GLACIER FLUCTUATIONS SINCE 1870 AT MOUNT SHASTA, CALIFORNIA

by

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Geology 150-T

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Note: Sections lined-out by marker pen are of questionable accuracy or merely extraneous. These omissions are the result of continued research into the subject matter of this report.

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ABSTRACT

Geologic, historic, and meteorologic evidence were used to determine significant glacier fluctuations of the last century at Mount Shasta, California.

Four intervals of glacier change have occurred since 1870. A period of shrinkage ~~from 1875~~ to 1905. Growth and moraine establishment from 1905 to 1920. 1920 to 1946 was characterized by large scale recession. The years since 1946 have witnessed a slight to moderate readvance. (All dates are approximate.)

Climatic cycles at Mt. Rainier, Washington and the Sierra Nevada, California generally agree with those at Mt. Shasta. Notable differences exist, however, in the severity and duration of the cycles.

INTRODUCTION

Present Climate

The Mount Shasta region is characterized by cool, wet winters and warm, dry summers. Considerable variation in average annual temperature is a result of extreme relief.

Expansion of the circumpolar vortex in the fall carries cyclonic systems from the North Pacific to Mt. Shasta, initiating the wet season. This process usually occurs during October. Continued Arctic cooling brings increased frontal activity with maximum precipitation normally coming in January. The snowlevel tends to decline as the season progresses.

Figure 1

Localities discussed in the report.

