruption and 1980 fit the pattern for average intervals during the past 4,000 years?

2. The dome-building eruption that began in 2004 is continuing in 2008. The eruption is producing about 0.6 cubic yards of new magma every second. Scientists with the U.S. Geological Survey estimate that about 3.5 billion cubic yards of the mountain was lost in the original eruption in 1980. Since 1980, dome-building eruptions have produced almost 200 million cubic yards of new rock. At the rate of 0.6 cubic yards per second, how long will it take the mountain to rebuild itself to its pre-1980 eruption shape?

3. A record of the growth of the 2004 dome is seen in a series of images from a LIDAR-sensing mission flown by NASA in conjunction with the U.S. Geological Survey (Figure 5.12a-f). The dates of each image are indicated in the upper left-hand corner of each image. The LIDAR image has a horizontal resolution of 2 m and a vertical resolution of 20–30 cm.

a. Examine Figures 5.12a (September 3) and 5.12b (September 24). Mark on Figure 5.12b any changes in topography that you see.

b. Describe what seems to have happened in the time between these two images.

4. On each of Figures 5.12c, d, e, and f, trace the outline of the dome that is building.

5. For each of Figures 5.12c, d, e, and f, describe the change from the previous image. Consider the area or size of the dome, the appearance of the surface of the dome, and the position of the dome in the crater. The circles in Figures 5.12a, b, c, and d provide a reference for the change.

Image c (changes from b)

Image d (changes from c)

Image e (changes from d)

Image f (changes from e)

6. As a journalist or a scientist, you have been asked to describe, on camera near the site, the changes that have taken place between September 24 and November 20. You think that percentage increase in the area of the new dome would be one interesting and important fact to report for viewers. You set out to determine the change in area. You recall that areas can be estimated from a formula, either for a rectangle [$A = L \times W$] or for a circle [$A = \pi r^2$], where $\pi = 3.14$ and r is the radius. Begin by calculating the areas of the dome in Figures 5.12c and 5.12f. Then calculate the percentage increase between the area of the dome in c and in f. Show your work.

(Note: The diameter of the circle is 300 m. You can use this as a scale to determine the sizes of the dome in Figures 5.12c and f.)

Optional online access required for the next question.

7. Compare your answer with new images that may have been posted on Mount St. Helens web sites http://vulcan.wr.usgs.gov/Volcanoes/MSH or http://www.fs.fed.us/gpnf/mshnvm/. Describe below the current status of the volcano. What possible events could occur today? What do the alert level and aviation color code mean?

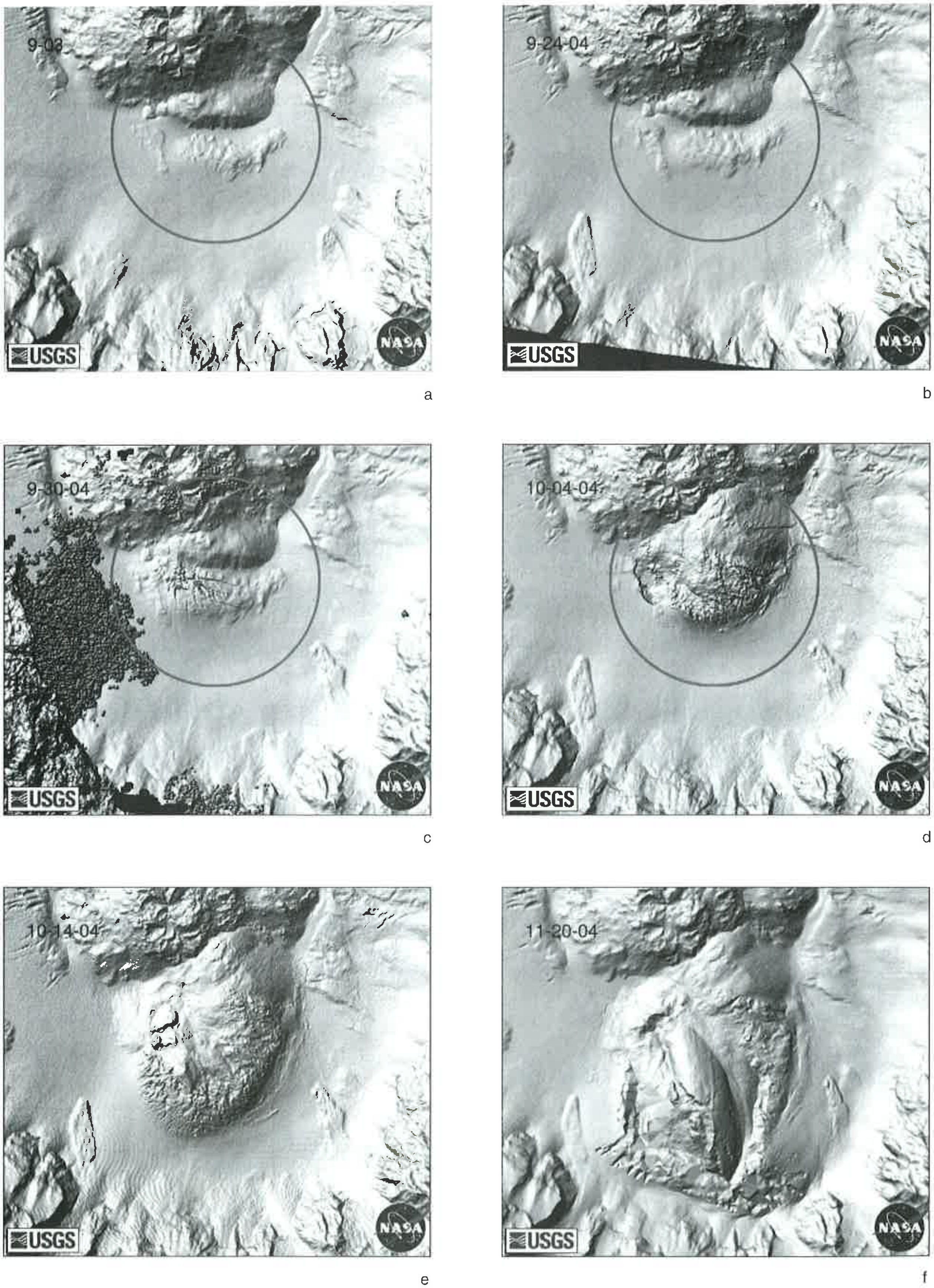


FIGURE 5.12 LIDAR images of Mount St. Helens showing 2004 dome growth (USGS). The date of each image is shown in the upper left corner.

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