Earth Sciences 409 Environmental Geology Spring 2008

Your name: ___________________________________

Lab 4: TOPOGRAPHIC MAPS AND VOLCANIC HAZARDS

Part I: Topographic Maps

The purpose of the first half of this week's lab is to become familiar with reading topographic maps, which are essential tools for earth scientists and others interested in the three dimensional configuration of the earth's surface: foresters, hikers, military strategists, etc. Topographic maps may also show "cultural" features such as roads and buildings.

PLEASE MAKE NO MARKS ON THE TOPOGRAPHIC MAPS

A. The United States Geological Survey (USGS) publishes topographic maps as **quadrangle** maps, each of which is named after a prominent town or feature in the area of the map. The most common USGS maps cover a regular area, 7.5 minutes or 15 minutes* on a side. The quadrangles are bounded by **latitude and longitude lines**. Latitude lines tell you the distance from the equator, and if north is toward the top of the map, they are parallel to the top and bottom of the map. They are equally spaced between the equator and the poles. Longitude lines converge toward the poles. (*One minute is one sixtieth of a degree on a circle. On a globe, one minute of latitude represents about 1.85 km, or 1.15 miles. Minutes of longitude vary in length.)

1. The corners of each quad are labeled in degrees (°), minutes (') and seconds ("). For example, consider the SE corner of the Shasta quad (may not be shown on your copy):

Latitude: 41°15' N of the equator. Longitude: 122°00' W of Greenwich, England.

Compare the SE corner of the Kilauea quad:

Latitude: _____________ Longitude: ________________

2. Which lies closer to the equator, Kilauea or Shasta? _______________

3. Record the coordinates of the NW corner of the Kilauea quad:

Latitude: _____________ Longitude: ________________

4. What size is the Kilauea quad, 7.5 minutes or 15 minutes? _____

5. The Shasta quad is the same size in minutes as the Kilauea quad, yet it is narrower in miles and covers less land area. This is because lines of longitude converge toward the poles. Where would a 15' X 15' quad be nearly square (17.25 X 17.25 miles)? ___________

6. What is the approximate position of the Halemaumau fire pit in Kilauea Crater?

Latitude: _____________ Longitude: ________________

(If you wish, check your results by looking up Kilauea on the Hawaii Volcano Observatory website: <hvo.wr.usgs.gov/kilauea/> Note that they record coordinates in decimals: 19°30' = 19.5°)

B. The **scale** of a map depends on the size of the paper that it's printed on relative to the size of the land area represented. Scale can be shown in graphical form or as a fraction. USGS maps commonly provide three **graphical scales** at the bottom center of the map, with units in miles, feet and kilometers. The **fractional scale** is given above the

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graphical scales, for example 1:24,000. This would indicate that one unit on the map represents 24,000 of the same units on the ground. One cm would be 24,000 cm (=240 m = .24 km) on the ground; one inch on the map would be 24,000 inches (= ________ feet) on the ground.

1. At what fractional scale are both these quad maps? 1 : ______________
2. Use the graphical scale and a ruler to estimate how many miles on the ground are represented by one inch on the map: ___________
3. Use math to confirm your results. (one mile = 5280 feet)

4. The numbered squares (called sections) on the Shasta map are part of a surveyed grid system used in northern Maine and the western United States. Each section equals how many square miles? ________
5. On the Kilauea map, use the scales to find the straight line distance between Kaaha and Keaoi Island, in miles to the nearest tenth: ___________
6. Suggest a method to estimate the wiggly distance along the shoreline between the same two points.

C. Most maps are drawn with north at the top. In the lower left of your quad maps, one arrow points toward **true north** (the rotation axis, or geographic north pole). However, compass needles do not point toward true north. They respond to the magnetic field of the Earth, along lines that converge at the **magnetic north**, a point in the Canadian Arctic. The difference between arrows pointing toward these two poles is called **declination.** A compass must be set to account for the declination when using a map to navigate. Both the amount of declination and whether it is east or west of true north must be noted.

1. Declination in Durham is about 16°west. How would you set your compass when working around Mt. Shasta? ______________

D. The USGS uses **contour lines** to show elevations above a certain datum, usually sea level. The **contour interval**, written below the graphical scales, tells you how much elevation changes between adjacent contour lines. Every fifth line is printed as a bolder line and its elevation is labeled. These lines are called **index contours**. The contour interval chosen for a particular map depends on the amount of detail desired, the scale of the map, and the amount of relief (range in elevation on the map).

1. Which would require a smaller contour interval to show the same detail, a 15' quad in Rhode Island or a 15' quad in the White Mountains? ______________________
2. What is the contour interval on the Kilauea map? ________ (Index contours are labeled every 250 feet.)
3. Find Hilina Pali at 19°17'30" N, 155°18'00" W. What does the close spacing of the contours suggest for the meaning of the Hawaiian word "pali"? __________________
4. Is the floor of Kilauea Crater steep or flat? _______________
5. The northwest third of the map is a slope on the side of Mauna Loa volcano. Does the spacing of the contour lines indicate a fairly uniform slope, or variable steepness?

____

6. Now consider Mt.Shasta. The summit lies at an elevation of __________ feet.
7. The town of McCloud lies near the lowest point on the map, __________ feet. (Note that "BM" stands for a surveying point called a Bench Mark.)
8. The difference between the highest and lowest is **topographic relief**: __________ feet
9. Find the topographic relief for the Kilauea quad: _____________ feet (Interesting coincidence!)

