UNCLASSIFIED

AD NUMBER: AD0209641
LIMITATION CHANGES
TO: Approved for public release; distribution is unlimited.
FROM: Distribution authorized to U.S. Gov't. agencies and their contractors; Administrative/Operational Use; 1 Jan 1958. Other requests shall be referred to the Army Quartermaster Rsch Eng Command, Natick, MA 01760.
AUTHORITY
USAETL LTR, 28 SEP 1976

THIS PAGE IS UNCLASSIFIED

UNCLASSIFIED

AD 20 641

Armed Services Technical Information Agency

ARLINGTON HALL STATION
ARLINGTON 12 VIRGINIA

FOR MICRO-CARD CONTROL ONLY

1 OF 2

NOTICE: WHEN GOVERNMENT OR OTHER DRAWINGS, SPECIFICATIONS OR OTHER DATA ARE USED FOR ANY PURPOSE OTHER THAN IN CONNECTION WITH A DEFINITELY RELATED GOVERNMENT PROCUREMENT OPERATION, THE U. S. GOVERNMENT THEREBY INCURS NO RESPONSIBILITY, NOR ANY OBLIGATION WHATSOEVER; AND THE FACT THAT THE GOVERNMENT MAY HAVE FORMULATED, FURNISHED, OR IN ANY WAY SUPPLIED THE SAID DRAWINGS, SPECIFICATIONS, OR OTHER DATA IS NOT TO BE REGARDED BY IMPLICATION OR OTHERWISE AS IN ANY MANNER LICENSING THE HOLDER OR ANY OTHER PERSON OR CORPORATION, OR CONVEYING ANY RIGHTS OR PERMISSION TO MANUFACTURE, USE OR SELL ANY PATENTED INVENTION THAT MAY IN ANY WAY BE RELATED THERETO.

UNCLASSIFIED

HEADQUARTERS
QUARTERMASTER RESEARCH & ENGINEERING COMMAND
U S ARMY

AD No. 207641
ASTIA FILE COPY

TECHNICAL REPORT
EP-79

FC
BAC

ENVIRONMENTAL HANDBOOK FOR CAMP HALE AND PIKES PEAK AREAS, COLORADO

FILE COPY
Return to
ASTIA
ARLINGTON HALL STATION
ARLINGTON 12, VIRGINIA
Attn: TISSS

QUARTERMASTER RESEARCH & ENGINEERING CENTER
ENVIRONMENTAL PROTECTION RESEARCH DIVISION

ASTIA
RECEIVED
JAN 12 1959
TIPDR E

JANUARY 1958 NATICK, MASSACHUSETTS

HEADQUARTERS
QUARTERMASTER RESEARCH & ENGINEERING COMMAND, US ARMY
OFFICE OF THE COMMANDING GENERAL
NATICK, MASSACHUSETTS

Major General Andrew T. McNamara
The Quartermaster General
Washington 25, D. C.

Dear General McNamara:

This report, "Environmental Handbook for the Camp Hale and Pikes Peak Areas, Colorado," is a guide to environmental conditions in parts of Colorado that have been used for mountain warfare training and testing of equipment. It contains a detailed analysis of the terrain, surface conditions, vegetation, and climate of the areas, considered especially with regard to seasonal variations in these conditions. This information is expected to aid Army personnel in selecting and evaluating sites for future training and testing in the mountains of Colorado. The report constitutes part of the continuing program to increase the Army's ability to operate in any environment in any part of the world.

Sincerely yours,

C. G. Calloway

C. G. CALLOWAY
Major General, USA
Commanding

1 Incl
EP-79

HEADQUARTERS QUARTERMASTER RESEARCH & ENGINEERING COMMAND, US ARMY
Quartermaster Research & Engineering Center
Natick, Massachusetts

ENVIRONMENTAL PROTECTION RESEARCH DIVISION

Technical Report
EP-79

ENVIRONMENTAL HANDBOOK
FOR THE
CAMP HALE AND PIKES PEAK AREAS, COLORADO

Will F. Thompson
Geographer

Arthur V. Dodd
Meteorologist

REGIONAL ENVIRONMENTS RESEARCH BRANCH

Project Reference:
7-83-01-005

January 1959

FOREWORD

This report is one of a series of handbooks, prepared by the Environmental Protection Research Division, on the physical environment of sites where tests are conducted by the Quartermaster Corps and other technical services of the Army. Originally requested by the Mountain and Cold Weather Training Command, the report is intended for use both in planning tests of mountain equipment and for orientation of soldiers who may be assigned to receive training and indoctrination in the mountains of Colorado. A section on comparisons of the Camp Hale and Pikes Peak areas with other mountain areas of the world has been included to indicate world-wide applicability of the findings.

AUSTIN HENSCHEL, Ph.D.
Chief
Environmental Protection Research
Division

Approved:

WILBUR M. SKIDMORE, Colonel, QMC
Commanding Officer
QM R and E Center Laboratories

A. STUART HUNTER, Ph.D.
Scientific Director
QM Research & Engineering Command

CONTENTS

ABSTRACT

This study is a detailed description and comparison of the physical characteristics—climate, terrain, soils, and vegetation—of Camp Hale and the Pikes Peak upland, two high-mountain military training and testing sites in the Colorado Rockies. Comparisons are also made, in more general terms, with mountain ranges elsewhere. The Rockies are found to differ markedly from such familiar mountain environments as the European Alps, and to resemble in many respects the mountains of inner Asia, such as the Hindu Kush and Tien Shan. However, the great height and distance from the sea of the mid-Asiatic ranges cause more extreme cold and dryness in particular regions than occur in the Rockies.

The Camp Hale Military Reservation includes moderately rugged mountains in which oversnow operations can be carried on with relative convenience and safety in midwinter. The reservation is surrounded by higher and steeper ranges, however, which may also be used for training and testing. The Pikes Peak upland lacks reliable winter snow cover but is conveniently close to Fort Carson, Colorado.

Both areas are covered mostly with rocky soil. Other surface types present are soil-free rocky rubble, cliffs, bogs, and valley flats. Glaciers are not present in either area, although there are many evidences of past glaciation.

Vegetation of the alpine zone (the area above timberline) consists mostly of dry sedge meadow, especially on Pikes Peak. In the subalpine zone (from timberline down to about 9,000 feet), there are forests of spruce, fir, and aspen, and scattered meadows. Sunny slopes in the lower part of the subalpine zone have sagebrush near Camp Hale and short grass steppe in the Pikes Peak area. Below the subalpine zone, montane forest of Douglas fir and ponderosa pine is widespread on the rugged flanks of the Pikes Peak upland.

Summers are mild and winters severe both at Camp Hale and on the Pikes Peak upland. Snow cover during winter is usually deeper in the Camp Hale area, but the Pikes Peak area is subject to heavy snowfalls in spring.

ENVIRONMENTAL HANDBOOK FOR THE CAMP HALE AND PIKES PEAK AREAS, COLORADO

1. Introduction

Camp Hale, close to the continental divide in the central Colorado Rockies, has been used intermittently as the U. S. Army center for mountain warfare training and testing. During the warmer part of the year, considerable training and testing have also been conducted in the nearby Pikes Peak region. Though the Army has used mountain and winter warfare experience acquired by individuals and military units in many parts of the world in developing its capability to operate in mountains, experience gained at Camp Hale has had special importance. Acceptance or rejection of tactical doctrine and materiel for mountain warfare have been based to a considerable extent on performance in tests and training there. Also, training at Camp Hale is an experience shared by many Army personnel who originate or utilize such concepts and items. This handbook discusses the environment of Camp Hale first, then relates the environment of the Pikes Peak region to it, and finally, broadly compares the environment of the two areas with mountain environments elsewhere in the world.

2. The Camp Hale Military Reservation

Camp Hale, at 39°25' N latitude, is at an altitude of 9,250 feet on the headwaters of the Eagle River, a tributary of the Colorado, which rises on the nearby continental divide. The camp occupies Eagle Park, a level, 2¼-square-mile valley floor, 1/2 mile wide in its wider parts (Fig. 1). It is 5 miles north of Tennessee Pass (elevation 10,400 feet)

Fig. 1. Camp Hale in February 1955, looking across Eagle Park to the mouth of Resolution Creek.

on the continental divide, and 12 miles north of the town of Leadville in the upper Arkansas River Valley. U. S. Highway 24 and the Denver and Rio Grande Western Railroad approach Tennessee Pass from the eastern slope of the Rockies by way of the Upper Arkansas. They descend the western slope of the range by way of the Eagle River Valley, passing along the western edge of Eagle Park. The railroad station serving Camp Hale is Pando, at the northern (downstream) end of the park (Fig.2).

The outstanding advantages of Camp Hale as a mountain warfare training and testing center are: (a) the proximity of extensive high altitude mountain areas (Fig. 3); (b) reliable winter snow cover; (c) a large area of slopes of considerable height and extent, most of which are free of difficult defiles, avalanche hazards, and barriers to casualty evacuation; and (d) relative lack of interference with civilian use of the training areas. About 250 square miles of mountainous land in the White River, San Isabel, and Arapahoe National Forests have been designated as the Camp Hale Military Reservation (Fig. 2). National Forest land outside the reservation is also available for training and has often been used; much of it is more rugged than any part of the reservation.

Access to the various parts of the reservation is possible by means of a fairly dense net of roads and trails. U. S. Route 24 bisects the reservation from north to south through Tennessee Pass and the Eagle River Valley. The eastern boundary of the reservation follows State Route 91 in Tenmile Valley, and U. S. Route 6 forms its northern boundary in the valley of the West Fork of Tenmile Creek. Truck and jeep trails follow many other valleys and ascend some of the lower slopes. Some foot and wagon trails built during the Leadville mining boom near the turn of the century have been restored to full use, and others are still passable. There are also many useful, though discontinuous, sheep trails near timberline.

High mountains adjacent to or easily accessible from the Camp Hale reservation are also used for training (Fig. 4). These include the inner Sawatch, Tenmile, Gore, and Mosquito Ranges. Routes that cross or give access to these ranges are shown in the overlay of Figure 3. Jeep trails and good foot trails reach certain parts of these ranges but other parts are not accessible by any improved route. The Mountain and Cold Weather Training Command made less use of the high ranges near Camp Hale than it otherwise might because there are no glaciers and little perennial snow in the area. In recent years, troops of the Command have gone to the Wind River Range in Wyoming for summer training because it has large glaciers as well as high and rugged peaks. Some notes on that area are included in a 1955 research study report of the U. S. Army Quartermaster Research & Development Command, Three Mountain Areas in Southwestern Wyoming.