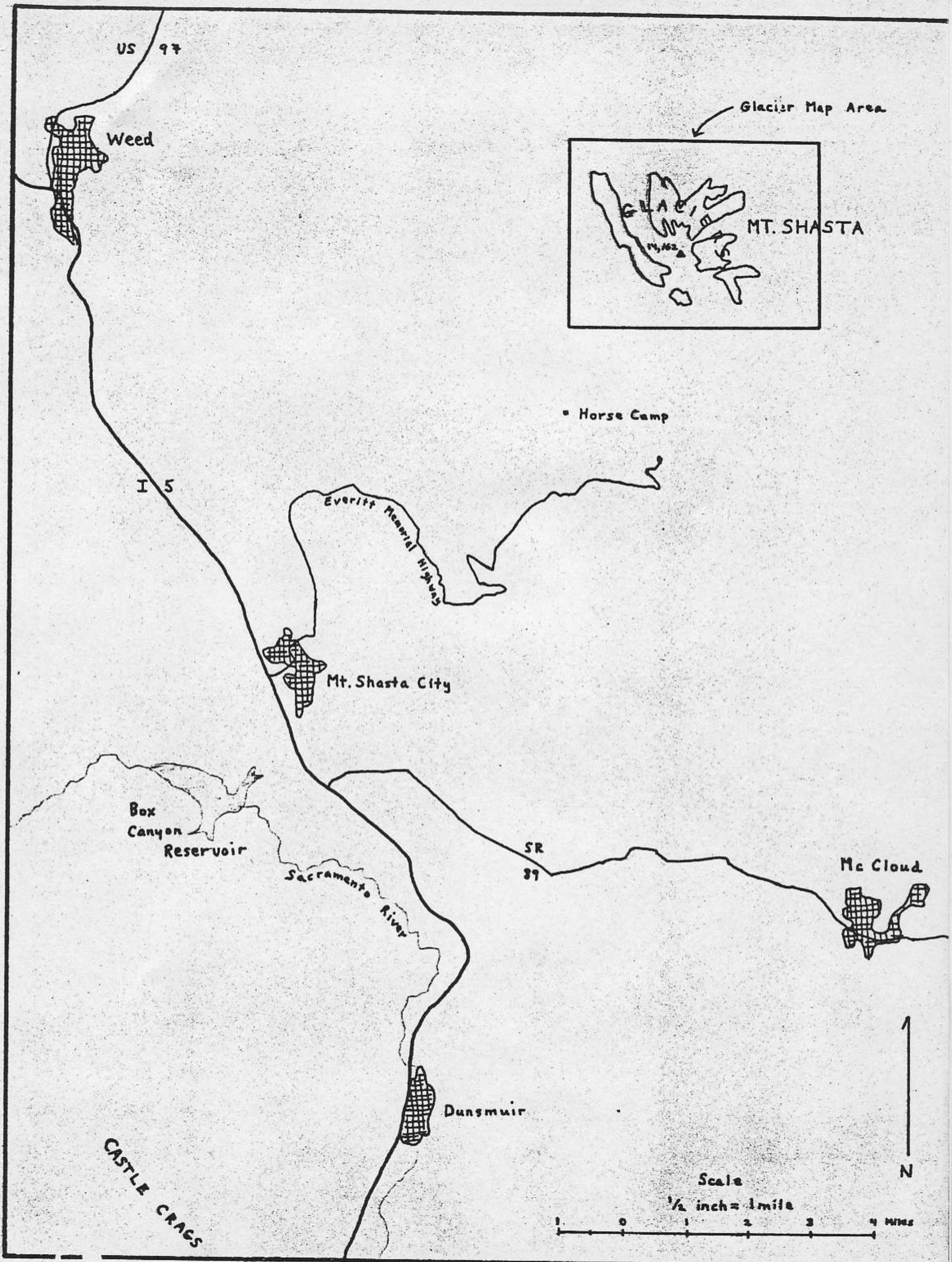


Figure 2. Mount Shasta region.

progresses, ~~reaching a minimum in March.~~ Most precipitation above 5,000 feet falls as snow. Maximum snowfall is on the south and southeast slopes of Mt. Shasta, most likely between 7,000 and 8,000 feet. At Horse Camp (Fig. 2) on the drier southwest slope at 7,900 feet, the snow-depth has exceeded 22 feet. (California Dept. of Water Resources, 1971, p. 68)

Mt. Shasta's topographically isolated nature results in it being the focus of unusually strong and frequent winds. Accordingly, there is an extreme redistribution of the snowpack above timberline. Summer duststorms dirty the glaciers and snowfields.

Storms decline rapidly in frequency and intensity during spring. Establishment of stable high pressure over the Pacific Coast in late April raises freezing levels. As a result general wastage of the snowpack begins.

June through September are monotonously warm and dry. Precipitation during these months is very light. When it does happen, it is usually the result of an incursion of moist subtropical air bringing afternoon thundershowers. The snow-level of these disturbances is typically above 10,000 feet and sometimes above the summit. On the rare occasions a North Pacific cyclone blows in, snow may fall as low as 7,000 feet.

According to the Köppen classification (Petterssen, 1969, p. 286), Mt. Shasta has a Dsb climate but is very near the boundaries of Csb ~~(marine)~~ and BSs ~~(steppe)~~ climates.

The orographic snowline of Mt. Shasta varies from 11,000 feet on the Hotlum Glacier to 12,400 feet on the Konwakiton Glacier. Mt. Shasta's climatic snowline is estimated to be at 13,400 feet (Flint, 1957, p. 47).

Geological History

Although not as high as Mt. Rainier, Mt. Shasta (14,162 ft) is the largest volcano of the Cascade Range. It rises 10,000 feet above its base with an approximate volume of 80 cubic miles (Williams, 1934).

Williams (1934) states that Mt. Shasta is formed mainly of pyroxene andesites and andesitic basalts, with tuff-breccias also being common. Earlier lavas formed a shield volcano. More recently, a steep strato cone rose from the shield, producing the uppermost 6,000 ft of the mountain. Mt. Shasta has suffered relatively little dissection by fluvial or glacial erosion so that it is probably post-Pleistocene in age. Very recent flows and plugs, including Shastina, have modified its classic profile.

Rather little has been learned about the glacial geology of Mt. Shasta. It is known from scattered, undifferentiated moraines on the lower slopes of Mt. Shasta and surrounding mountains that an ice cap formed on an ancestral cone and spread outward. A lobe extended down the Sacramento River Canyon at least as far as Dunsmuir, possibly with the help of tributary ice from highlands around Mt. Eddy and Castle Crags (Aune, 1970).

Very late Pleistocene or Holocene glaciation is evident from the shallow cirques and glacial valleys on the southern half of the cone. A series of end moraines probably associated with this glaciation exist on the plateau just southwest of Horse Camp(Williams, 1934, p. 251).

The latest eruption of Mt. Shasta probably occurred in 1786, when the explorer La Perouse saw smoke from an eruption in the vicinity of Mt. Shasta while sailing along the California coast. This eruption created the well known Red Banks and showered a thin layer of pale brown pumice over the entire mountain (Williams, 1934, p. 231).

In the summer of 1924, a series of mudflows, originating at the Konwakiton Glacier, swept down Mud Creek Canyon and out onto the plain near McCloud where they caused considerable property damage. Sediment from the flows discolored the Sacramento River and eventually San Francisco Bay, over 200 miles to the south.

EARLY STUDIES

Clarence King discovered the Mt. Shasta glaciers in 1870, while working on the United States geological exploration of the fortieth parallel. King provides some useful descriptions. Nevertheless, one must keep in mind his tendancy to exaggerate. ~~He noted that an advance of a till covered lobe of one of the glaciers knocked over trees~~ (King, 1871, ~~p. 375~~).