E. USGS maps use standard **colors** and **symbols** for different features.
1.Look at the two maps to determine what color is used for the following categories:

Oceans, lakes, streams	_____________	("hydrologic" features)
Forested areas	_____________	
Contour lines	_____________	
Contour lines on glaciers	_____________	
Cultural features	_____________	

2. A legend for USGS maps lists dotted green patterns as "scrub brush, vineyards, or orchards". Which seems most likely on the Shasta quad? ____________________
3. Brown dots can represent "sand dunes, gravel outwash, or pyroclastic deposits". Which seems most likely on the Kilauea quad? _______________________
4. Blue lines indicate rivers, brooks, or creeks. Contour lines usually cross valleys such that they form V's which point upstream. Find one stream on the Shasta map that illustrates this rule, and tell which direction the water is flowing (opposite direction as the V's point):

____________________ Creek flows toward ____________________

5. Streams in which water flows only seasonally or intermittently are shown as dash-dot blue lines. Are there any permanent (solid blue) streams on the Kilauea quad? _____ What does this suggest to you about the ease with which water percolates down into the volcanic rocks (permeability)? Are they highly permeable, or not very permeable?

____

F. **Topographic profiles (Homework)**. When portraying what lies underground, it is often desirable to construct a topographic profile to show the shape of the land surface as if viewed from the side, or in cross section. Draw a profile from A to A' on the attached map. See Fig. 4 for an example of a topographic profile through Mt. St. Helens.

Contour lines have these characteristics:

- Each line separates points on the map that are higher than its value from lower points.
- Every point on a specific contour line has the same elevation.
- A contour line may close on itself to form a loop, or run off the edge of the map.
- Contour lines never cross each other.
- Contour lines join and split only where there's a cliff taller than the contour interval.

Part II. Volcanic Hazards

In Part II of this lab you will look closely at maps of shield volcanoes and stratovolcanoes, particularly with an eye toward evaluating hazards to life and property. You will study the effects of the 1980 eruption of Mt.St.Helens, a benchmark in geologists' understanding of eruptions.

PLEASE MAKE NO MARKS ON THE TOPOGRAPHIC MAPS

A. Shield Volcanoes: Kilauea, Hawaii, 15' quadrangle

The quadrangle map shows parts of two volcanoes, Mauna Loa in the northwest half, and Kilauea. "Volcano Road" runs diagonally across the map, more or less following the line between them. Compare the maps of Hawaii in your textbook, page 111-113.

1. How steep is Mauna Loa's slope, from the NW corner of the map to the top of Kaoiki Pali? Give your answer in feet per mile, and as a percent. Show your work.

2. Do the same for Kilauea, averaged from BenchMark 3654 to sea level. Your results for both volcanoes should be typical of shield volcano slopes.

3. Go to the microscopes on the side bench and find <u>Station A</u>: Kilauea
   a. Are the cinders and ash from Kilauea mafic or felsic? ________
   b. Would lava of this composition be viscous, or flow easily? Explain.

   c. Glassy threads formed as fountaining lava is caught by wind are called Pele's hair.

4. Go back to the map. Find "Lava Flow of 1881" on the slope of Mauna Loa.
   a. Toward what direction did it flow (relative to N, S, E and W)? __________
   b. How wide is the main channel, in feet? ________
   c. This flow originated high up on the mountain (summit at 13,550'). What, in the shape of the flow, suggests that the lava was <u>not</u> very viscous?

   d. Is this consistent with your observations in questions #1 - 3?

5. In 1912 Thomas Jaggar of MIT established the Hawaiian Volcano Observatory on the NE rim of Kilauea Crater ("Volcano House" on the 1924 map). Craters wider than one kilometer, especially if they contain a smaller vent within them, are often called calderas. Does Kilauea Crater qualify as a caldera? ____

6. Jaggar monitored the rise and fall of the lava lake within the inner crater, called Halemaumau (House of Eternal Fire) by the Hawaiians. Which of the following hazards would be of concern at Kilauea (see class notes and text p.103-110): (circle them)

   lava flows, lava fountains, pyroclastic flows, ash falls, lahars, vog

7. The outline of Kilauea quad is dashed on the map in Fig. 1A below. Major eruptions at Kilauea break out along the East and Southwest Rift Zones. These "rift zones" are not rifts in the sense of plate boundaries - - they are simply zones of cracks and fissures,

shown as straight brown lines on the 1924 quad map. Look closely at features on the topographic map, and speculate as to the basis for hazard zones on Fig. 1A (1 = high hazard, 5 = moderate, 10 = none).

