ES322 Geomorphology
Cascade Ice Budget Exercise

Introduction

The Cascade Mountains form part of the Cascadia Volcanic arc, driven by subduction of the Juan de Fuca plate beneath North America. The High Cascades are comprised of volcanic mountain peaks that range from 10,000 to 14,000 ft in elevation. As such, these mountains are associated with a long history of abundant annual snowfall and glacier development.

The 1980 eruption of Mt. St. Helens removed an estimated 4.6 billion cubic feet of ice and snow from the mountain, aiding formation of lahars (volcanic debris flows) and floods. The 1980 event represents a combined volcanic-hydrologic hazard that has potential to adversely impact human population in the region. There is evidence of similar glaciovolcanic interactions on other Cascade volcanoes, and man can anticipate such threats during future eruptions. Therefore determining the volumes of the ice and snow on these mountains is useful in assessing the potentia hazard from eruptions of individual volcanoes. The objective of this lab is to analyze glacial ice budgets for a select set of Cascade volcanoes and to determine the factors that control the spatial distribution of ice and snow in the Pacific Northwest.

Methodology / Techniques

Ice and snow budget data are tabulated in attached Tables 1 through 5. The data are also available at the class web site (go to the "Week 6" section, and click on the "Ice Data" link for the "mtnicevol.xls" workbook). To analyze the data, complete the following tasks and answer the questions in the section below. Ice and snow budgets are tabulated for selected drainage basins at Mt. Rainier, Mt. Hood, Mt. Shasta, and Three Sisters. Data include Area Distribution, and Volumes in cubic feet.

Task 1 - Using the data presented in Tables 1-4, use Excel (and formulas) to complete Tables 5A and 5B. Format and print all of your work to include in your "report".

Task 2 - Systematically plot the following graphs using Excel. Make sure you format them and print them sc that they are readable and visually attractive (refer to the "Graphing Instructions" below).

Scatter Plot 1 - Total Ice Volume (y axis) vs. Latitude (x axis)
Scatter Plot 2 - Total Ice Area (y axis) vs. Latitude (x axis)
Scatter Plot 3 - Total Ice Volume (x axis) vs. Maximum Elevation (y axis)
Scatter Plot 4 - Total Ice Area (x axis) vs. Maximum Elevation (y axis)
Scatter Plot 5 - Total Ice Volume (Y axis) vs. El.-Lat Coefficient (x axis)
Scatter Plot 6 - Total Ice Volume (Y axis) vs. El.-Lat Coefficient (x -axis)

Column Chart 1 (Histogram) - Ice Area (y axis) vs. Drainage Basin (x-axis) -Mt. Rainier
Column Chart 2 (Histogram) - Ice Area (y axis) vs. Drainage Basin (x-axis) -Mt. Hood
Column Chart 3 (Histogram) - Ice Area (y axis) vs. Drainage Basin (x-axis) -Mt. Shasta
Column Chart 4 (Histogram) - Ice Area (y axis) vs. Drainage Basin (x-axis) -Three Sisters

Column Chart 5 (Histogram) - Ice Volume (y axis) vs. Drainage Basin (x-axis) -Mt. Rainier
Column Chart 6 (Histogram) - Ice Volume (y axis) vs. Drainage Basin (x-axis) -Mt. Hood
Column Chart 7 (Histogram) - Ice Volume (y axis) vs. Drainage Basin (x-axis) -Mt. Shasta
Column Chart 8 (Histogram) - Ice Volume (y axis) vs. Drainage Basin (x-axis) -Three Sisters

Column Chart 9 (Histogram) - Total Ice Area (y axis) vs. Mountain
Column Chart 10 (Histogram) - Total Ice Volume (y axis) vs. Mountain

Graphing Instructions in Excel

Scatter Plots - we have practiced this before, you should know what to do. Make sure to put titles anc axis labels on all of your charts. Size them so that they look pretty in your lab report.

Column Charts (Histograms): To construct a column chart for drainage basins vs. Ice Area, highlight the "Drainage Basin Name" and the "Ice Area Subtotal" cell data for one mountain range (e.g. Rainier Click on the "chart" tool icon and select the "Column" chart type, and the "Clustered Column" subtyp Remember that you can click on the "Press and hold to view sample" bar to preview your data plot. Format and size the "Column Chart" in the same manner as the "scatter plot" techniques that we've worked on in class. Make sure to put titles and axis labels on all of your charts. Size them so that the look pretty in your lab report. This should get you started.

Task 3 - Historic Rates of Glacial Retreat at Mt. Rainier.