With a few exceptions, main highways are kept open all winter throughout the region. Snow-covered truck and jeep trails are usable by oversnow

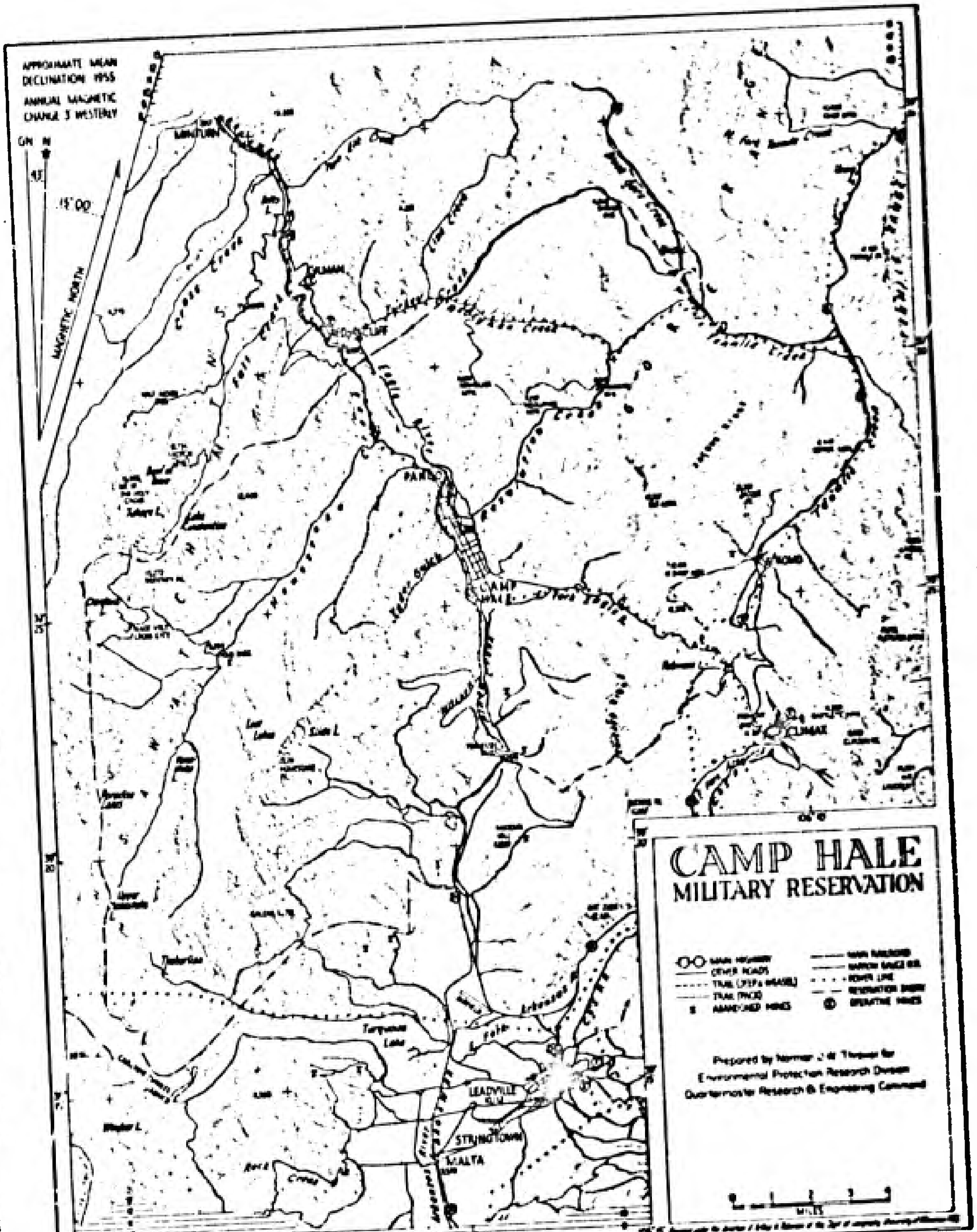

CAMP HALE
MILITARY RESERVATION
MAGNETIC NORTH
CLIMAX
LEADVILLE
MALTA

Figure 2

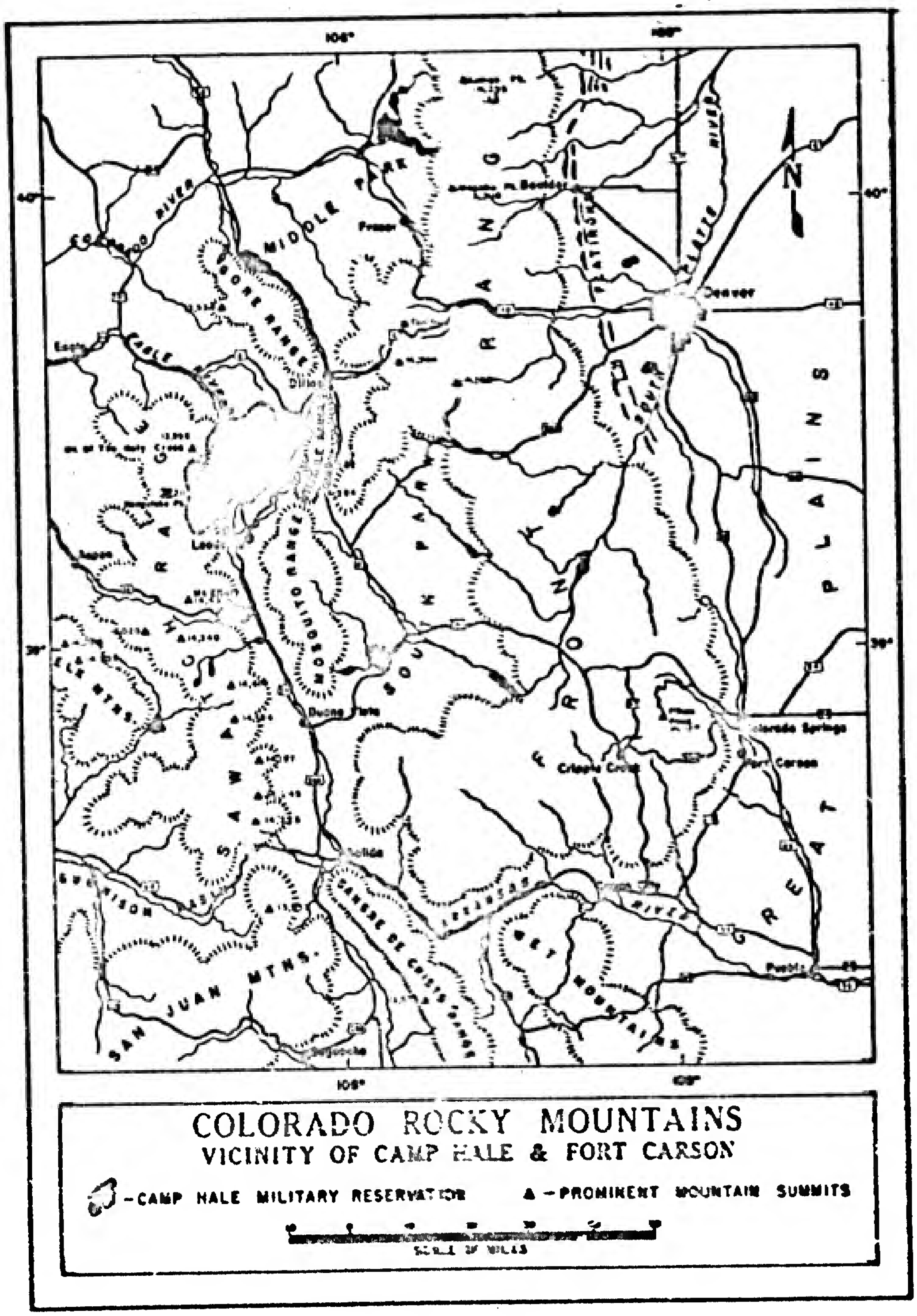

COLORADO ROCKY MOUNTAINS
VICINITY OF CAMP HALE & FORT CARSON
-CAMP HALE MILITARY RESERVATION
▲-PROMINENT MOUNTAIN SUMMITS
MIDDLE PARK
GORE RANGE
MOSQUITO RANGE
SAN JUAN MTNS.
ELK MTNS.
PLAINS
Denver
Colorado Springs
Fort Carson
Pueblo
Cripple Creek
Buena Vista
Salida
Dillon
Leadville
Fraser
Saguache

Figure 3

vehicles which can also move cross-country in winter on some of the upland slopes.

Army aircraft on observation and courier missions use an improvised light-plane landing strip within Camp Hale. The usefulness of light aircraft is somewhat limited, however, by altitude and by periods of turbulent air. Because of the altitude, helicopters thus far have been unable to operate well enough to participate regularly in training and testing at Camp Hale.

Since movement on foot is a very important element of training and testing operations in the Camp Hale area, it should be noted that the altitude there is not great enough to affect the ordinary movements of acclimatized troops, though it does reduce their ability to maintain extreme activity.

a. Topography.

The Camp Hale Military Reservation is an area of mountains of moderate relief almost surrounded by higher, more rugged ranges. Though there are no glaciers in the region today, the ruggedness of its higher summits and the form of the broader valleys are due to Ice Age glaciation.

The Eagle River valley divides the Camp Hale reservation into two nearly equal parts (Fig. 2). The western half is in the Sawatch Range and is a region of durable granitic and metamorphic rocks thinly capped near Eagle Park by a remnant of the sedimentary rocks which once overlaid them. The eastern half is almost entirely carved out of sedimentary rock. Gneiss appears on that side of the reservation only as low cliffs at the base of the mountainside east of Camp Hale, where it is used for rock climbing practice. Elsewhere in the eastern half of the reservation, conspicuous outcrops are generally igneous intrusive rocks that weather somewhat less than the sedimentary rock, though they are brittle and unable to form high, steep cliffs.

The western edge of the reservation lies close to the crestline of the northernmost part of the Sawatch Range. Just outside the reservation is the Mount of the Holy Cross, 13,996 feet above sea level, which marks the northern end of the range. A less rugged spur of the Sawatch, the Homestake upland, extends north into the reservation between Tennessee Pass and the deep glacial trough of Homestake Creek. Its highest summit is Homestake Peak, 13,211 feet. The eastern half of the reservation reaches almost equal altitude (Jacque Peak, 13,201 feet) but has less relief than the Homestake upland, the Homestake Valley being about 1,000 feet deeper than the upper Tenmile Valley.