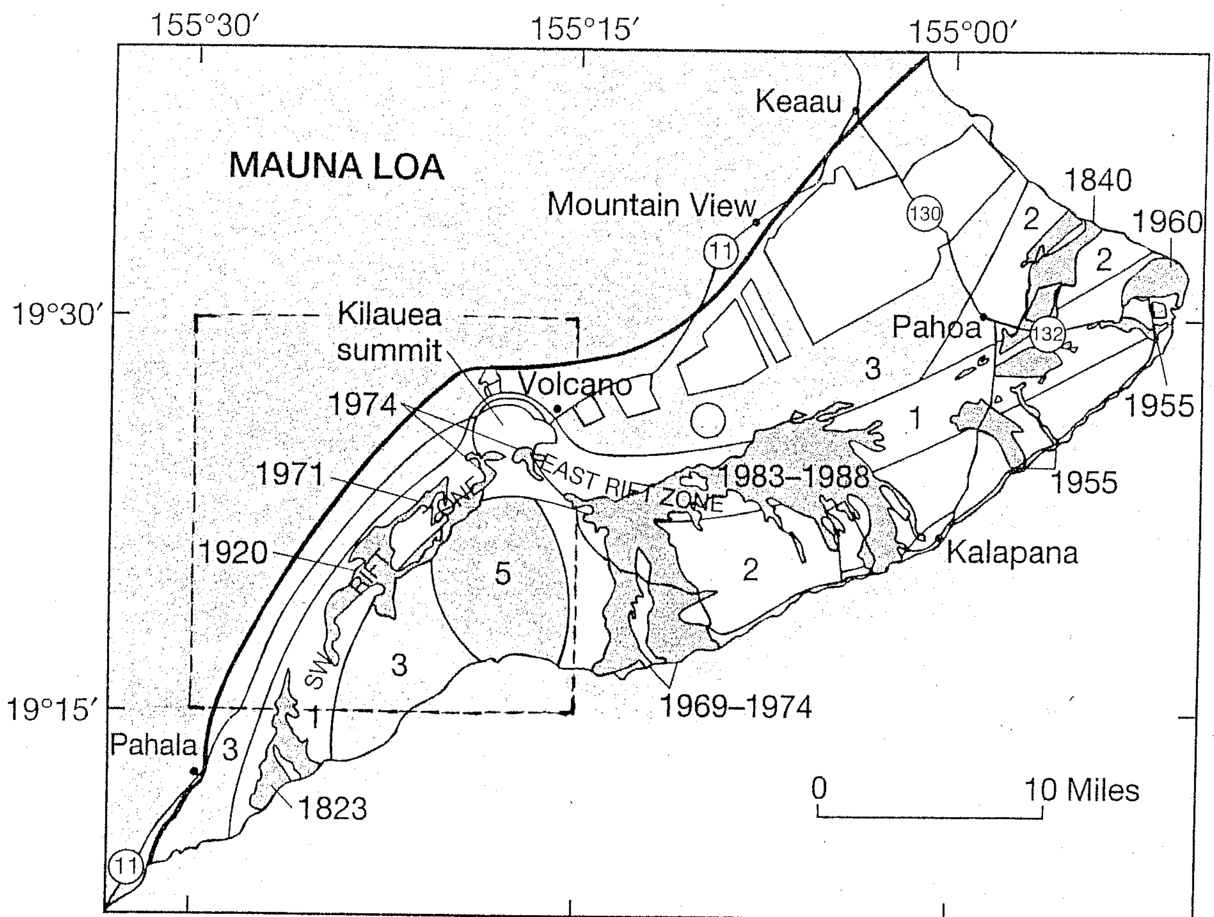


Fig. 1A. Kilauea lava flows and hazard levels. (from Blatt, 1997)

8. Jaggar also set up seismometers and tiltmeters. Since 1955 most of Kilauea's flows have been along the East Rift Zone, due east from Halemaumau on your map. However, the summit continues to rise and fall as pulses of magma enter and leave the magma chamber. Look at the map in Fig. 1B (next page). Kilauea and Halemaumau are outlined as heavy lines. What is the diameter of the area affected by deformation? _______________

9. Monitoring this deformation helps predict lava outbreaks. The elevation changes (in cm) were found by surveys between September 1982 and February 1983. Was the area inflating or deflating during that time? ______________

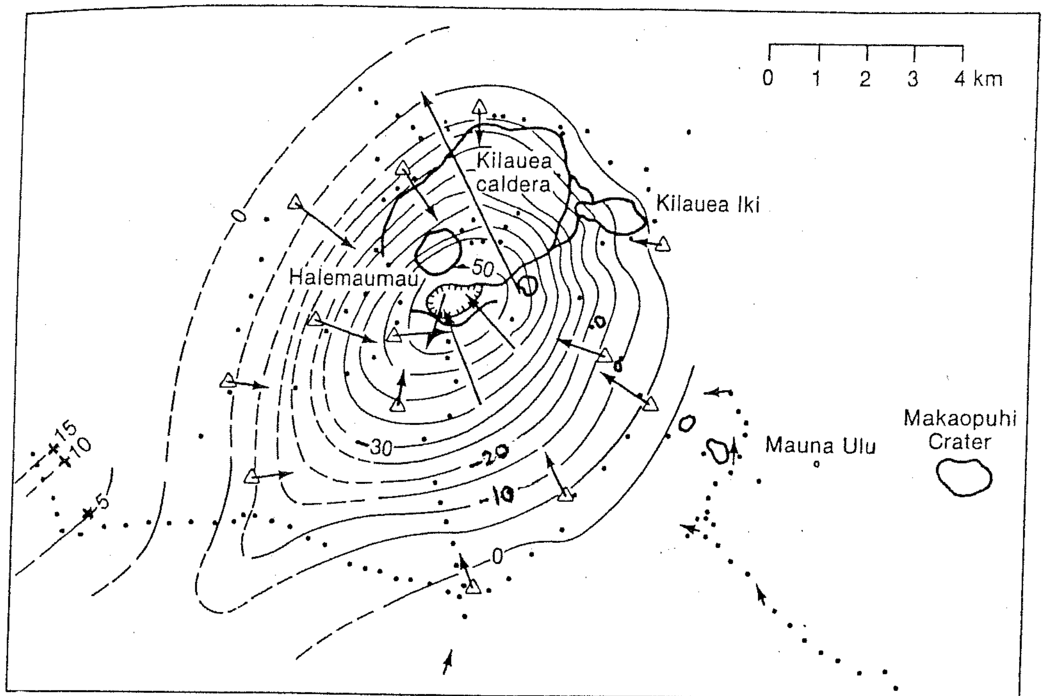


Fig. 1B. Deformation at Kilauea (from Wolfe et al., 1987)

KEY

- Leveling bench mark
- 100 µrad — Spirit-level tilt station with direction and amount of tilt change
- Crater or caldera rim
- 30 — Contour of elevation change—Dashed where approximately located; hachures indicate closed low. Contour interval 5 centimeters

10. Lava flows are the main hazard at shield volcanoes. However, where lava piles up rapidly along the coast, the land may become unstable due to the weight, and a huge slump into the ocean may occur. Where on the Kilauea quad map do you see a curved cliff that might be the scarp of an ancient slump?

B. Stratovolcanoes: Shasta, California, 15' quadrangle

Note that this map is at the same scale as the Kilauea map. Shasta was active in 1786 and emitted ash a few times in the 1850's, but has been dormant since then. The main cone, about 8000 years old, is made of andesite, with a dacite dome at the top. Shastina is older (it grew from 9700 to 9400 years ago), and it too has dacitic plugs in its crater. (Dacite is intermediate in composition between andesite and rhyolite.)