A. Look at the attached copy of the Mt. Rainier topographic map. This task assumes that you know how to read a topo map. The photocopy isn't that great, the scanned color version of the map is available in the "lab data" section of the web site.

B. There are two historic maps of Mt. Rainier, one for 1924 and one for 1984. Locate the Nisqually Glacier south of Mt. Rainier and observe the relative change in position of the glacial front over time. Notice that valley glaciers on Rainier have undergone considerable ablation (melting) between 1924 and 1984. Fig. 1 (below) is a blank graph of time vs. the location of the snout of Nisqually Glacier ov time.

C. In looking at the 1984 map, the terminus of Nisqually Glacier was located at "pt. X" in 1924. Thus the position for that glacier is at zero kilometers for 1924 in Figure 1 below.

D. Now measure the distance up valley that the terminus of Nisqually was located at in 1984, and plo this distance for 1984 on Figure 1.

E. Draw a line that connects the two points plotted (for 1924 and 1984) on Figure 1.

F. Using the values of ice position for 1924 and 1984, calculate the rate of ablation of the terminus of Nisqually Glacier in meters / decade and mm/year.

Task 4 - Examine the copy of the attached Three Sisters quadrangle. Note the positions of mapped glaciers (pen outlines). Record the elevations for each of the glaciers. Answer the questions below.

FIG. 1

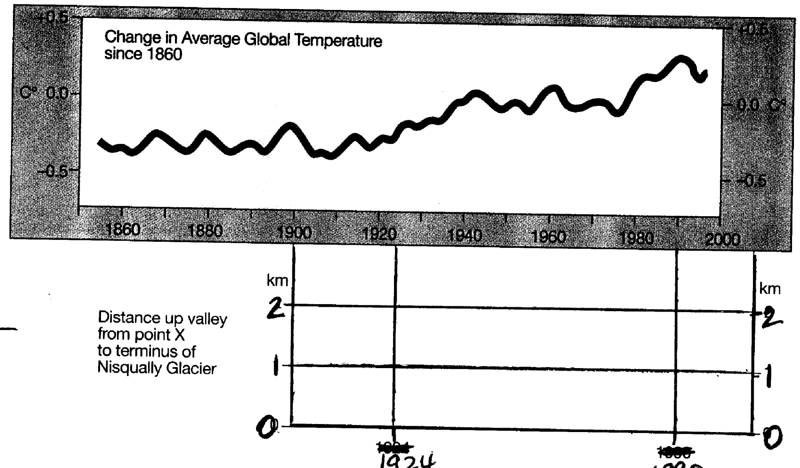


FIGURE 12.16 Graph for completing Questions 29–32.

Summary Questions (answer in word processing format on a separate sheet)

1. In referring back to Figure 1 and the Nisqually glacier problem, explain the relationships between average global temperature and historic records of Nisqually ice volume change.

2. Based on your answer in 1 above, explain how valley glaciers can be used as indicators of climate change. Very specifically discuss a hypothetical research plan that you could propose using glaciers as a proxy for climate change. Discuss all of your assumptions and relationships.

3. Refer back to your observations on the occurrence of glaciers in the Three Sisters area, as related to elevation. (a) What is the lowest elevation that you observe glacial ice? (b) Referring to the meteorology section of your text, expl the relationship between altitude, air temperature, and precipitation levels in the Pacific Northwest. (c) How will the: elevation-ice occurrence relationships change if there is net global cooling? Net global warming?

4. Examine all of the Cascade ice volume calculations and graphs that you created. Answer the following questions

A. Describe all relationships that you observe relating mountain elevation, latitude position, ice volume, and areas. Is there a consistent pattern that emerges?

B. Which Cascade mountain is associated with the greatest ice volume, and the least? Explain the relationsh that you observe.

C. In terms of glacio-volcanic hazard and mudflow potential, which Cascade mountains are related to the highest hazard? Which the lowest? Relate your data to you discussion.

D. In terms of volcano hazards planning in the Pacific Northwest, what types of data should state and federal administrators consider, and why?

Table 1. Areas and volumes of glacier ice and snow on Mt. Rainier.