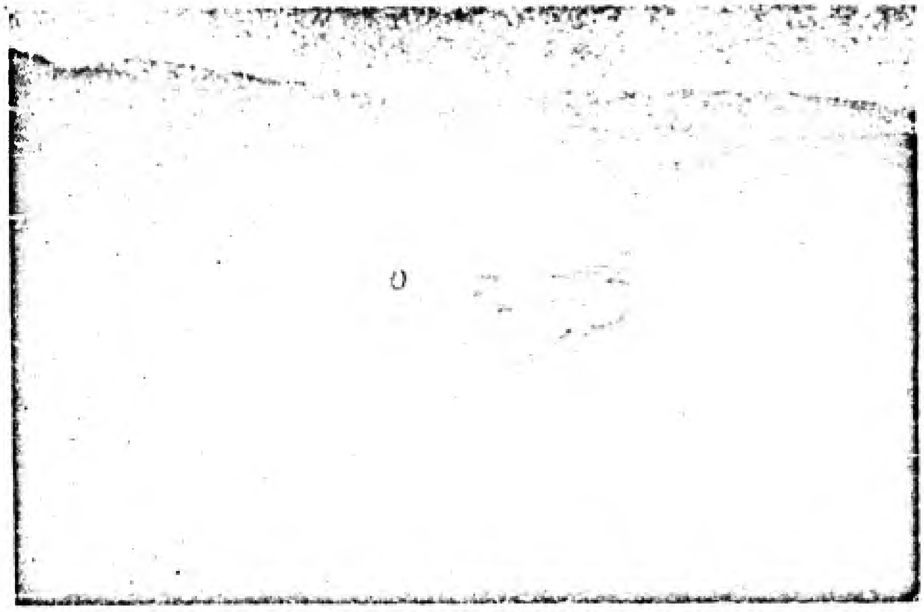


Fig. 4. Camp Hale (Eagle Park) from Chicago Ridge; view northward.

Fig. 5. Avalanche scars on the west face of the Tenmile Range, February 1955; a glacially steepened scarp which faces the snow-bearing winds in winter.

(1) Alpine Zone*

Though the rocks of the Homestake upland and the eastern part of the reservation are unequally resistant to weathering and erosion, the crestlines of the two areas have similar topographic characteristics because snow drifts off their windward (western) faces and accumulates to leeward. The windward slopes, unable to accumulate much snow, have no glacial cirques and have developed rather smooth slopes similar to those common on the east flank of the Sawatch and Tenmile Ranges. The north and northeast faces of the ridges, lying to leeward, do have cirques. The relative position of glaciated and non-glaciated areas on these ridges is thus the reverse of that on the east and west flanks of the Sawatch and Tenmile Ranges (Fig. 5). Because Ice Age glaciation was weaker on the lower ridges near Camp Hale than on the summits of the high ranges, the cirques are only 500 to 1,500 feet deep compared to depths of 2,000 to 3,000 feet in the high ranges. Except along the main crest of the northern Sawatch, none of the cirques near Camp Hale have especially steep headwalls. However, the headwall cliffs of the Homestake upland do have considerable outcrop (Fig. 6). In the sedimentary terrain east of the installation, except for the north face of Jacque Peak, cirque headwalls are almost completely rubble-mantled and are only slightly steeper than the windward faces of the ridges in which they have been carved (Fig. 7). The north face of Jacque Peak is a long rubble slope interrupted by a few rather low outcrops.

Rubble soils and rubble masses at high levels in the Colorado Rockies are subject to creep which, though imperceptible, has a definite effect on their form, distribution, and surface stability. Creep may stabilize an alpine rubble slope, as it seems to do commonly in areas of resistant rock such as the Homestake upland, or it may bring excessive material down from above and thus overload certain slopes. The headwalls of cirques in the eastern part of the reservation thus have some areas of unstable surface where troops will have to be careful not to start rocks rolling.

* In this report reference is made to certain altitudinal zones commonly recognized as existing in the Colorado Rockies. The zones differ topographically and climatically as well as in vegetation, but vegetation is used to define them because it gives the sharpest boundaries. Two of the zones, the alpine and subalpine, occur both at Camp Hale and on Pikes Peak. A third, the montane zone, is found on the lower flanks of the Pikes Peak upland. The alpine zone is the region above timberline. The subalpine zone extends from timberline down to the lower limit of spruce-fir forest, usually at 8,000 to 9,000 feet.

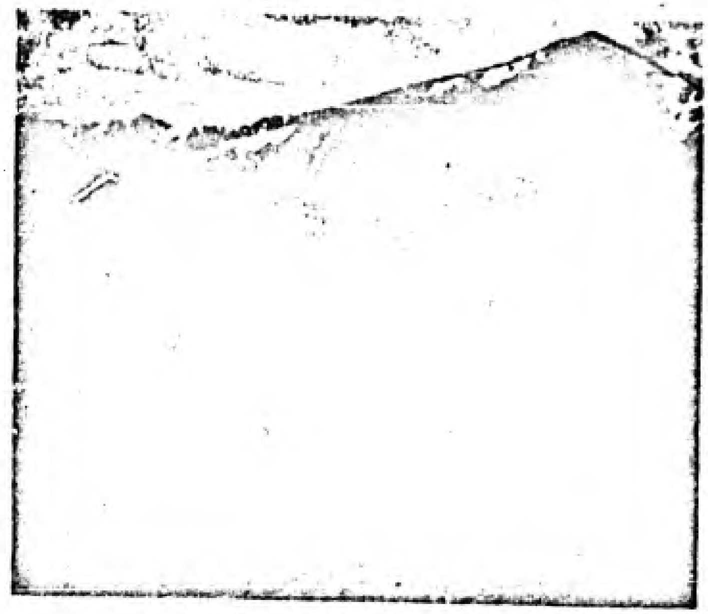


Fig. 6. Homestake Peak (13,211 feet) and Slide Lake (11,725 feet). The lake lies in a cirque developed in resistant rock a few miles southwest of Camp Hale.

Fig. 7. The Eagle River cirque on Chicago Ridge, near Tennessee Pass. The shadowed slope is a rubble-covered portion of the headwall, typical of cirque headwalls cut into sedimentary rocks in the Camp Hale reservation.

Avalanches are a serious problem only locally and occasionally in the alpine zone of the Camp Hale reservation. As has already been noted, headwalls and upper basin floors on the east and northeast side of ridge crests in the Homestake upland and in the eastern part of the reservation accumulate a great deal of snow blown over from the adjacent windward slopes. Release of unstable masses of such snow during winter or early spring is the only serious source of avalanche danger in the reservation. Such hazard is far less persistent and widespread here than in nearby higher ranges. Where it exists, however, it cannot be reduced much by ordinary care except by avoiding the slopes in question, and it thus forms definite barriers to travel.

There are only a few other serious barriers to foot movement in the alpine zone. The mountainous character of the terrain affects troop movements mostly by (a) channeling them along convenient grades unless dispersal is deliberately sought; (b) reducing the efficiency and carrying capacity of mechanized transport and drastically reducing the number of points which it can reach; and (c) increasing the time and energy required, especially for movement uphill.

(2) High summits

The Camp Hale reservation is almost enclosed by the Gore, (Fig. 8,9) Tenmile, and northern Sawatch Ranges (Fig. 4). Although outside the reservation proper, these ranges are frequently used by the M&CWTC and are, therefore, briefly considered in this report. These high and rugged mountains are composed of durable granitic and metamorphic rocks which are covered locally on the range flanks by less resistant rocks. The Sawatch and Tenmile Ranges rise to the southwest and east of the reservation, respectively, and trend north and south, transverse to the moisture-bearing westerly winds. In passing over these ranges in winter the westerlies drop a great deal of snow, mostly on their windward flanks. The height, width, and complexity of the topography of the high ranges is such that relatively little of this snow drifts from their windward to their leeward flanks. The western flanks of the high ranges were thus more heavily glaciated and are more rugged than their eastern flanks, a situation contrasting with that on the summits within the Camp Hale reservation described above. Glaciers originating in the central Sawatch Range, west of its highest peaks, extended tongues down several valleys that cross the crestline of the range eastward and drain into the upper Arkansas Valley. The inner Sawatch is thus pitted with steep-walled cirques, and the gorges connecting them with the Arkansas Valley have been enlarged and deepened into low-gradient troughs.

Where the high peaks on the east flank of the Sawatch face the Arkansas Valley, their slopes are rather smooth and regular, though they rise 5,000 feet in a relatively short distance. These slopes

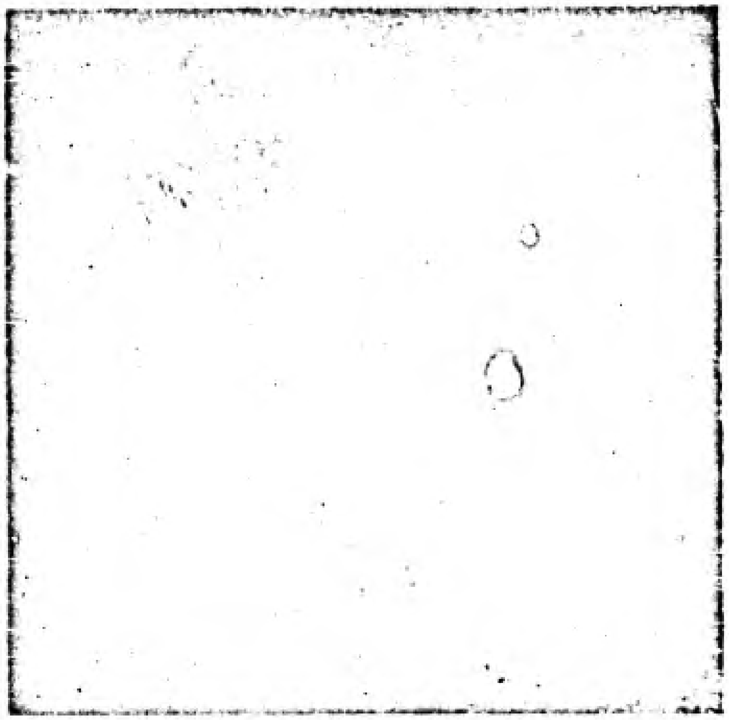


Fig. 8. The Gore Range in winter. An aerial view from over the Booth Creek-Piney Creek divide. The summits shown are more than 13,000 feet high.

are covered with rocky soil and, near their crests, with gradually creeping masses of angular rubble. Over large areas this soil and rubble mantle is interrupted only by small, scattered outcrops and troops can move about freely. Road construction is not difficult, and it is possible for jeeps and oversnow vehicles to move cross country in the less steep areas above timberline.