1. Find the steepness of Shasta's slope from the summit to the tree line at about 8000 feet, in ft/mile and percent.

2. Why is Shasta steeper than the Hawaiian volcanoes?

3. If a major eruption were to occur from the summit, potentially what areas would be affected by ash flows (pyroclastic flows)? Would the town of McCloud be in danger?

4. What is a likely origin for the lobe of hummocky land on the NE side of Shasta, in sections 24, 25 & 26 extending to about 6200' elevation?

5. What information would be needed to predict the areas affected by ash fall? Are these areas likely to be large or small?

6. In the very hot summer of 1924 Konwakiton Glacier (south of summit) retreated rapidly. Note the name of the creek downstream from this glacier. What do you think happened in 1924, giving this creek its name?

7. What other streams on Shasta are vulnerable to this hazard?

C. Case Study: Mt. St. Helens, Cascade Mountains, Washington

Because close monitoring of the Cascades began around 1970, and because distinct warning signs preceding the May 18, 1980 eruption allowed close predictions, lessons learned at Mt. St. Helens have been applied to stratovolcanoes elsewhere. The experience of geologists who witnessed those events is now in demand around the world when other volcanoes "crank up" their levels of activity.

The main events on May 18 were (1) an earthquake of Richter magnitude 5.1, (2) a landslide on the bulging north side of the mountain, (3) a lateral blast to the north, (4) an eruption column that soon became vertical, (5) lahars down many of the river valleys, and (6) extensive tephra deposits, carried by the wind to eastern Washington and beyond. Following the huge eruption, a lava dome grew in the crater from 1980 to 1984.

Mt. St. Helens: Topography Before and After

Fig. 2 is a topographic map of Mt. St. Helens prior to the eruption, and Fig. 3, afterwards. Fig. 4 shows topographic profiles from South to North through the summit.

1. How much elevation was lost from the top of the mountain?

2. Are the slopes prior to the eruption more like those of Mauna Loa or Shasta?

3. What does the shape of Mt. St. Helens suggest about the silica content of rocks that you would expect to find there?

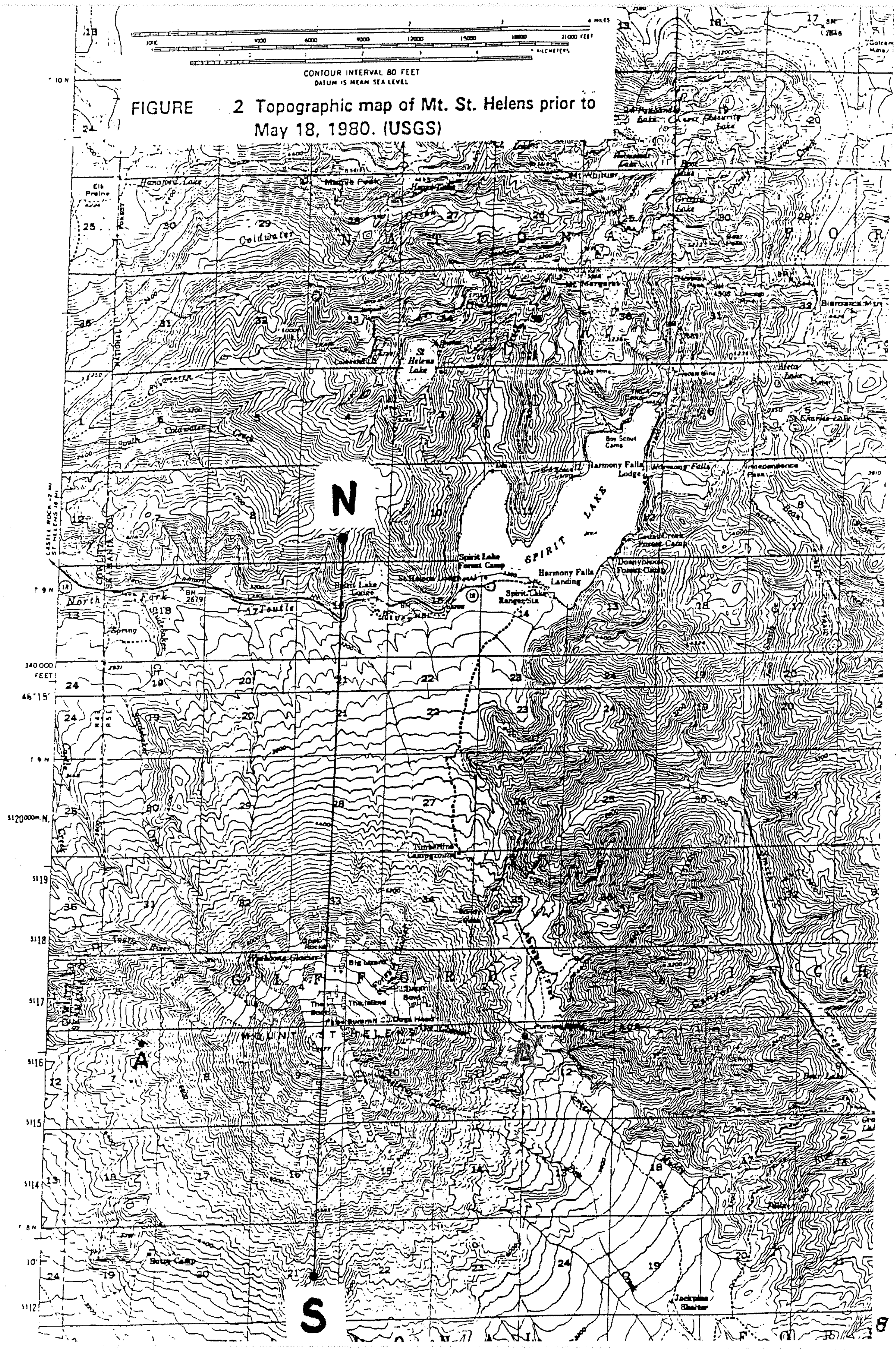


FIGURE 2 Topographic map of Mt. St. Helens prior to May 18, 1980. (USGS)