Retreat of the Bolam Glacier from its moraine was noted by Gilbert Thompson in 1885. Early settlers told him of a general decrease in snow on Mt. Shasta since they arrived in by Gilbert Thompson in 1883. Early settlers told him of a general decrease in snow on Mt. Shasta since they arrived in the 1850's (Russell, 1885, p. 334).

J. S. Diller (1895) described large masses of till covered ice at the lower ends of the Whitney and Hotlum glaciers. He referred to these features as "terminal moraines", which suggests that they were still attached to the body of the glaciers.

TWENTIETH CENTURY WORK

The major study of the geology of Mt. Shasta is that of Howel Williams (1934). In his brief and at times misleading discussion of the history of glaciation he describes essentially what has been mentioned above.

Oliver Kehrlein photographed and measured Mt. Shasta glaciers during the 1920's and 1930's. Kehrlein came up with quantitative evidence for a rapid shrinkage of these glaciers beginning about 1920.(Table 1), [illegible] unpublished)

In 1955, R. H. Watkins noted regrowth of the Konwakiton Glacier (Harrison, 1956, p. 667). By comparing old photographs with ones taken from 1955 to 1962, at comparable sites, Watkins determined that growth was occuring on the Hotlum and Wintun glaciers as well (personal communication, 1974).

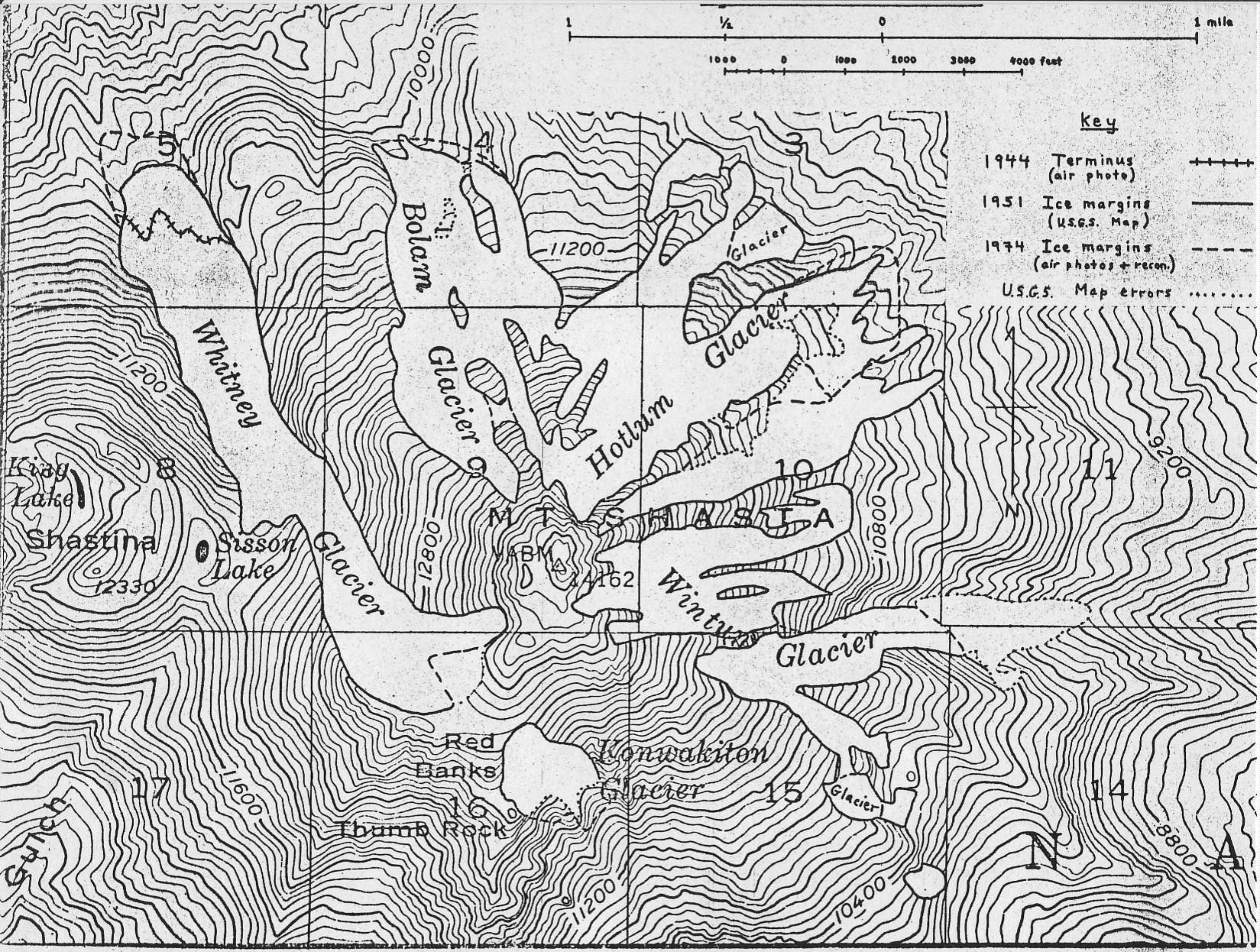
The author spent a few days in the field in 1972, 1973, and 1974. This time was spent mainly traversing the glacier bearing region of Mt. Shasta with the intent of setting up photographic survey stations and reconnaissance mapping the termini. Unfortunately, little time was spent mapping the moraine series associated with the existing glaciers, so that most of the information in this report concerning moraines comes from aerial photographs. U. S. Geological Survey and U. S. Forest Service aerial photos taken in 1944, 1951, 1955, 1970, and 1972, were used to measure fluctuations of the glaciers. In addition to confirming Mr. Watkins' observations, the author's studies led to the discovery of a considerable increase in the length of the Whitney Glacier (Fig. 3).