Drainage Basin Name	Glacier or Snow Patch	Area Total ($x10^6$ ft^2)	Volume Total ($x10^9$ ft^3)
Cowlitz River	Snow Patches	14	0.7
	Whitman	23.8	4.4
	Ingraham	42.6	7
	Cowlitz	36.8	6
	Paradise	10.9	0.8
	Ohanapecosh	17.3	1.3
Nisqually River	Snow Patches	8.3	0.3
	Muir Snowfield	10.1	0.7
	Nisqually	49.7	7.8
	Wilson	15.5	1.9
	Kautz	12.4	1.3
	Success	7.4	0.5
	Van Trump	6.7	0.5
	Pyramid	5.8	0.4
	S. Tahoma	30.4	4.6
	Tahoma	32.1	4.3
Puyallup River	Snow Patches	9.9	0.4
	Tahoma	60.8	11.8
	N. Mowich	66.4	9.5
	Liberty Cap	1.7	0.1
	Flett	3.2	0.2
	Edmonds	15	1.1
	S. Mowich	38.4	4.5
	Puyallup	54.8	10.2
Carbon River	Snow Patches	9.5	0.5
	Carbon	85.2	25.1
	Russell	35.5	3.1
White River	Snow Patches	18.6	1
	Winthrop	98.1	18.5
	Emmons	120.2	23.8
	Inter	8.4	0.6
	Fryingpan	35.2	2.9
	Sarvent	6.2	0.4

Table 2. Areas and volumes of glacier ice and snow on Mt. Hood.

Drainage Basin Name	Glacier or Snow Patch	Area Total ($x10^6$ ft^2)	Volume Total ($x10^9$ ft^3)
White River	Snow Patches	2.9	0.2
	Coalman	0.6	0.03
	White River	5.8	0.3
Hood River	Snow Patches	19.4	1
	Newton-Clark	21.4	1.4
	Coe	13.4	1.9
	Ladd	9.7	0.9
	Eliot	18.1	3.2
	Langille	4.3	0.3
Zigzag River	Snow Patches	13.9	0.7
	Zigzag	8.3	0.6
	Palmer	1.4	0.07
	Coalman	0.3	0.01
Sandy River	Snow Patches	4.7	0.2
	Sandy	12.8	0.8
	Reid	8.1	0.6

Table 3. Areas and volumes of glacier ice and snow on Mt. Shasta.

Drainage Basin Name	Glacier or Snow Patch	Area Total ($x10^6$ ft^2)	Volume Total ($x10^9$ ft^3)
Valley Basin	Snow Patches	0.7	0.5
	Hotlum #1	14.4	1
Klamath	Snow Patches	3.9	0.2
	Bolam	11.4	0.8
	Whitney	13.8	0.9
Sacramento	Snow Patches	6.8	0.3
McCloud	Snow Patches	1.4	0.07
	Hotlum #2	5	0.3
	Wintun	13.2	0.9
	Konwakiton	3.2	0.2

Table 4. Areas and volumes of glacier ice and snow on Three Sisters.

Drainage Basin Name	Glacier or Snow Patch	Area Total ($x10^6$ ft^2)	Volume Total ($x10^9$ ft^3)
Squaw Creek	Snow Patches	6.4	0.3
	Linn	0.6	0.03
	Villard	0.5	0.02
	Thayer	1.7	0.1
	Hayden	7.8	0.6
	Diller	7.1	0.5
	Carver	3.5	0.2
	Prouty	10.5	0.7
	Collier	0.4	0.004
Fall Creek	Snow Patches	3.1	0.1
	Lewis	4.2	0.3
Separation Creek	Snow Patches	2.7	0.1
	Clark	3	0.2
	Lost Creek	5.8	0.4
	Crater	1.1	0.06
	Eugene	1	0.05
	Skinner	3.1	0.2
	Irving	4.1	0.3
White Branch	Snow Patches	5.3	0.3
	Renfrew	6	0.4
	Collier	11.4	0.7

Table 5A. Summary of Ice Budgets for Select Cascade Volcanoes.

Mountain	Drainage Basin Name	Area Subtotal ($x10^6$ ft^2)	Volume Subtotal ($x10^9$ ft^3)
Rainier	Cowlitz River		
	Nisqually River		
	Puyallup River		
	Carbon River		
	White River		
	Mt. Rainier Total		
Mt. Hood	White River		
	Hood River		
	Zigzag River		
	Sandy River		
	Mt. Hood Total		
Mt. Shasta	Valley Basin		
	Klamath		
	Sacramento		
	McCloud		
	Mt. Shasta Total		
Three Sisters	Squaw Creek		
	Fall Creek		
	Separation Creek		
	White Branch		
	Three Sisters Total		

Table 5B. Data Analysis for Select Cascade Volcanoes.