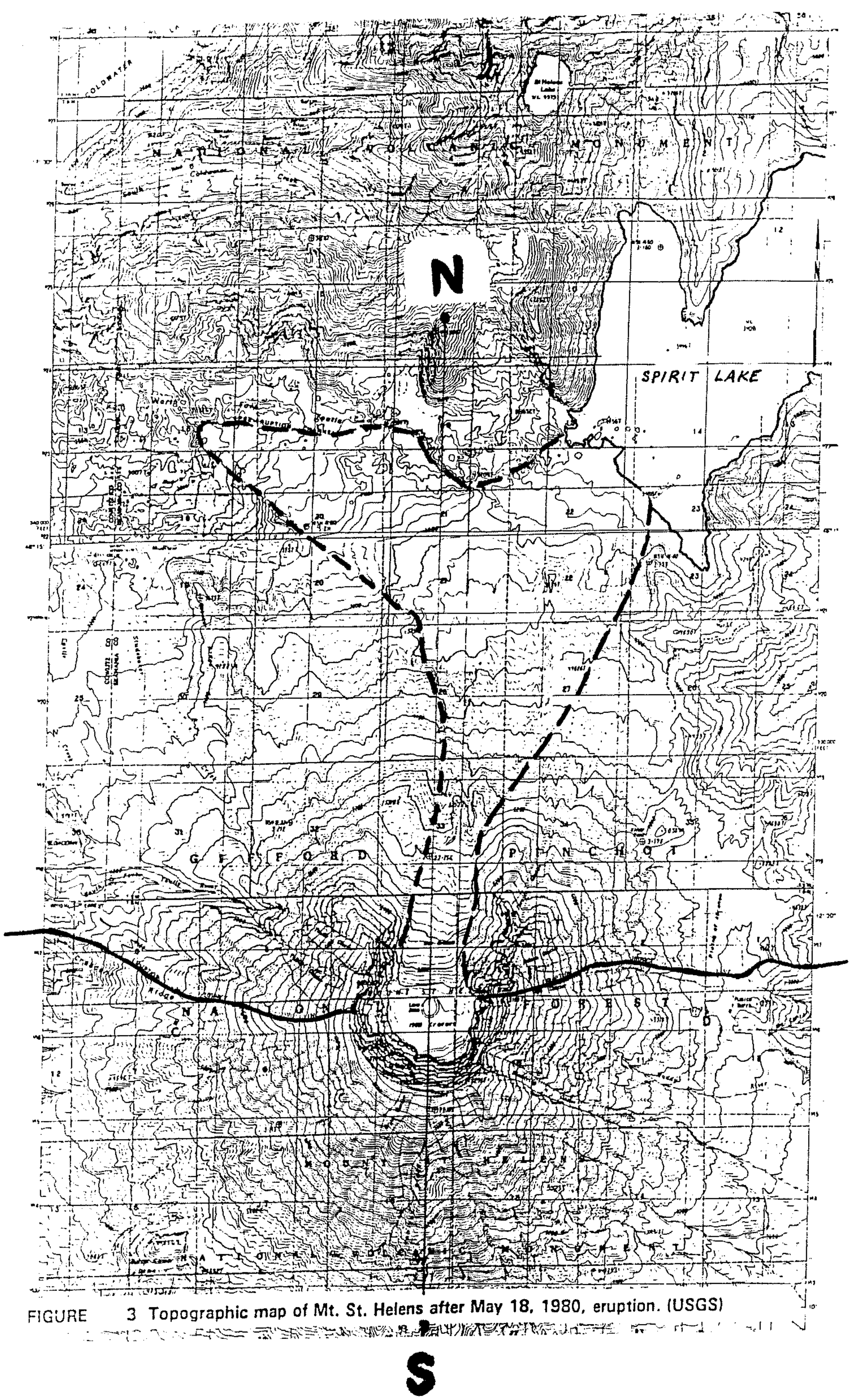


FIGURE 3 Topographic map of Mt. St. Helens after May 18, 1980, eruption. (USGS)