EVIDENCE OF GLACIER FLUCTUATIONS

Geological Evidence

All of the glaciers, with the exception of the Konwakiton, have prominent moraines associated with them. None of these moraines extend more than 1.5 miles beyond the present glaciers. The discussion below will be confined to this group of moraines.

~~Only one moraine arc with small recessional moraines was found below the Whitney Glacier. The Hotlum and Bolam glaciers had two nearly equal advances.~~ Two moraines are also present with the Wintun Glacier, but they have a large difference in magnitude. The outer moraine extends down to 7,900 ft, while the the inner arc suggests an advance to the 8,500 foot level. Mature whitebark pines grow on the


1
1/2
0
1 mile
1000
0
1000
2000
3000
4000 feet
Key
1944 Terminus (air photo)
1951 Ice margins (U.S.G.S. Map)
1974 Ice margins (air photos + recon.)
U.S.G.S. Map errors
Whitney
Glacier
Bolam
Glacier
Hotlum
Glacier
Glacier
Wintun
Glacier
Konwakiton
Glacier
Glacier
MT SHASTA
VABM
14162
Shastina
12330
Sisson
Lake
Red
Banks
Thumb Rock
Gulch
N
A
11200
10000
12800
10800
9200
11600
11200
10400
8800
3
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5
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Table 1. Summary of historical information concerning Mt. Shasta glaciers.

Year (source)

1870 (King, 1871)

Whitney Glacier: Three miles long.
Hotlum Glacier: 4.5 miles long.
~~Undifferentiated: Advance crushing trees.~~

1883 (Russell, 1885)

Whitney: Area: 1,900,000 square yards, terminus: 9,500 ft, length: 3,800 yards.
Hotlum: Area: 3,200,000 sq. yds., term: 10,500 ft, leng: 2,500 yds.
Bolam: Area: 1,800,000 sq. yds., leng: 3,200 yds., terminus retreated from moraine and divided into two lobes.
Wintun: Area: 2,000,000 sq. yds., leng: 3,400 yds., term: 8,000 ft. Terminus "several hundred feet high", furrowed by stream-cut channels.
Konwakiton: Area: 320,000 sq. yds., term: 12,000 ft.
Undiff: Decreased snow since 1870.

1884 (U.S.G.S. topo map)

Whitney: Term: 9,500 ft.
Hotlum: Term: NW lobe: 9,500 ft, SE lobe: 9,000 ft.
Bolam: Term: 9,700 ft.
Wintun: Term: 8,300 ft.
Konwakiton: Term: 11,000 ft.

1884 (Diller, 1895)

Whitney: Length 2.2 miles plus one mile long "moraine".
Hotlum: Length 1.62 mi plus half mile long moraine.
Wintun: Length "over two miles".

1920 (Kehrlein)

Undiff: Glaciers extended to moraines. Air photos taken by Army Air Force.

1924 (Williams, 1934)

Konwakiton: Length decreased by 3/8 mile.

1927 (Matthes, 1935)

Wintun: Term: 8,300 ft.