Mountain	Ice Area Total ($x10^6$ ft^2)	Ice Volume Total ($x10^9$ ft^3)	Maximum Elevation (ft AMSL)	Latitude (dec. deg. N)	Water-Equivalent Volume Total ($x10^9$ ft^3)#	Elevation-Latitude Coefficient**
Mt. Rainier			14410	46.9		
Mt. Hood			11245	45.5		
Mt. Shasta			14162	41.3		
Three Sisters			10354	44.2		

**Elevation-Latitude Coefficient = (Max. El.)*(Lat.)

Water Equivalent Volume = [(Ice Vol. cu. ft.)*(1.8)]/(1.94)

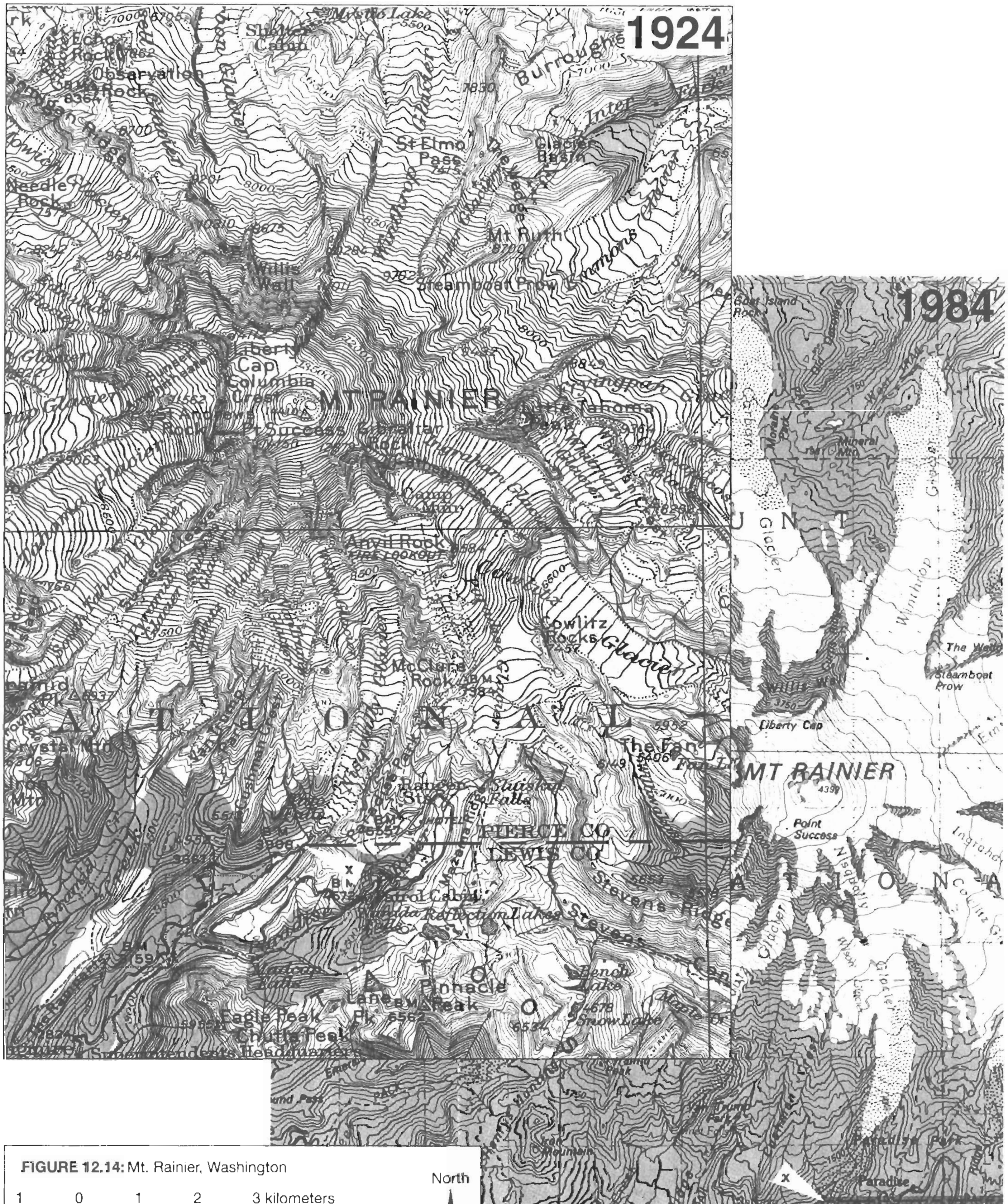