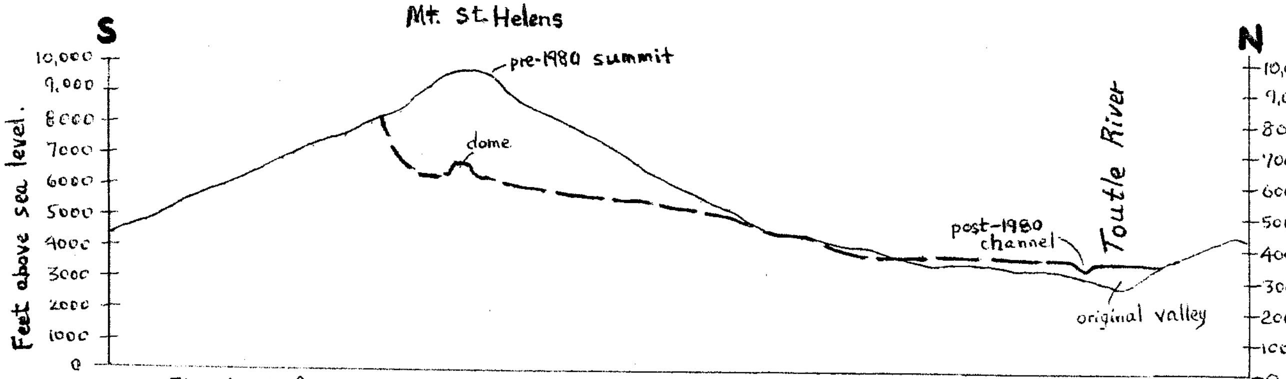
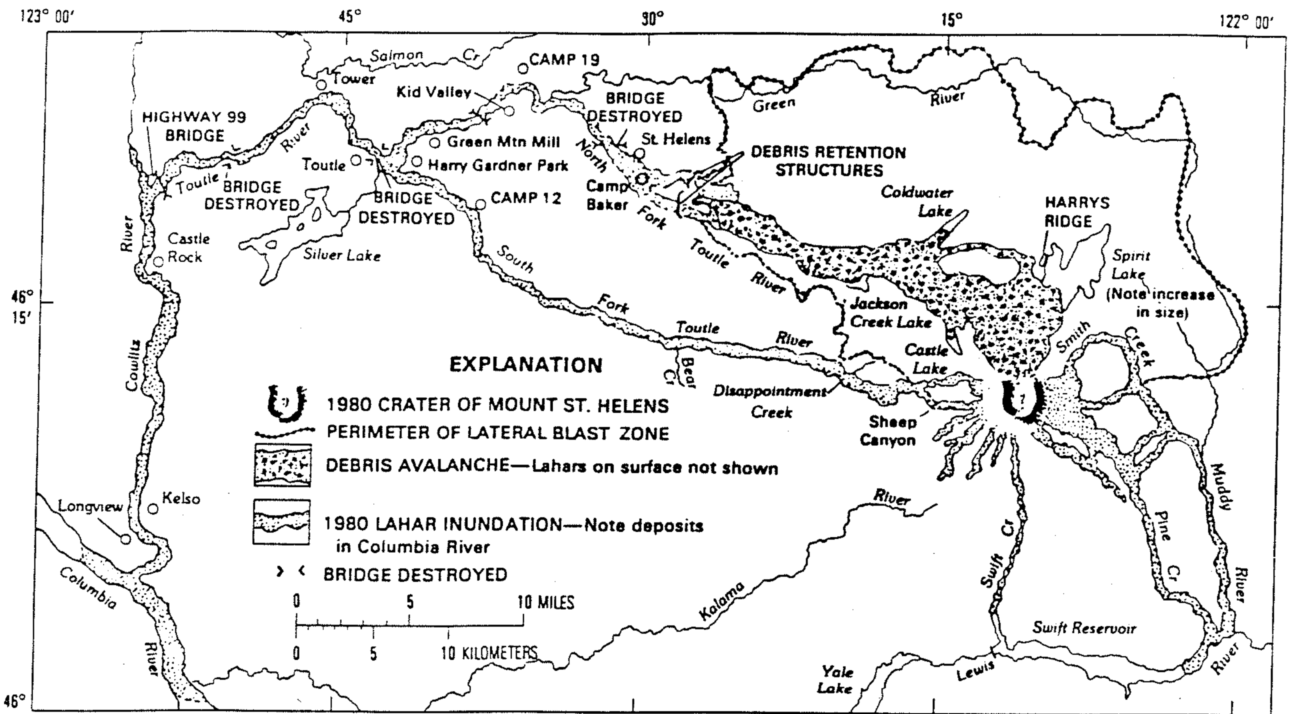


Fig. 4 Before and after topographic profiles. Vertical exaggeration X 3.5



Map of study area showing locations and extent of 1980 lahars

FIGURE 5 The general area impacted by lahars (mudflows) from Mt. St. Helens. (Scott, 1988)

4. Describe the location of the volcanic dome in relation to the 1980 crater, and to the original summit. (See lab Fig.4 and photo on p.102 of your textbook.)

5. Why are such domes sometimes referred to as "volcanic plugs"?

Volcanic Deposits near the Mountain

1. The lateral blast at Mt. St. Helens affected the entire area of Fig.3 north of the heavy black line. Why is Spirit Lake now larger than before the May 18 eruption? (See Fig.4)

2. Look back at your observations at Mt. Shasta. Is there any way you could predict the direction of a lateral blast from this dormant volcano? _____ What should be closely monitored immediately prior to an eruption in order to predict such an event, judging from the Mt.St.Helens experience (see textbook p.112-113)?

3. After May 18, nueés ardentes swept down into the area enclosed by the dashed line on Fig.3, as the dome alternately grew and collapsed. Why was access to this area completely restricted until after 1984?

Eruption Effects Farther from the Volcano

1. Fig.5 shows the general area impacted by lahars. Although the major direction of the first volcanic burst was to the north, why do you suppose lahars flowed down <u>all</u> <u>sides</u> of the volcano?

2. Go back to the microscopes. <u>Station B</u>: This sample was collected from lahar deposits along the Toutle River. Describe what you see under the microscope (color, grain sizes, sorting):

3. <u>Station C</u>: This ash fell near Yakima, Washington, on May 18, 1980.
a. How does it compare in color to the material from Hawaii? ____________________
b. Does this make sense in view of Mt.St.Helens' shape? _________
c. How does this wind-blown ash compare to the Toutle River lahar sample?
(color, grain sizes, sorting):

4. Find Yakima, Washington, on the map in Fig.6 of your lab.
  a. How deep was the ash at Yakima? ____ mm
  b. What direction was the wind blowing when the ash fell? Toward the ________.
  c. Fig.7 is a wind rose showing directions of wind in western Washington. What percent of the year does the wind blow from Mt. St. Helens toward Yakima? _______

Homework:

Complete the A-A' topographic profile across Mt. St. Helens and compare it with the one shown on figure 4.

Review the www.youtube.com/watch?v=vBJpxZws7ro and
www.youtube.com/watch?=2mgyCuLOOIQ&NR=1
for a sense of the character of this eruption.