Table 1. (Continued from previous page)

1933 (Matthes, 1934, and Kehrlein)

Konwakiton: Shorter and thinner than present.
"Mud Creek Glacier" (near Konwakiton) Receeded 1,300 feet since 1924 due to undercutting of snout.

1934 (Matthes, 1935, and Kehrlein)

Hotlum: Thinner than present.
Wintun: Terminus at 10,000 ft. Virtually stagnent, no ice moving over icefall.

1935 (Matthes, 1936, and Kehrlein)

Hotlum: Much till covered ice.
Bolam: Thinner than present.
Mud Creek: Snout undercut 60 ft since 1933.
Undiff: Less snowfields, more exposed rock.

1944 (air photo)

Whitney: Terminus 9,950ft, irregular and gently sloping.
Bolam: Terminus ill defined, about 10,050 ft.

1951 (U.S.G.S. topo. map and air photo)

Whitney: Terminus 9,820 ft with steep lobate front. 700 ft advance since 1944.
Bolam: Same as 1944.
Konwakiton: Term: 12,000 ft.

1955 (Harrison, 1956, and air photo)

Whitney: Slight advance since 1951.
Konwakiton: Thicker than 1933.

1959 (Watkins photo)

Konwakiton: Thicker and more crevassed than 1955, apparent advance of terminus.

1962 (Watkins photos)

Hotlum: Thicker and more crevassed than 1934, appears to be advancing.
Wintun: Vigorous flow over icefall, appears to be advancing.

Table 1. (page three of table)

1972 (air photo)

Whitney: Terminus 9,640 ft, 800ft advance since 1951, steep linear snout.
Bolam: Slight advance since 1951.
Hotlum: Terminus 10,280 ft, 600 ft advance since 1951, steep linear snout.

1974 (author)

Whitney: No recognizable change in terminus since 1972. Lowest 1/4 to 1/2 mile becoming stagnent.
Hotlum: Advance since 1962, no rec. change since 1972.
Bolam: No rec. change since 1972.
Wintun: Advance since 1962.
Konwakiton: No rec. change since 1959.
Undiff: Photo survey initiated. Glaciers smothered by heavy snowpack.

outer moraine. Almost all of the other Matthes aged moraines on Mt. Shasta are above treeline.

Within the moraines of the Whitney, Bolam, and Hotlum glaciers relatively large areas of beveled bedrock with a thin veneer of ground moraine in spots and a few medial moraine ridges could be seen. Much of this terrain has been covered by advances of the Whitney and Hotlum glaciers since 1944. One area separating the snout of the Bolam Glacier from a mass of till covered stagnant ice, still exists.

The geologic evidence infers that at least two Matthes advances occurred, the latter being somewhat less vigorous. A rapid, severe recession followed. Less than a third of the recession has been recovered by the latest advance, which has had little moraine formation associated with it.

Climatic Data

When studying the variations of several glaciers on a large mountain it must be kept in mind that climatic conditions, i.e., meteorological parameters which affect accumulation and wastage, do not always mirror those of the region in which it exists. Surprising changes often occur within distances of a few hundred yards (Paterson, 1969). However, general trends of the two most important components of climate; temperature and precipitation, are almost always the same over areas of several hundred square miles.

Meteorologic records from the National Weather Service office in Mount Shasta City (3544 ft), nine air miles southwest of the summit of Mt. Shasta, as well as snow survey data from Horse Camp (7,900 ft), three miles southwest of the summit, provided raw material.

The Horse Camp water content graph (Fig. 4, Graph A), is based on annual measurements of the snowpack on or about May first. This record, continuous since 1936, represents information obtained when the snowpack is near its seasonal maximum. Being less than three miles from the névé of the Konwakiton and Whitney glaciers, it is the best indicator of precipitation trends on the glaciers. Graph A also serves as a check of the applicability of the Mt. Shasta City precipitation curve (Fig. 4, Graph B).

Precipitation and temperature records of Mt. Shasta City are an excellent source of climatic information. Lack of urbanization or site changes make this record, dating back to 1888 for precipitation, one of the more reliable records of Northern California. Graph C (Fig. 4) was compiled by averaging daily maximums for the period April to October of each year. This results in a much better representation of ablation conditions than the annual averages used by many workers. Seasonal precipitation (July to June) was the basis for graph B. Data was plotted on the year of the spring of the precipitation season. (For example, the precipitation for 1889-1890 was plotted on 1890.)

A problem arose when it was noted that seasons of above normal precipitation tend to be followed by summers of extreme warmth and vise-versa. This made it difficult to determine a net change in climate. If one knew the relative effect of a change in precipitation versus a change in temperature for a glacier the problem would be solved. Unfortunately, this relationship is not known for the glaciers of Mt. Shasta or few, if any, other glaciers.