Similar slopes occur on the eastern side of the Tenmile Range (Fig. 10). The highest peaks of the Tenmile Range are situated along the crest of its western scarp. The deep Tenmile Valley, a glacial trough, parallels the western side of the range very closely and the scarp is steepest near the north end of the range where the valley is deepest. Because it faces the westerly winds, this scarp was heavily glaciated during the Ice Ages, being carved into a series of deep cirques which open directly into the Tenmile glacial trough. There are also many cirques east of the range crest but they are shallower and drain eastward through steep and relatively shallow glacial troughs.

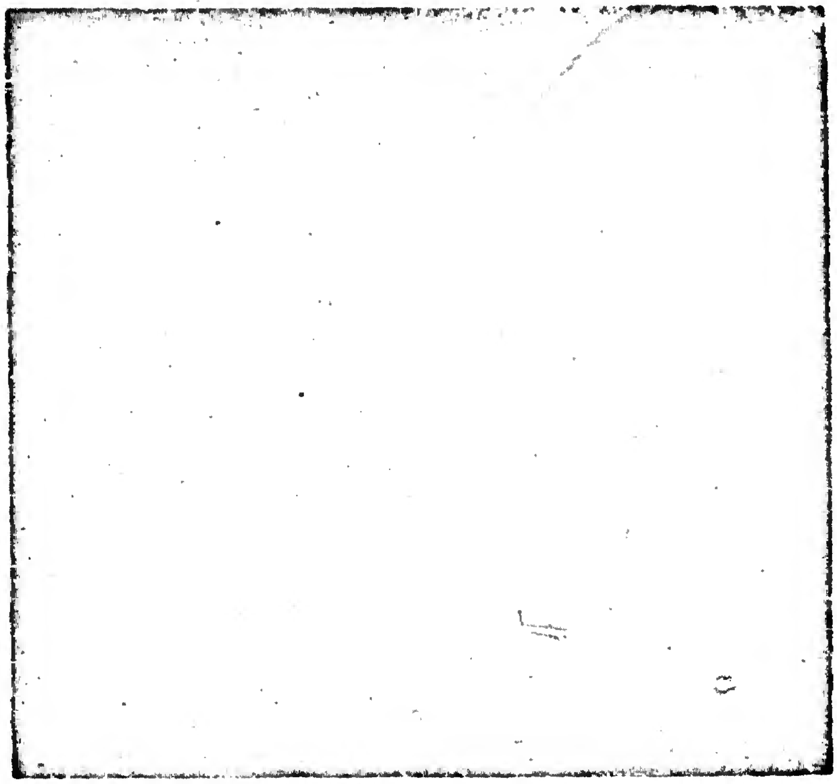


Fig. 9. The Gore Range in summer. Spruce-fir forest at about 11,500 feet in the Bighorn Valley. Subalpine meadow appears in the foreground.

The Gore Range, which lies just north of the reservation, is an area of especially difficult movement, even on foot, because strong glaciation has steepened both of its flanks. The axis of the Gore Range runs northwest-southeast, more nearly in line with the winter westerlies than the Tenmile and Sawatch Ranges. Its shaded northeastern flank shows at least as heavy glaciation as the southwestern flank, and deep, cliff-walled cirques on both sides of the divide sharpen most of its crest to knife edges of almost sheer rock.

The Sawatch Range has a number of passes. Independence Pass (12,100 feet) is most used because it is crossed by Route 82. However, it is open only in summer. The Sawatch passes lie in the zone of heavy snow west of the high peaks of the range, and are approached through the low-gradient glacial gorges described above. The Tenmile Range has no vehicular passes but is crossed by a number of trails that might be suitable for pack animals. East of Leadville a jeep trail

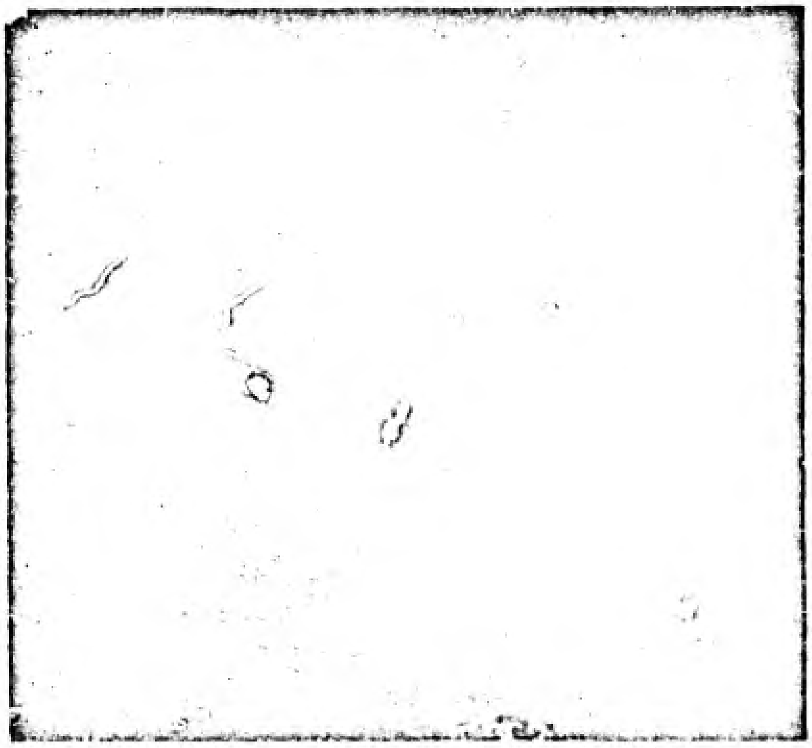


Fig. 10. An east-facing slope in the Tenmile Range near Camp Hale. Note the even slope uniformly covered with rubble, into which mine-access roads have been bulldozed.

crosses the 13,000-foot Mosquito Pass in the Mosquito Range, a southward extension of the Tenmile Range. The Gore Range, on the other hand, lacks good passes even for pack animals over most of its extent.

(3) <u>Subalpine Mountainsides</u>

In the Camp Hale area, as in other parts of the Colorado Rockies, the trend toward reduced steepness of slopes which is noted in descending from high-alpine to low-alpine levels continues generally down into the upper subalpine zone. Mountainside gradients are distinctly more variable in the western (Sawatch Range) half of the Camp Hale reservation than in the eastern half. The resistant rocks of the western part often stand more steeply on the headwalls of cirques and the flanks of glaciated valleys than the weak rocks of the eastern part. Conversely, extensive gently sloping uplands have been formed in the western area by erosion of weak rocks overlying the more durable metamorphic rocks. Such broad, gentle

uplands are much less usual on the eastern side. Steep slopes, of approximately 60 percent gradient, are formed on either side of Eagle Park wherever gneiss is capped by a bed of hard quartzite. To the east, however, this steep ground, partly cliffed, occurs only along part of the valley wall, and rises above Camp Hale only 500 feet at most. The rest of the eastern side of the valley sweeps up either from the quartzite rim or from the floor to the mountain crest 2,000 feet above, at a gradient which is only moderately steep (approximately 30 percent) and is formed on sedimentary rocks (Fig. 1).

East of the installation, 60-percent slopes formed on gneiss rise 500 to 1,000 feet to a steep, rimrock cliff of quartzite. Slopes are gentle above the crest of the rimrock, and the upland surfaces rise only gradually from that point to the Homestake summit area.

(4) Stream courses and valley floors

Although there are some perennial mountainside torrents in the Camp Hale area, they are much less common there than in more humid mountain regions such as the Alps and the Cascades. Even intermittent torrent courses are scarce in the Camp Hale area; broad slopes are often without distinguishable drainage lines. Such perennial streams as do exist are normally the main streams of well-defined valleys.

Perennial streams in this region are generally flanked by bog, either as a narrow ribbon 10 to 100 yards wide in unglaciated valleys or as a broad irregular zone in glaciated troughs.

In the lower alpine and upper subalpine zones the principal drainage lines descending to the main axis of a valley are often boggy. Only along short, steep reaches of the perennial streams are their banks likely to be free of bog. Crossing the bogs can sometimes be more difficult than crossing the stream itself. Even in winter many of the streamside bogs are obstacles. Snow accumulates on them unevenly, piling high on well-drained bars, frost knolls, willow clumps, beaver dams and lodges, but leaving deep pits where snow has been thawed by running water. Oversnow vehicles and even skiers often find such areas hard to traverse unless a trail is built. The boggy areas which formerly existed in Eagle Park had to be filled to render that area usable.

In addition to such bogs, the broad floors of the Eagle Park, Homestake, and Tenmile glacial troughs have wide areas of alluvial fan and stream terrace along their flanks. Such well-drained, gently sloping surfaces are absent from unglaciated valleys such as that of Resolution Creek, tributary to the Eagle River from the east. In that kind of narrow unglaciated valley, bogs generally extend to the foot of the slope on each side.

Alluvial fans and terraces in the broader valleys are convenient sites for main routes and buildings. Private resorts, homesteads, and other civilian property occupy much of the floor of the Homestake and Tenmile valleys, and military use of such terrain is thus largely limited to Eagle Park.

b. <u>Surface types</u>

The distribution of surface types in the Camp Hale area is shown in Fig. 11. The principal types present are cliffs, rubble masses (including rock glaciers, felsenmeers, talus, and rock streams),* normal rubble soils, terraced alpine soil, well-drained alluvial surfaces, and bogs. Such glacial moraines as are present in this area have been greatly modified by frost action and no longer exist as a distinctive surface type.

(1) <u>Cliffs</u>

As a rule the rocks of the eastern part of the Camp Hale reservation do not form high cliffs. The most extensively cliffed slopes in that area are the north face of Jacque Peak and the flanks of the Eagle Valley near the head of Eagle Park. On cirque head-walls of the Homestake upland, cliffs are high though not very steep, comprising a considerable part of the eastern flank of the upland.

(2) <u>Rubble Masses</u>

Rubble masses are deep accumulations of rock rubble, usually without soil between the fragments, at least near the surface. In the alpine and subalpine zones in the Colorado Rockies they frequently assume forms which indicate that they creep more rapidly than the adjacent soil. Such forms are known as rock glaciers, felsenmeers, rock streams, or creeping talus. The rubble often forms tongue-like masses of various dimensions, which over-ride soil lying down-slope. The motion of the rubble is very slow, a few inches per year at most. In many places the motion may have ceased in recent decades, though its effect on the landscape seems fresh. Rockfalls are especially frequent where creeping rubble masses occupy slopes above the crests of cliffs, and individual boulders on rubble slopes are often unstable because of creep.