Visit Mt. St. Helens and Mauna Loa using GOOGLE EARTH on your own or University Computer. You should be able to "fly about" to review both mountains in perspective and compare the sizes of crater and caldera, examine the character of flows (both lava and pyroclastics.

What kinds of information is needed to establish a risk and hazard assessment for these two types of volcanoes. Are there some data that work better for one than the other?

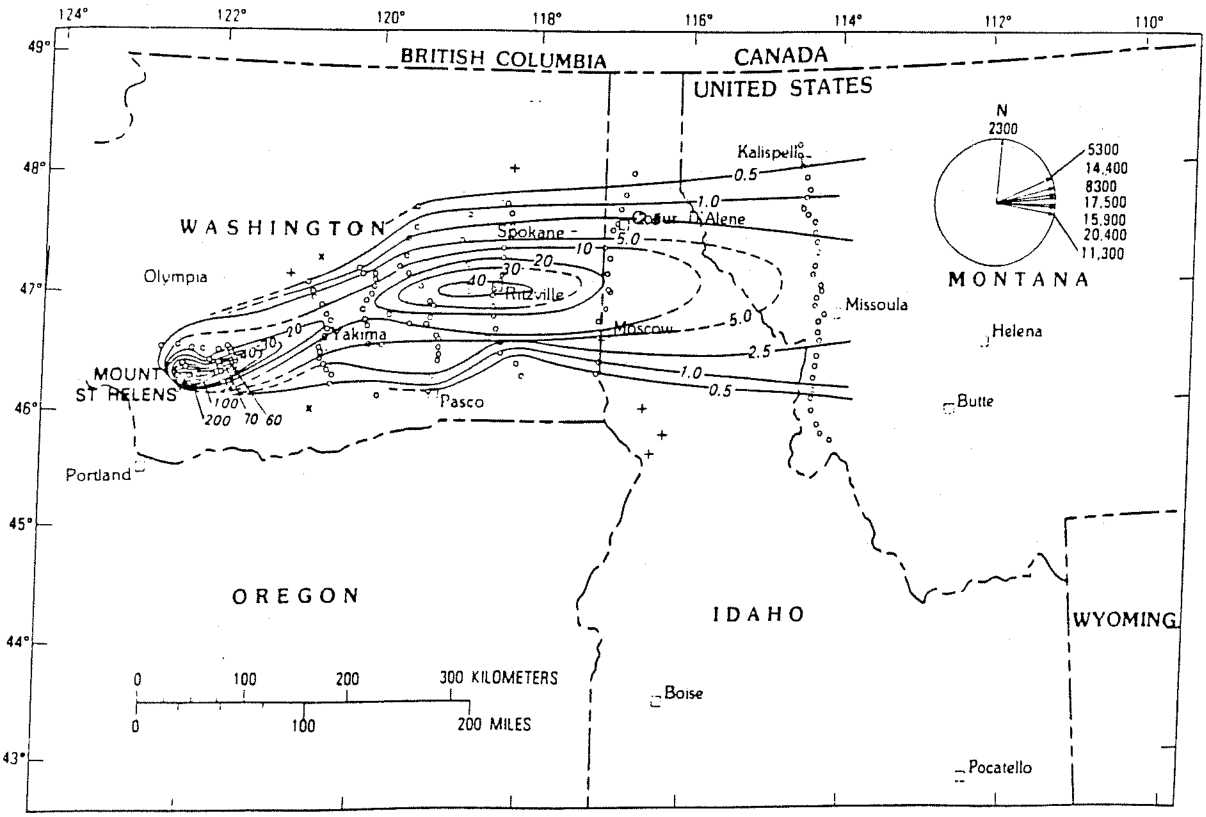


FIGURE 6 Isopach map of air fall ejecta on May 18. Lines represent uncompacted thickness in millimeters. + = light dusting of ash, x = no ash observed, and o = observation sites. Wind circle shows directions of wind at different altitudes (mm) at 1020 PDT on May 18 at Spokane. Data from U.S. National Meteorological Service. (Sarna-Wojcicki, et al., 1981)