To construct graph D (Fig. 4), a change of one average deviation of temperature or precipitation was considered to have an equal effect on the climate. Above normal precipitation and below normal April-October temperatures were given positive values while their opposites received negative notations. By adding the values, a climatic index could be compiled for each year. (To illustrate: A value of +320 percent of the average deviation for precipitation plus a value of -70 percent of the average deviation for temperature equals a climatic index of +250 percent.)

Graph E (Fig. 5) from Antevs (1938) correlates well with graph B. ~~It extends the record back far enough to determine whether or not there is any basis for King's observation of an advancing glacier. Graph E does support King.~~

Caution is necessary when using the graphs. Smoothing, particularly running means, tend to offset climatic maxima and minima, making a check of the raw data advisable. The time lag between a climatic change and response of the glacier terminus varies from glacier to glacier and may be several years(Paterson, 1969). ~~Small cirque glaciers such as those~~

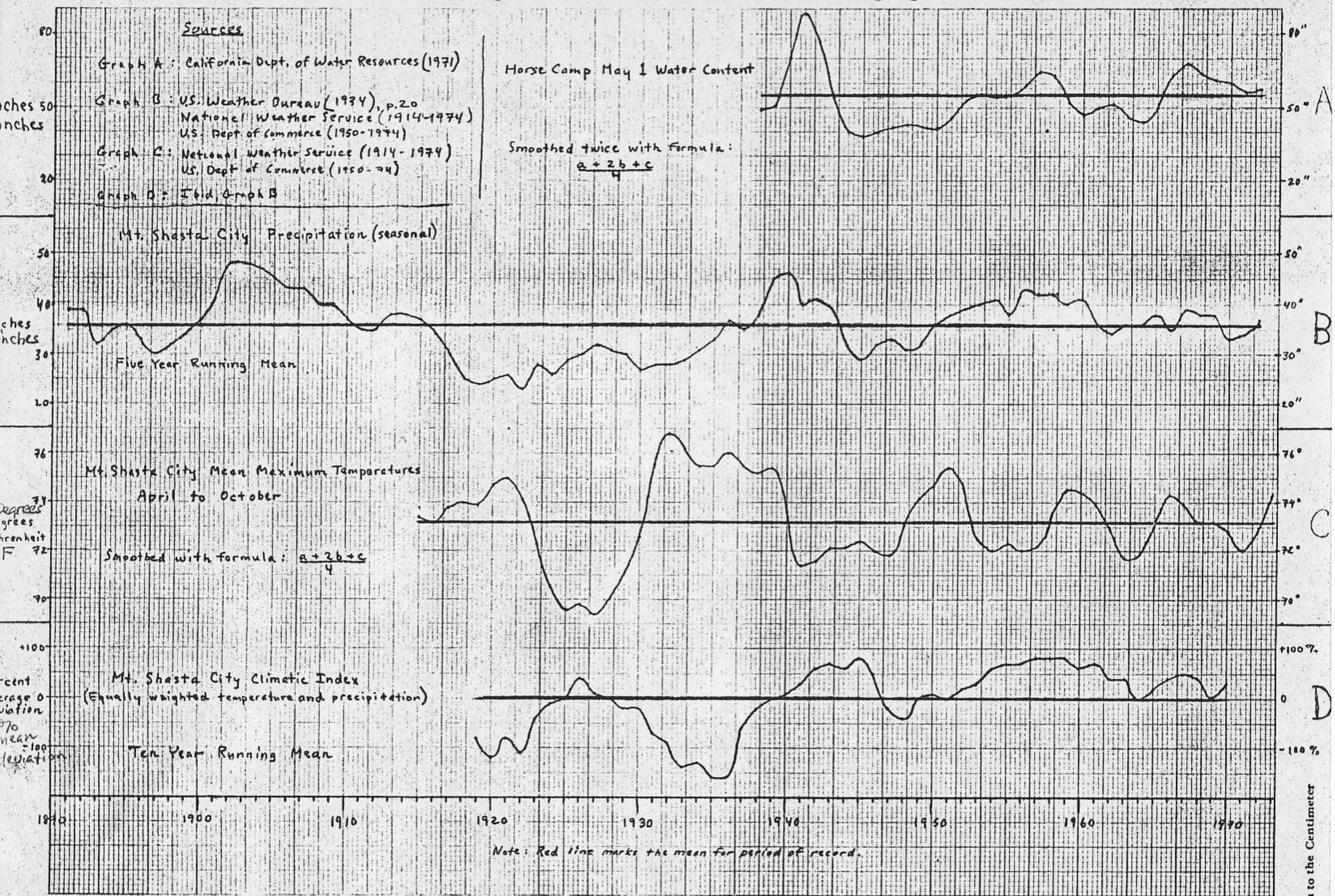
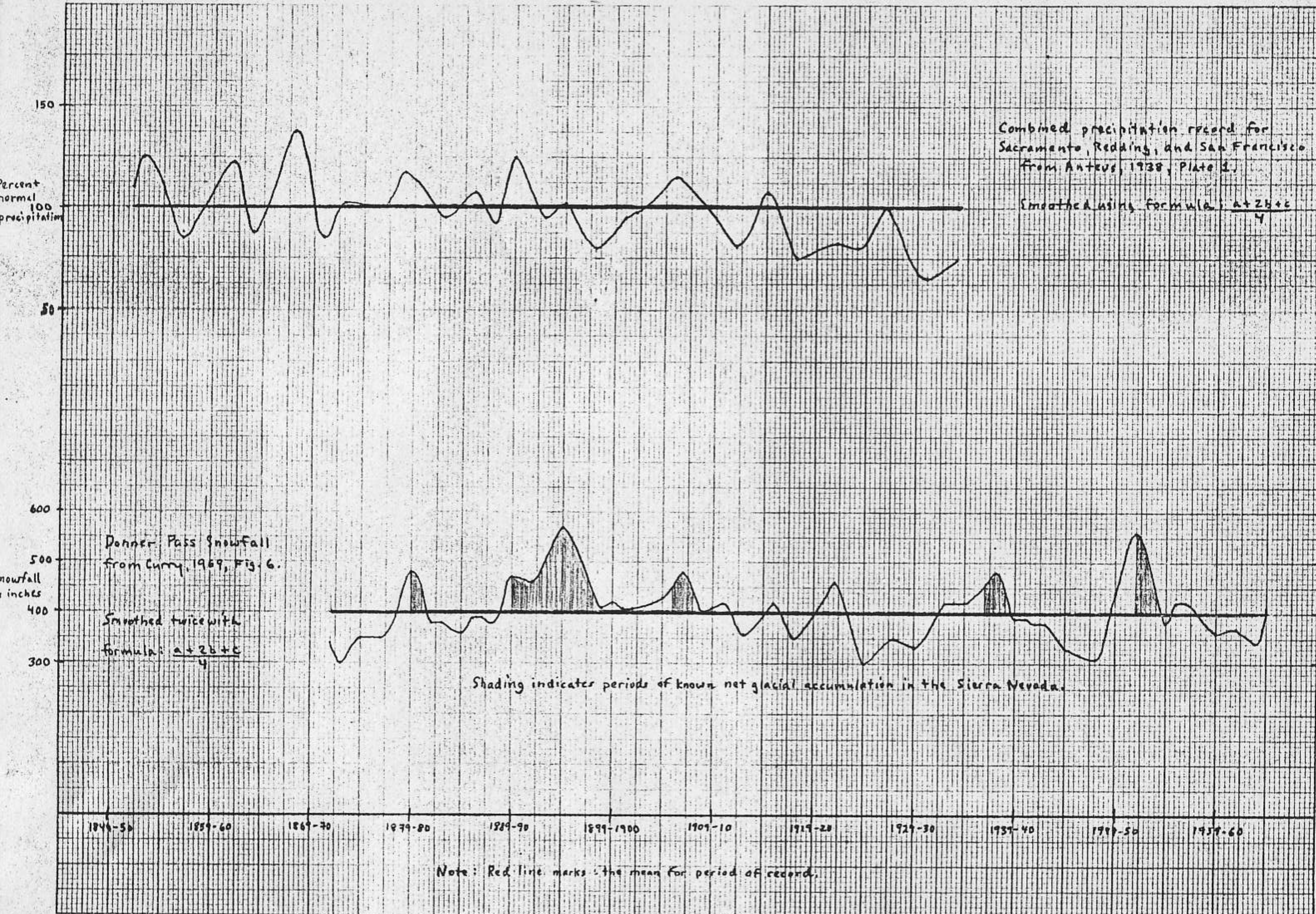