Many such rubble masses above timberline are considered by Retzer (1950) to contain permafrost (perennial ground frost). The mechanism of accumulation and conservation of the ice is not completely known. Extensive ice was observed within talus at Camp Hale during July 1955, in a north-facing slope near the north end of

* These and other technical terms are defined in the glossary (appendix D).

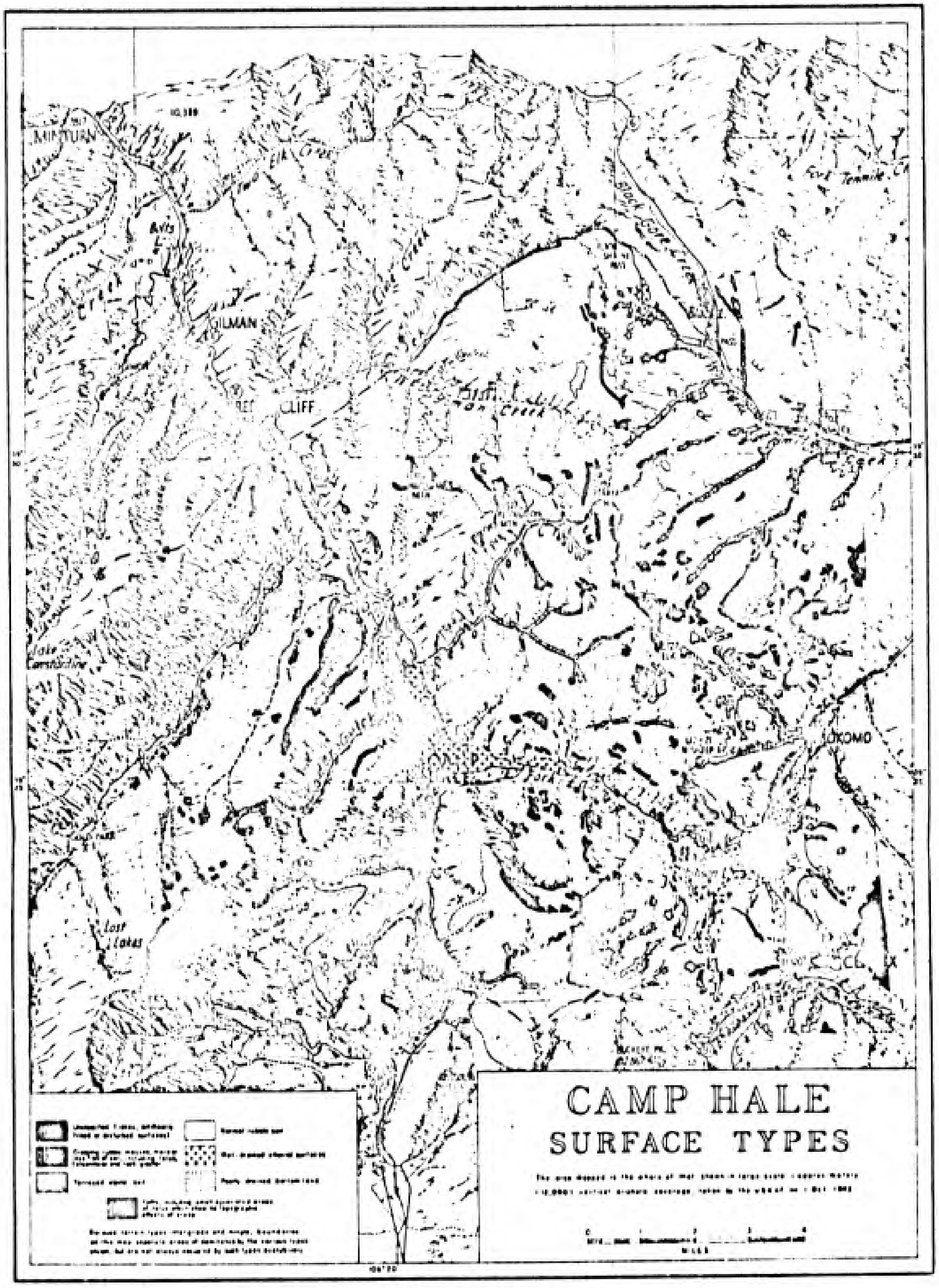


Figure 11

REPRODUCED AT GOVERNMENT EXPENSE

Eagle Park. It was at an altitude of 9,250 feet, which is 2,500 feet below timberline and far below any known occurrence of permanent ice in finely divided soil in Colorado. The ice was uncovered during excavation of quartzite talus to feed a rock crusher, and lay approximately 5 feet below the original surface of the slope.

Rubble masses in the Camp Hale area fall into several classes. Rock glaciers are large rubble masses ranging in thickness from 10 to 100 or more feet. They are glacier-like in form and location, occurring most frequently in north-facing cirques and in other shadowed places at the base of glacially steepened alpine and upper subalpine slopes. Their upper surfaces are often thrown into a series of curved or chevron-shaped transverse waves of rubble, the ends of which are retarded by friction along the flanks of the mass.

Felsenmeers are broadly convex rubble surfaces on or near ridge crests (Fig. 21). They are produced by deep riving of bedrock. Deep felsenmeers sometimes show ridge patterns similar to those found on rock glaciers, though less well developed (Fig. 12). The motion of felsenmeers is likely to be divergent, however, whereas rock glaciers converge to form tongues and often follow definite channels. Most high ridge crests in the Camp Hale reservation are covered by felsenmeer. The lower margins of the felsenmeers extend down the slopes of the ridges in many places to timberline and beyond, especially on west- and southwest-facing slopes. They often assume the tongue-like form characteristic of rock glaciers before reaching such low levels.

Talus is rubble which has fallen down cliffs and accumulated at their base. Large talus masses in the Colorado Rockies consistently show evidence of slow creep by their form and extent (Fig. 13). Rock streams are ribbons of rubble extending down subalpine slopes or following the beds of steep subalpine valleys (Fig. 14). They are gross forms of the small rock stripes often noted on arctic and alpine slopes (Fig. 15). The surfaces of the rock streams of the Colorado Rockies are usually flush with the surface of the adjacent soil, the rocks occupying the space which would otherwise contain a brook and its boggy margins. The brook, which filters among the boulders of the rock stream, presumably thaws any ice present beneath it in summer but promptly freezes up again in the fall, giving the rock stream a mobility similar to that associated with permafrost in other types of rubble mass.

(3) Normal rubble soil

Soil developed on mountainsides in the Camp Hale area generally contains enough rubble to hold it in place during spring thaws. In spring, freezing and thawing while the rubble soil is saturated with melt water often render its fine-earth component

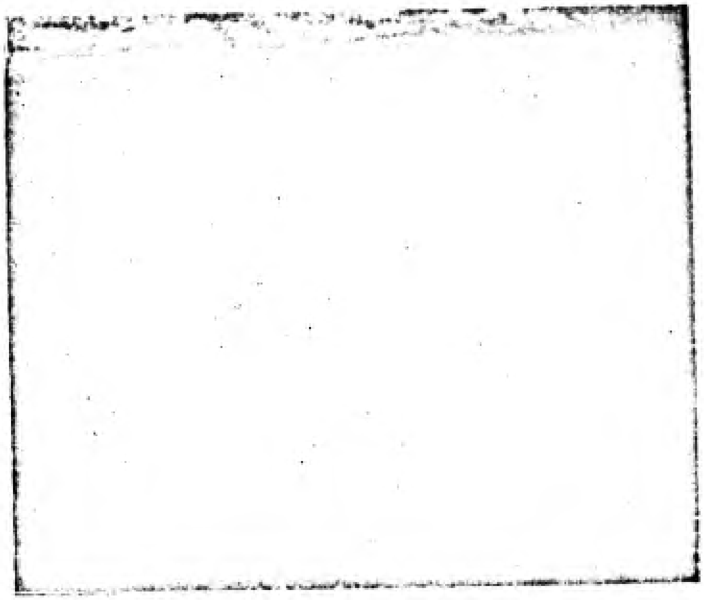


Fig. 12. Alpine topography between Elk Mountain and Jacque Ridge. The light area in the middle left is an incipient rock glacier developed from felsenmeer.

Fig. 13. Talus slopes in the Maroon Valley, Elk Mountains, near Camp Hale. Slope in foreground illustrates formation of lobate tongues by creeping talus masses containing ice.

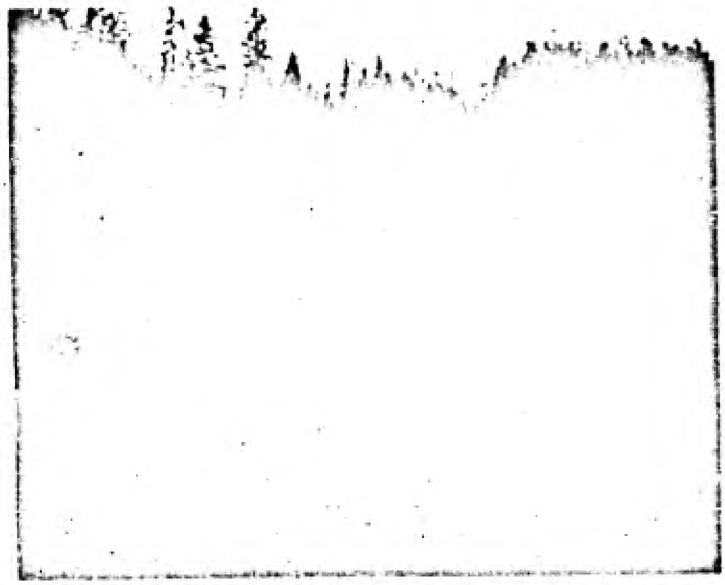


Fig. 14. A well developed rock stream in the subalpine zone of the San Juan Range, Colorado. There is one near Camp Hale in a gulch a mile southwest of Pando railroad station.

semifluid. At other seasons it is an entirely stable, though somewhat stony, surface. In the alpine zone it often contains permafrost, though not enough to render it impermeable over considerable areas or to prevent its drying out in summer.

Ground showing stripes or polygons of rubble (usually rather irregular), which enclose areas of fine soil, is particularly soft until dust during spring and early summer and is converted into deep mud or mud flows if subjected to heavy foot traffic.

Such areas are generally down slope from late-lying snowdrifts such as those just leeward of the high ridges in the eastern part of the Camp Hale reservation.