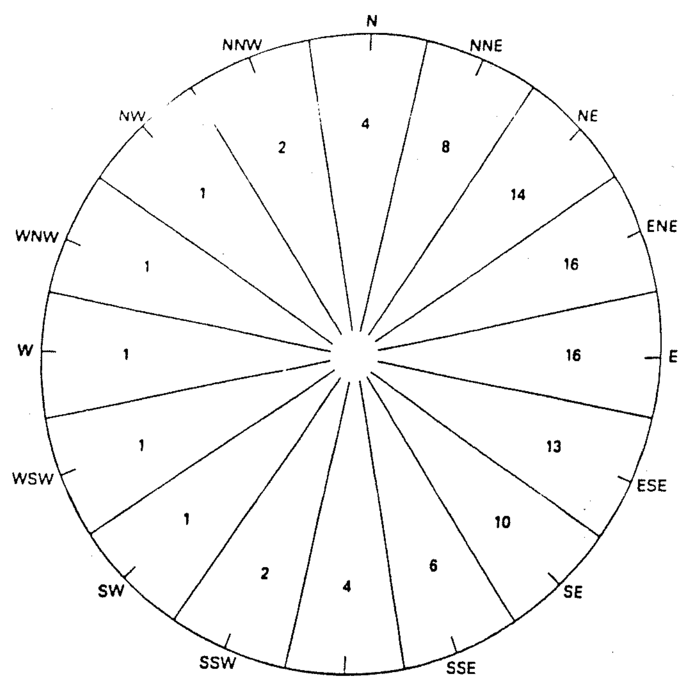
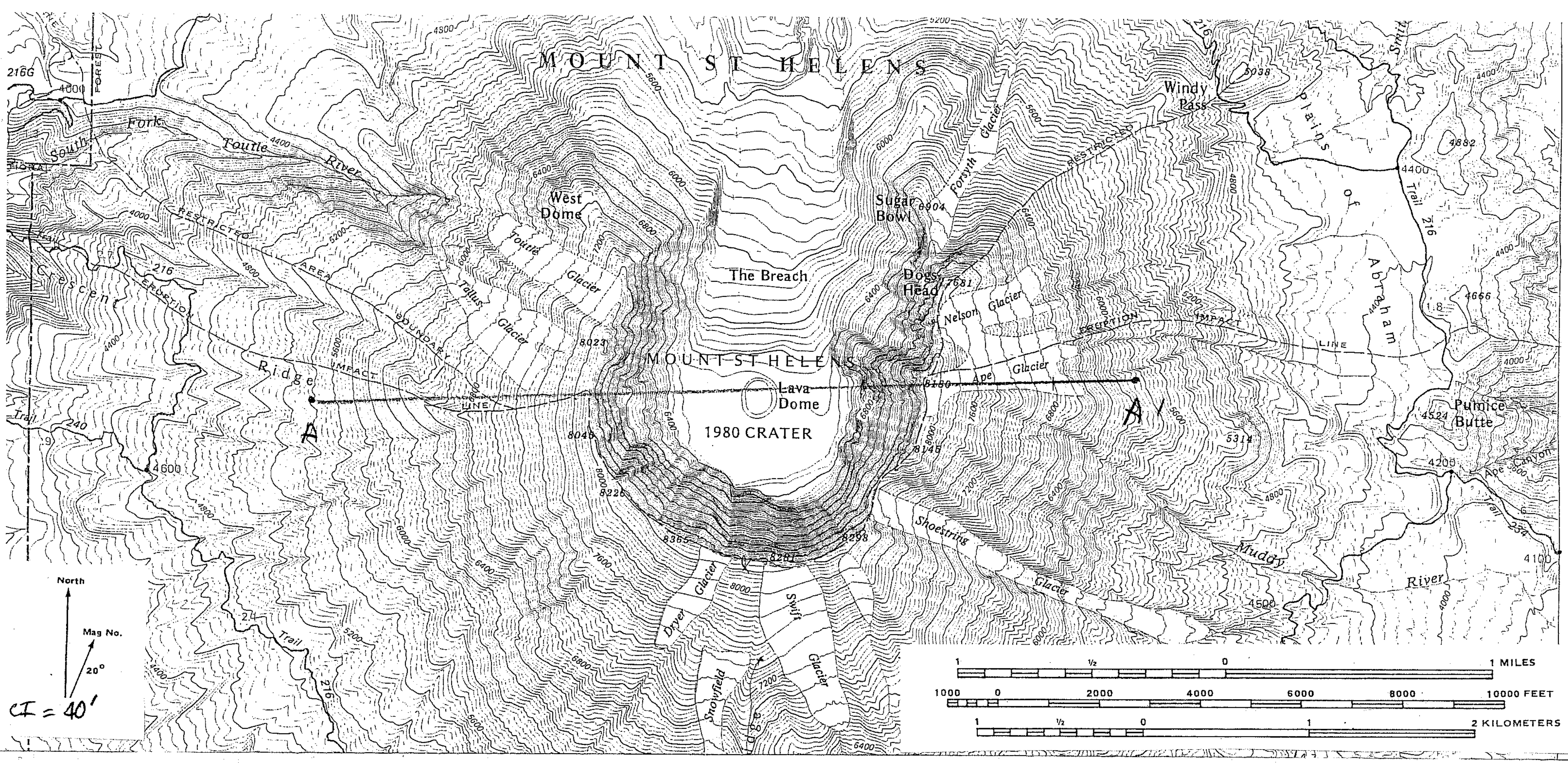
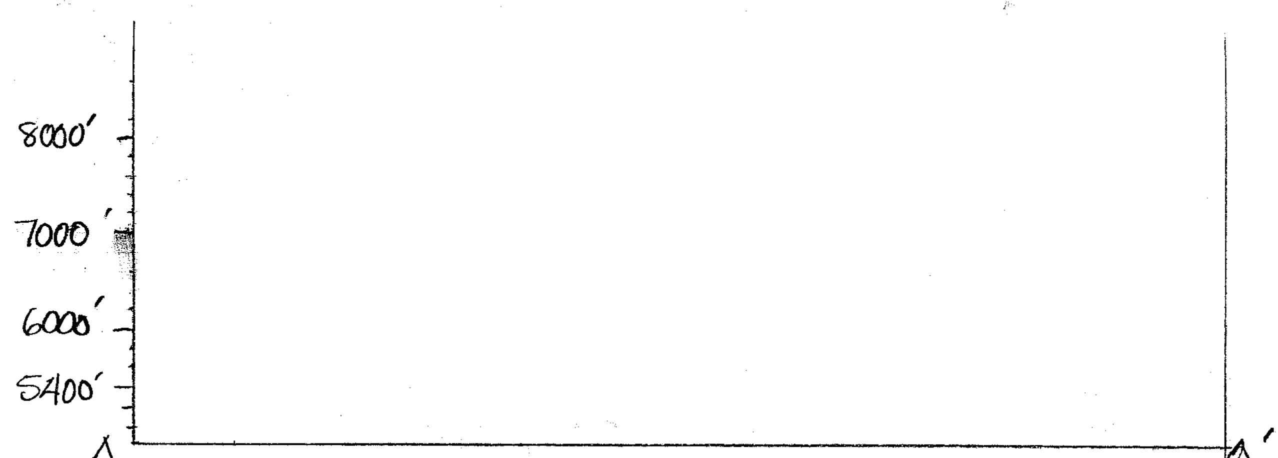


FIGURE 7 Approximate percentage of time, annually, that the wind blows toward various sectors in western Washington. Frequencies determined between 3,000 m and 16,000 m at Salem, OR and Quillayute, WA. (Crandell and Mullineaux, 1978)





Vertical exaggeration ~ 2X