Sources
Graph A: California Dept. of Water Resources (1971)
Graph B: U.S. Weather Bureau (1934), p.20
National Weather Service (1914-1974)
U.S. Dept of Commerce (1950-1974)
Graph C: National Weather Service (1914-1974)
U.S. Dept of Commerce (1950-74)
Graph D: Ibid, Graph B
Horse Camp May 1 Water Content
Smoothed twice with formula: (a + 2b + c)/4
A
Mt. Shasta City Precipitation (seasonal)
Five Year Running Mean
B
Mt. Shasta City Mean Maximum Temperatures
April to October
Smoothed with formula: (a+2b+c)/4
Degrees Fahrenheit
F
C
Mt. Shasta City Climatic Index
(Equally weighted temperature and precipitation)
Ten Year Running Mean
D
80
50
20
50
40
30
20
76
74
72
70
+100
0
-100
80"
50"
20"
50"
40"
30"
20"
76°
74°
72°
70°
+100%
0
-100%
1890
1900
1910
1920
1930
1940
1950
1960
1970
Note: Red line marks the mean for period of record.
10 Millimeters to the Centimeter

Figure 5. Northern California climate graphs.



10 Millimeters to the Centimeter

~~in the Sierra Nevada have terminus response times of less than a year (Dean, 1974, p. 5). Comparison of the graphs with known variations suggests an average response time of about five years for Mt. Shasta glaciers.~~

When the above is taken into consideration, the curves can be used to estimate the direction and duration of glacier fluctuations when historical or geological information is lacking.

GLACIER FLUCTUATIONS SINCE 1870

Evidence in this report suggests four major periods of glacier change since 1870. ~~After an advance culminating in the early 1870's,~~ recession dominated until about 1905. ~~Net ice loss, however, was probably less than 25 percent.~~ An advance of ten to fifteen years duration followed. Moraines were formed ~~within the Matthes deposits~~ at the end of the period.

Beginning about 1920, rapid wastage of the glaciers began. A short period of climatic improvement around 1927 was not enough to halt the recession. Between 1920 and 1940 the glaciers may have lost more than half their combined mass.

Circa 1946 to present has been characterized by advance or stability of the termini. Relatively speaking, Wintun Glacier has grown the most and Bolam Glacier the least. The greatest advance, 1,500 feet, was made by the Whitney Glacier. 700 feet of this advance was accomplished between 1944 and

1951, probably as the result of a kinematic wave. In the last few years ice has stagnated near the terminus so that retreat or stranding of the lowest ice could happen soon.

CORRELATION WITH OTHER AREAS

Recent glacier variations in the Sierra Nevada (Fig. 1) were studied by R. R. Curry (1969). He discerned six episodes of net glacial accumulation in the period 1870 to 1966. These are noted on graph F (fig. 5) which is based on Donner Pass snowfall and photographs. The longest advance lasted from 1890 to 1897, and ended with the Sierra glaciers having reached the moraines of the previous neoglacial (Matthes) advance. In 1907 or 1908, recession began. Apparently the Sierra advance, though of similar duration to that on Mt. Shasta, was centered about ten years earlier.

The Sierra was not affected by drought in the 1920's and 1930's to the same degree as Mt. Shasta, nor has there been recovery since that time. Net shrinkage has slowed markedly in the last forty years, possibly because there is less glacier to supply.

Glaciers of Mount Rainier (Fig. 1) have been extensively studied. Variations of the Nisqually Glacier are particularly well documented.

~~Sigafoos and Hendricks(1972) recognized two moraine forming advances on Mt. Rainier during the past century.~~ Photographs in Veatch (1969) suggest a vigorous advance of Nisqually Glacier around the turn of the century, with a maximum position being reached about 1907. A 56 year retreat followed. In 1946 a thickening of ice in the accumulation zone was noted. Eventually this and other kinematic waves moved down Nisqually Glacier and initiated an advance in 1963. The 56 year retreat was by no means confined to the Nisqually Glacier. Most Mt. Rainier glaciers receded considerably and some are continuing to do so. During the last twenty years, however, increased snowfall has reduced the number of retreating glaciers. Mark Meier predicted that many Rainier glaciers will begin advancing in a few years (Chronicle, 1974).

As in the Sierra we have a history of glacier fluctuations similar to that of Mt. Shasta except for some variation in length and intensity of the cycles. If it is kept in mind that even on a single mountain there may be differences of several years in the advance and retreat times of the glaciers thereon, it is not surprising that variations occur over distances of several hundred miles.

CONCLUSIONS

Statistical analysis of climatic data and historical research were found useful in obtaining information necessary to compile this report. These methods are no substitute for annual photographs and measurements of glaciers. Effects of climatic change on individual glaciers was often generalized, due primarily to lack of information. This paper barely scratched the surface of the Holocene glacial history of

Mt. Shasta. It must be considered an initial effort rather than an end product.

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