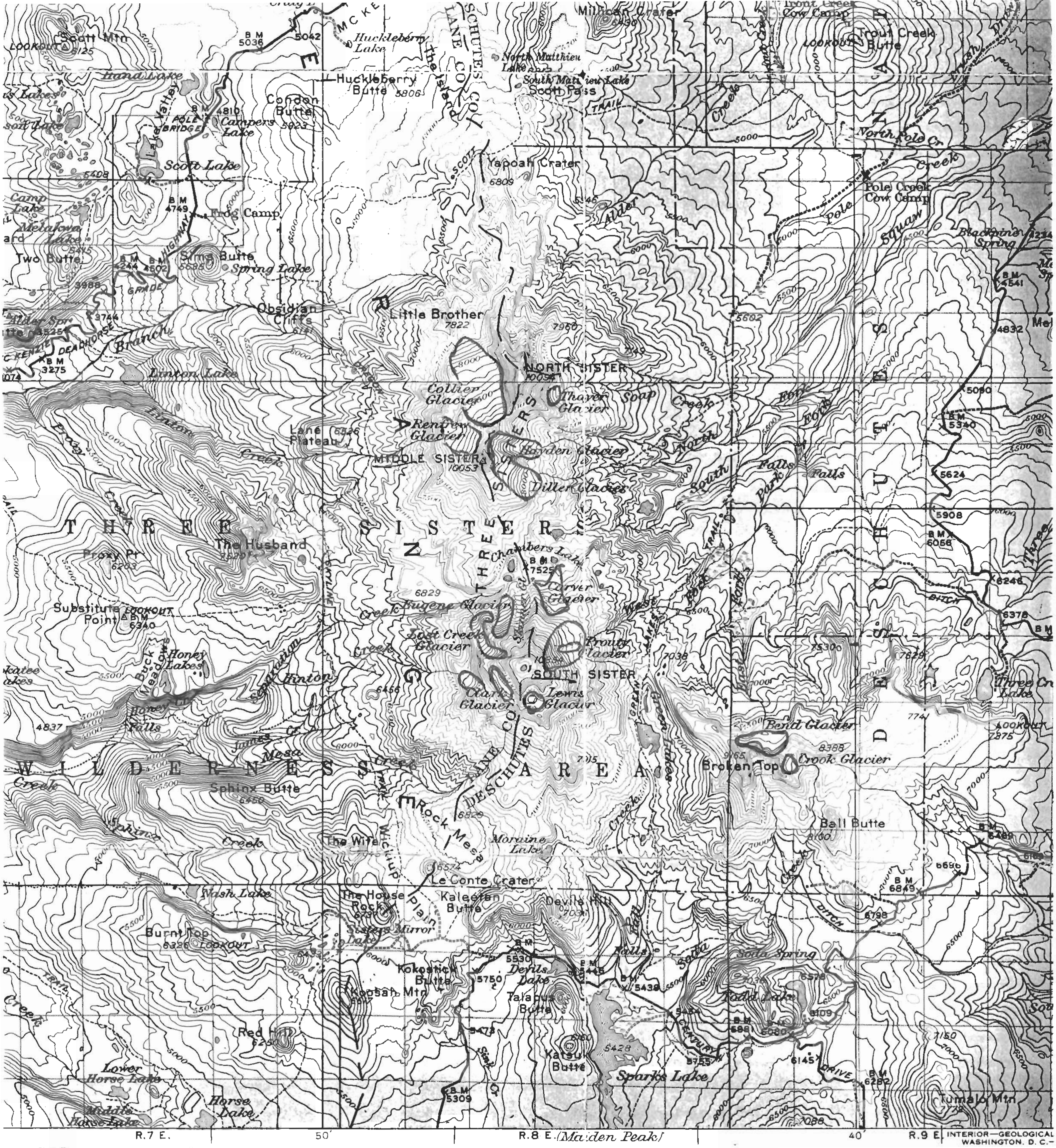
FIGURE 12.14: Mt. Rainier, Washington

North

1 0 1 2 3 kilometers

1 ½ 0 1 2 3 miles

Contour interval = 100 ft. 1:95,040



Davis, F.H.Purdy,

dirt

Route

TRUE NORTH
MAGNETIC NORTH
21°
APPROXIMATE MEAN DECLINATION, 1929

SCALE 1:125000

1 ½ 0 1 2 3 4 5 6 7 8 9 MILES

5000 0 5000 10000 15000 20000 25000 30000 35000 FEET

1 0 1 2 3 4 5 6 7 8 9 KILOMETERS

CONTOUR INTERVAL 100 FEET
DATUM IS MEAN SEA LEVEL

GLACIAL ICE

THREE SISTERS, QUAD