(4) <u>Terraced alpine soil</u>

Certain areas in basins near timberline close to the high ridges of the Camp Hale reservation have coarse alluvial soil forming moderately steep slopes which support stands of low willows. Such

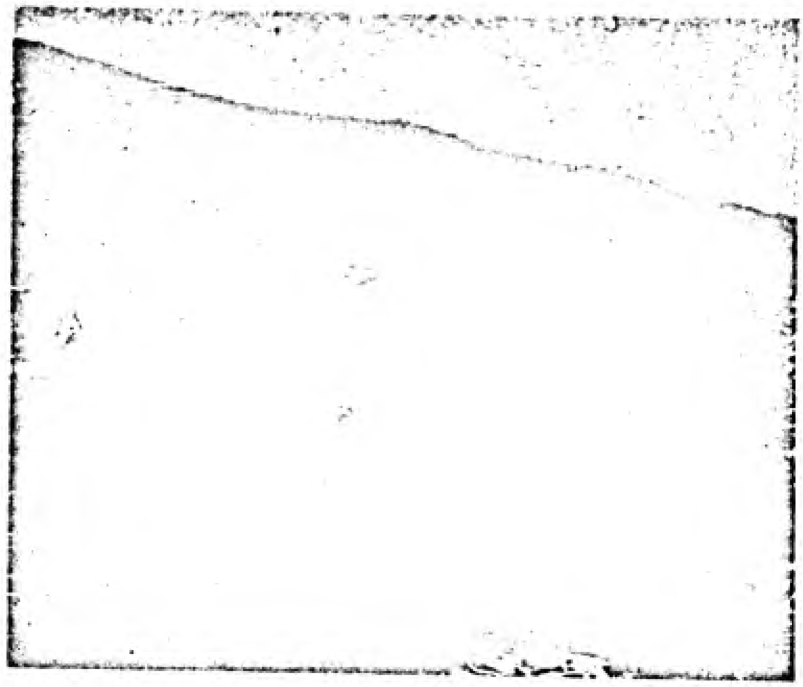


Fig. 15. Rock stripes in sedge turf at 12,000 feet elevation on Elk Mountain, 5 miles east of Camp Hale.

slopes have a close pattern of coarse transverse wrinkles or terraces in the soil. They support willows because they are continually supplied with water either by normal drainage from the slopes above or, when that ceases, by the melting of underlying permafrost. Permafrost is also believed responsible for the creeping motion which throws the soil into folds. Such ground is soft underfoot in spring but dries out to a considerable depth below the surface in summer. Where the slope is not too steep, jeeps easily travel over such areas because the surface lacks coarse boulders. The basin enclosed by Jacque Ridge has a higher proportion of such ground than any other basin in the Camp Hale reservation.

(5) Well-drained alluvial surfaces

Alluvial fans and terraces, which include the greater part of the floors of the larger valleys in the Camp Hale area, are generally composed of boulders or gravel, often covered with fine silt. They are more easily traversed by vehicles than any other unprepared surface in the region and are particularly well suited to economical

construction of roads and buildings.

(6) Poorly-drained bottom land

In high, steep valleys, bogs have been formed among coarse stream-laid boulders which give them stability. Erosion of bogs is further prevented in many subalpine valleys by numerous beaver dams. Frost hummocks, willow clumps, and many new or abandoned beaver dams and lodges render the surface of the bogs rough and unevenly drained.

c. Vegetation

The whole of the Camp Hale reservation and most of the adjoining region falls within the alpine and subalpine altitudinal zones, each of which is marked by a characteristic vegetation. A third zone, the montane, lies just below the subalpine forest. It almost reaches the lowest part of the reservation near Redcliff but its extent there is so limited that it will be described in the section on the vegetation of the Pikes Peak area rather than here.

Timberline, the boundary between the subalpine and alpine vegetation zones, is considered here to be the uppermost limit of conifers. Scrub conifers (krummholz) occur up to about 11,750 feet at a number of places within and near the reservation (Fig. 6), but are seldom found above that altitude.

The distribution of vegetation types in the Camp Hale area is shown on Figure 16.

(1) Sagebrush

Usually associated with lower, drier, and warmer areas and considered a form of semiarid scrub, sagebrush maintains its normal habit of growth up to an elevation of 10,000 feet in the Camp Hale area. At that level it occurs only on the steeper south-facing soil-covered mountainsides. Such slopes thaw even when air temperatures are well below freezing and are usually nearly free of snow within a few days after any ordinary snowstorm. When they are bare of snow they are easy to traverse on foot. When such slopes are snow-covered, however, skiing is difficult because of the large number of

low bushes of sage scattered evenly over them. Most are too steep for vehicles.

(2) Aspen forest

In the Camp Hale area only sagebrush slopes are sunnier than those occupied by aspen forest. Aspen so consistently occupies slopes intermediate between those supporting sagebrush and coniferous forest that one usually must pass through them in moving from one to the other. Aspen is a deciduous tree with pale green bark and small, vibrant green and silver leaves. In dense stands aspens are tall and straight. Their slim trunks are generally rather uniform in size in any one stand and usually are rather small but occasionally reach 8 to 12 inches in diameter. Aspen forests accumulate much more snow and retain it longer than sagebrush slopes.

Stands of aspen which are dense or which have considerable down timber are serious barriers to skiers and may even impede foot travel considerably.. Stands near streams are often opened up or even cleared off completely by beavers. Aspens have been cut to a considerable extent by engineers and other troops training at Camp Hale, for use in field construction.

(3) Willow stands on bogs and ice-laden soil

Scrub willow thickets occur on consistently moist sites from timberline down through the subalpine zone in the Camp Hale area. At timberline the willows form low mats, while farther down in the subalpine zone willows 6 or 8 feet high grow in boggy ground along stream margins.

(4) Coniferous forest

There are two types of subalpine coniferous forest in the Camp Hale area. By far the more extensive type is spruce-fir forest, the usual subalpine forest of the Colorado Rockies. Near Camp Hale it consists mostly of Engelmann spruce with a few subalpine firs. Both spruce and fir are tall, spire-like trees which in open stands have branches from the ground up. In dense stands the trees retain a high tapering crown but lose their lower branches. It is usually easy to move about on the forest floor, which normally has only a low undergrowth of blueberries. The only spruce stands in the area which are difficult to move through are those in which young trees occupy areas that have been opened up by avalanches or windfall (Fig. 17).

Stands of lodgepole pine, the other type of coniferous forest, occur practically to timberline in old burns and logged-off areas in the southeastern part of the Camp Hale reservation. They do not form dense stands at that elevation, however. Open-grown lodgepole pines

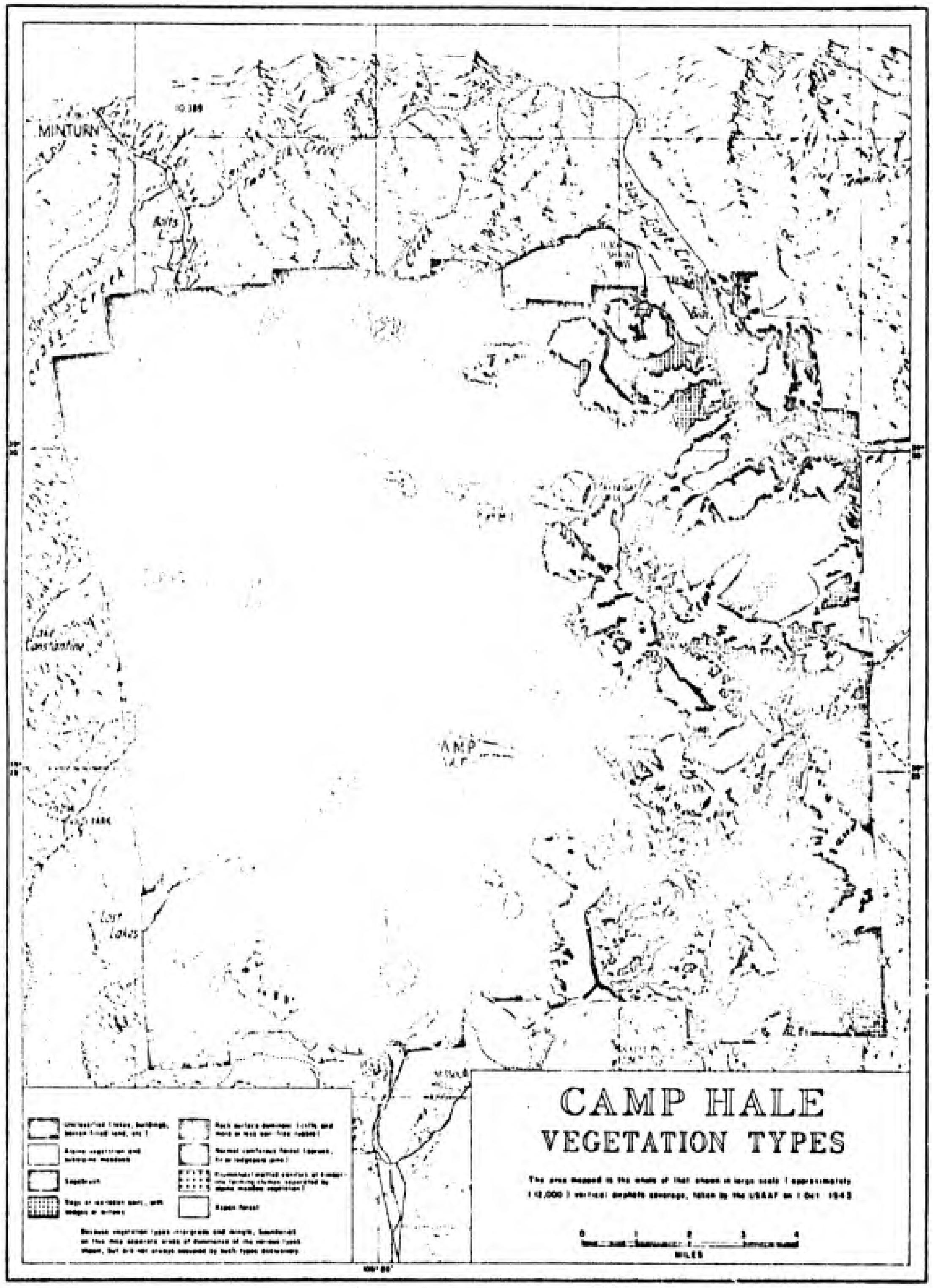


Figure 16

REPRODUCED AT GOVERNMENT EXPENSE

Fig. 17. Avalanche damage in subalpine forest (Engelmann spruce) at about 11,000 feet elevation; North Rock Creek Valley in the Gore Range. Avalanche snow remained unmelted under this debris in early August 1955.

are much shorter and broader trees than the spruces and firs. In dense stands such as those of the lower subalpine zone in the Camp Hale area, on the other hand, lodgepole becomes very tall, slim, and straight, though the crowns are broad or even flattish. Young stands of lodgepole are often so dense as to be nearly impassable.

Less snow reaches the ground in dense subalpine forests than in open forests because it is intercepted by the canopy of branches. Although dense forest retains its snow well because of its shade, open forest may have snow cover longer because of greater initial accumulation. Conifers are almost entirely absent from the sunnier slopes of the lower subalpine zone in the Camp Hale area, occupying only those relatively shady slopes where snow lies throughout the winter.

(5) Krummholz

In many places at timberline in the Camp Hale area low mats of

stunted spruce and other conifers (krummholz) are scattered along the upper margin of the forest, often marking the highest points reached by trees. The broadest areas of scattered krummholz occur on cirque floors and other heavily-glaciated uplands on resistant rock. In such places the krummholz grows on the crests of bedrock knolls. The intervening swales have alpine or bog vegetation. Krummholz is occasionally extensive enough to be a serious obstacle: its mats are much too deep and dense to walk through but not quite dense enough to walk on top of. Snow usually drifts off the krummholz mats during winter until their uppermost branches are just exposed. The intervening swales have deeper drifts of snow.

(6) Alpine vegetation and subalpine meadows

As in mountains throughout the world, vegetation above timberline near Camp Hale is low and consists mostly of sedges, grasses, herbs, more or less flat-lying heaths and willows, and lichens. At high alpine elevations, vegetation is thin, scattered, and in many places absent, but it becomes more dense and widespread at lower levels until on many slopes near timberline it can be described as meadow. In the Camp Hale area, as in most parts of the Colorado Rockies, the most widespread type of alpine meadow is a dense, tough, and well-drained sod dominated by a sedge, Kobresia (Fig. 15 and 24). Better drained slopes are generally rocky, with scant soil. Moister sites have a somewhat richer vegetation than typical Kobresia sod, though sedges generally remain dominant. Even Kobresia meadow is seldom uniform over any considerable area because of the many local differences in altitude, exposure, slope, snow cover, and particularly soil texture and drainage which occur on alpine slopes. Alpine meadow in general and Kobresia sod in particular provide excellent footing on moderate slopes. Troops wearing the boot, ski-mountain, with rubber cleated sole and heel, have no difficulty even on steep meadow slopes, but when the turf is wet such slopes are difficult for smooth-shod troops.

There are also considerable areas of meadow below timberline. Avalanches, wind, excessive depths of drifted snow, poor drainage, logging, fire, and overgrazing hold the forest back from its maximum altitude on many slopes near Camp Hale. As one moves down from alpine to subalpine meadows, bare rock becomes less conspicuous and grass begins to crowd out the sedges. Except where the trunks of burnt forests still litter them, the subalpine meadows are easier to walk across than alpine meadows, both because they are less rocky and because they are generally less steep than the alpine meadows.

Subalpine meadows are particularly extensive in the eastern and southeastern parts of the Camp Hale reservation where much of the forest was destroyed by fires and logging during the Leadville mining boom around the turn of the century. Many burns in that part of the reservation are near timberline. At that level, lodgepole pine does

not seed in after dense meadow sod becomes established: if a good lodgepole seed year does not occur shortly after a fire, regeneration awaits the slow spread of spruce forest. Burns of the same age near the mines at Gilman and Redcliff, on the northwest edge of the reservation, are at a much lower elevation and have been completely overgrown by lodgepole pine.

d. Climate

(1) General

The Camp Hale training area has lower temperatures and greater precipitation than adjacent lowlands. In comparison with climates of many mountain ranges in similar latitudes, however, the Camp Hale area is dry and warm, particularly in summer. Summers are pleasant, with most of the rain occurring in brief thundershowers. Winters are cold and snowy but are tempered by low humidity and strong radiation. At all seasons sunburn protection may be necessary.

The expected decrease in temperature with increasing elevation is evident from an examination of weather records of 71 stations in the Colorado Rockies. In summer the average decrease in temperature with increasing height is 3.7 F degrees per 1,000 feet, and in winter the comparable but less consistent figure is 2.6 F degrees. Locally this relationship is often reversed at night when cold air, being heavier, settles in the valleys. The valleys near Camp Hale are thus often colder than any higher part of the nearby area except perhaps the highest ridges. When such conditions exist, winds are usually light in the valleys, and an individual on the windier uplands may feel colder even though the temperature is higher.

Topography has important effects on the amount and areal distribution of precipitation in any mountain area. In the Camp Hale area most winter precipitation comes from the west, with the result that range flanks facing the westerlies receive the heaviest precipitation. The winds associated with summer rains often come from the Gulf of Mexico; consequently such rains are heaviest on the eastern flanks of the mountains. In general, on any given range flank, precipitation increases with altitude. Winter precipitation in the form of snow tends to be greatest high on the western slopes, while summer rains are greatest at high elevations oriented towards the east or southeast.

Other aspects of climate also are affected by terrain. Cloud cover is at a maximum near the high summits and at a minimum to the lee of the high points. Windiness generally increases with elevation but is subject to other terrain effects. No wind data are available for the Camp Hale area. It is generally true in mountains, however, that the higher a ridge or summit stands above adjacent ridges, the windier it is likely to be during unsettled weather. In fair weather, on the other hand, summits are often less windy than adjacent slopes.

Climatic data from observations at four weather stations in or near Camp Hale are in Tables I to IV. The most pertinent of these data were recorded at the improvised airstrip at Camp Hale (9,250 feet) during each winter from 1952 to 1955. Weather data from Climax, just beyond the eastern margin of the Camp Hale reservation at an elevation of 11,300 feet, are also utilized in this study. The climatic records at Camp Hale and Climax cover short periods of record and have been supplemented by longer records from Dillon (8,900 feet), in a valley 20 miles northeast of the Camp Hale station, and Leadville (10,200 feet), across the continental divide 12 miles south of Camp Hale. Location of these weather stations is shown in Figure 3. Climatic data for stations in the Camp Hale area are presented graphically in Appendix A, as well as in Tables I and II.

(2) Winter climate (December, January, February, and March)

The winter temperature and snowfall record at Camp Hale is summarized in Table I.

TABLE I

WINTER TEMPERATURE AND SNOWFALL AT CAMP HALE, COLORADO

Temperature (°F)	Jan. 1952-55	Feb. 1952-55	Mar. 1952-54
Absolute maximum	45	48	49
Mean daily maximum	28	30	34
Mean	13	15	19
Mean daily minimum	0	1	5
Absolute minimum	-39	-34	-29
Snowfall (inches)			
Average snowfall	17	22	23
Average snow depth	15	14	19
Maximum snow depth*	21	22	-
Minimum snow depth*	10	5	-

*During 1954 and 1955 only

Comparing the data from stations in the vicinity of Camp Hale, it is evident that minimum temperatures at the four stations show the effect of cold air drainage into the low spots (Table II). Dillon, the lowest station, has a mean daily minimum temperature in January of -4°F; Camp Hale has a corresponding figure of 0°F; Leadville has 5°F; and Climax, the highest station, 6°F. Other winter months have minima only slightly less severe. The effect of cold air settling at Dillon and Camp Hale is particularly evident from a study of values for the lowest temperatures

recorded each month. From Figure 26 (Appendix A) it can be seen that temperatures usually go below -20°F and often below -30°F in January at Dillon; -46° has been recorded there in December. During its short period of observations Camp Hale has recorded -39°F in January, -34° in February, and -29° in March (Table I). The fact that mean and extreme minimum temperatures are higher at Leadville than at Dillon is clearly evident in Figure 29. In its short record (3 years), Climax never has experienced temperatures below -25°F.

TABLE II

MEAN AND EXTREME TEMPERATURES NEAR CAMP HALE TRAINING AREA (°F)

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Ann
Dillon, 8,900 feet, 40-year record													
Absolute max.	57	60	61	76	79	87	89	87	83	77	65	51	89
Mean daily max.	31	34	38	48	60	69	74	73	67	55	41	32	52
Mean	13	16	21	32	42	49	55	53	47	37	24	16	34
Mean daily min.	- 4	- 1	4	16	25	29	36	34	27	18	7	- 1	16
Absolute min.	-44	-45	-38	-25	- 8	11	22	20	4	-17	-30	-46	-46
Leadville, 10,200 feet, 47-year record													
Absolute max.	59	59	60	71	76	84	86	83	79	74	66	64	86
Mean daily max.	30	33	37	45	55	66	72	70	64	53	40	32	50
Mean	18	20	24	32	41	50	56	55	48	38	27	20	36
Mean daily min.	5	6	11	19	28	35	40	40	33	24	14	7	22
Absolute min.	-29	-31	-20	-14	6	14	28	25	9	- 5	-17	-27	-31
Climax, 11,300 feet, 3-year record													
Absolute max.	46	46	49	55	60	75	74	69	69	58	56	49	75
Mean daily max.	26	25	28	38	46	58	65	62	57	47	34	25	43
Mean	16	14	18	26	35	46	52	50	45	35	23	14	31
Mean daily min.	6	2	7	14	24	33	39	38	33	23	12	3	19
Absolute min.	-18	-25	-13	-11	0	13	30	30	21	3	-23	-17	-25

Maximum temperatures are lower at the higher elevations. In January the highest station, Climax, has a mean daily maximum temperature of 26°F while the lowest station, Dillon, has 31°F. In the three winters of record the temperature never rose above 50°F at Camp Hale or Climax. Temperatures above 60°F have occurred each winter at Dillon and the average monthly maximum* is between 50°F and 55°F in the winter months (Fig. 26).

*The average highest temperature of the month during the period of record.

TABLE III

MEAN AND EXTREME PRECIPITATION NEAR CAMP HALE TRAINING AREA (INCHES)

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Ann
							Dillon, 8,900 feet, 45-year record						
Max.	4.0	7.0	4.8	6.0	4.1	3.1	5.6	4.4	5.8	5.0	3.5	4.8	
Mean	1.3	1.6	2.0	2.1	1.6	1.1	2.0	1.8	1.3	1.3	1.2	1.5	18.8
Min.	0.1	0.1	0.1	0.3	0.3	0.0	0.5	0.2	T	0.1	T	0.1	
							Leadville, 10,200 feet, 57-year record						
Max.	3.7	4.8	4.8	4.9	M	4.1	8.7	6.0	4.1	3.3	2.9	4.0	
Mean	1.2	1.5	1.7	1.8	1.3	1.2	2.9	2.2	1.3	1.2	1.0	[illegible]	18.5
Min.	0.1	0.2	0.6	0.2	0.2	0.1	T	0.4	0.1	0.0	T	0.1	
							Climax, 11,300 feet, 4-to 6-year record						
Max.	5.1	3.9	4.2	6.6	2.6	1.7	4.2	4.9	3.1	2.9	3.8	7.2	
Mean	3.0	2.0	2.4	2.9	2.0	1.0	2.9	2.0	1.4	1.1	1.9	3.1	25.7
Min.	1.0	1.1	1.6	1.0	1.5	0.4	1.4	0.9	0.6	0.3	0.7	1.1	

T=trace
M=missing

TABLE IV

MEAN AND EXTREME SNOWFALL NEAR CAMP HALE TRAINING AREA (INCHES)

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Ann
							Dillon, 8,900 feet, 15- to 22-year record						
Max.	43	42	59	46	14	14	0	0	7	20	38	67	
Mean	24	24	29	24	8	1	0	0	1	6	16	19	152
Min.	7	10	19	5	T	0	0	0	0	T	2	6	
							Leadville, 10,200 feet, 10-to 18-year record						
Max.	27	32	32	34	13	10	T	T	10	17	34	30	
Mean	18	20	20	19	6	2	T	T	2	9	14	15	125
Min.	11	2	6	4	T	0	0	0	0	0	2	6	
							Climax, 11,300 feet, 5-year record						
Max.	60	57	49	81	34	9	.5	1.0	6	22	46	104	
Mean	40	32	35	36	16	7	.1	.2	3	9	31	57	266
Min.	17	18	26	15	10	5	0	0	T	1	15	23	

T=trace

Practically all of the winter precipitation in the Camp Hale area is in the form of snow (Tables III and IV). In the 4 years of climatic observations at Camp Hale the average amounts of snowfall for January, February, and March were 17, 22, and 23 inches respectively (Table I). This volume of snow was reduced, mostly by compaction and sublimation, to average depths on the ground of 15, 14, and 19 inches in those months. Climax, 2,000 feet higher, averaged more than 30 inches of snowfall in each month from November through April in a 5-year record (Fig. 32 and Table IV). The average depth of snow on the ground in a 3-year record was 2 feet in December, 3 feet in January and February, and 4 feet in March. Depth of snow on the ground usually but not necessarily increases with altitude.

In February 1955, when Climax had no more than its normal 3 feet, Shrine Pass (Fig. 18) at the northern end of the Camp Hale reservation, 500 feet lower than Climax, had approximately 5 feet of soft snow, enough to render movement by mule or oversnow vehicle difficult. This difference in snow cover is probably the result of heavier snowfall where the Gore Range and Ten Mile Range intercept the prevailing westerlies. Another contributing factor is the drifting of snow off the broad ridges just southwest of Shrine Pass.

Fig. 18. The Shrine Pass bivouac at about 11,000 feet elevation, February 1955, showing the deep winter snow and gentle terrain of the subalpine area 9 miles northeast of Camp Hale. The massive snow cornice on the divide in the background is the principal barrier to movement on skis.

Precipitation in excess of 0.01 inch (i.e., a definite layer of snow) falls at Dillon 8 or 9 days in each winter month, on the average. Leadville gets such falls an average of 10 or 11 days per month in December and January, and 12 days per month in February and March.

The frequency of cloudy days increases during the winter season. In December Dillon has an average of 10 cloudy days and in March, 14. Leadville has an average of 8 cloudy days in December increasing to 12 in March. As would be expected, the number of clear days decreases over the same period; Dillon reports only 6 clear days in an average March. Cloudiness varies greatly from year to year. Dillon has had as few as 31 and as many as 67 cloudy days in the 4-month winter period.

(3) Spring Climate (April, May, and June)

During this period of rising temperatures both the highest and lowest readings at the four stations near Camp Hale are observed at Dillon. Morning temperatures at Dillon are usually below freezing as late as May and frost is common as late as June. Few afternoons in April and no afternoons in June have freezing temperatures. On an average June day, Dillon has a temperature range of 40 F degrees. In June, temperatures as high as 87°F and as low as 11°F have been recorded. Climax and Leadville have considerably less variation in temperature.

In April, rain or snow may occur at any level in the Camp Hale area, although most of the precipitation at Climax is snow. The heaviest total April snowfall at Climax in a period of 5 years was 81 inches; the average for that month was 36 inches. Dillon and Leadville, with longer records, have had 46 and 34 inches respectively of snowfall in April. Their average falls in that month were 24 and 19 inches. The greatest depth on the ground in April ranges from about 5 feet at Climax to 2 feet at Leadville. Even in June, Climax may have 2 feet of snow cover. Snow cover is uncertain at Leadville and Dillon in May and unusual in June.

During the spring period the number of days a month on which measurable precipitation is recorded gradually decreases. At Leadville there is an average of 13 days in April, 11 days in May, and 8 days in June with precipitation. In extreme years at Leadville as many as 20 days in April and as few as 2 days in June have precipitation. Dillon averages fewer days with precipitation than Leadville, with 11 in April and 6 in June.

March, April, and May are the cloudiest months in the Camp Hale area. Dillon averages 4 clear days and 13 cloudy days in April with as many as 20 cloudy days in some years. Cloudiness is reduced in June, with an average of 7 cloudy days per month at Dillon, but in some years as many as 11 cloudy days.

Thunderstorms are a regular feature of the spring climate of Camp Hale. No data are available on their frequency but they are less frequent than on the east slope of the Colorado Rockies.

(4) Summer Climate (July and August)

Frost occasionally occurs during summer nights in the Camp Hale area, most frequently at the lower levels. The mean daily minimum temperature in August at Dillon, a relatively low station, is 34°F (Table II), while at Climax, 2,400 feet higher, the mean daily minimum is 38°F. The highest afternoon temperatures in the area also occur at low elevations. In August, Dillon has a mean daily maximum of 73°F and temperatures above 80°F occur in some years. Leadville, 1,300 feet higher, has an August mean maximum of 70°F and temperatures above 80°F have occurred. At Climax, the August mean maximum temperature is 62°F and the absolute maximum is only 69°F. A higher absolute maximum would be expected in a record longer than 3 years.

Leadville, just east of the continental divide, has a well-marked summer maximum of precipitation, similar to but less strong than the summer maxima characteristic of most stations on the east slope of the Colorado Rockies. Mean rainfall in July at Leadville is 2.9 inches and in August, 2.2 inches (Table III). The maximum monthly precipitation recorded in July, the greatest of any month at Leadville, is 8.7 inches. At the other extreme, Leadville was almost rainless during one July. Dillon, though west of the divide, also has a summer maximum of precipitation. Its July average is 2.0 inches and its maximum for that month is 5.6 inches. Snow has never occurred at Dillon in July or August during its 22 years of record, and only a trace has been reported for July at Leadville in a 19-year record (Table IV). Climax, being higher, has had one July and one August snowfall in a 5-year period. Summer snowfall is more common at elevations above that of Climax (11,300 feet).

Leadville had an average of 13 days a month with precipitation in July and August during a 13-year period of record. During this relatively short period there were as many as 21 days and as few as 7 days in August with measurable precipitation. During the same period Dillon averaged 8 days a month in July and August with precipitation. At Dillon there were as many as 17 days and as few as 1 day in August with measurable precipitation.

Because summer precipitation is mainly in the form of showers, including many thundershowers, periods of rain in summer are usually not long. Partly cloudy days are much more common than entirely cloudy days. Dillon and Leadville have an average of 17 partly cloudy days per month in July and August.

(5) Fall Climate (September, October, and November)

The transition from mild summer to cold winter is under way in the Camp Hale area by late August or early September. In September freezing temperatures can be expected on most nights at Dillon (mean daily minimum 27°F) and about half the nights at Climax and Leadville (mean daily minimum 33°F). Daytime temperatures are still mild. At Leadville, after-

noon temperatures are often in the 60's during September and in the 50's during October. Dillon is slightly warmer during the day and Climax is considerably cooler. The mean daily range at Dillon is 40F degrees in September, 16F degrees greater than the range at Climax.

By November, mean monthly temperatures are below freezing throughout the Camp Hale area. Some nights are very cold with below zero temperatures; some days are quite mild with afternoon temperatures above 50°F. Temperatures as high as 65°F and as low as -30°F have occurred in November at Dillon.

Fall is drier than summer throughout the area. Leadville and Dillon both average about one inch of precipitation in each fall month (Table III). Snow occurs occasionally in September (Table IV) but only in unusual years will there be significant snow cover in that month. By October a considerable part of the precipitation for the month is snow, and snow cover is general at the higher elevations and intermittent at low levels. During October 1954, Climax had 22 inches of snowfall but not more than 5 inches of snow on the ground at any one time. Snow cover may remain scant in November, although the area is usually covered. Total falls during the month at Climax have varied from 15 to 46 inches during its short period of record (5 years). Maximum depth on the ground there during the same period was 13 inches. Leadville and Dillon have somewhat less snowfall in November.

Measurable precipitation in the form of rain or snow occurs in September on an average of 7 days at Leadville and 4 days at Dillon. By November the number of days with precipitation has increased to 10 at Leadville and 7 at Dillon. In a 13-year period of record Leadville had as many as 15 and as few as 3 days with precipitation in November.

3. <u>The Pikes Peak mountain training area</u>

As a mountain warfare training area the Pikes Peak upland has both advantages and disadvantages when compared with Camp Hale. The relief of the Pikes Peak area is 2,500 feet greater than that of the Camp Hale area. The high points of both regions are slightly above 14,000 feet but the mountainsides of the Pikes Peak region rise from approximately 6,000 feet whereas those near Camp Hale generally start from 8,500 feet or more. Below the alpine and subalpine vegetation zone (Fig. 19), which are also present at Camp Hale, the Pikes Peak region has first a montane forest zone, then a narrow belt of either scrub oak chaparral or pinion-juniper woodland, and finally the short-grass steppe vegetation of the western margin of the Great Plains.

In one important respect Pikes Peak compares unfavorably with Camp Hale: the lack of reliability of its winter snow cover. Like much of the eastern slope of the Colorado Rockies, it is usually almost bare of snow above timberline through much of the winter and may have too little snow for skiing even in the upper subalpine zone.

There is no land reserved especially for military use on the Pikes Peak upland. Much of the high country around Pikes Peak, including the part which has the most precipitation, is utilized as watershed by Colorado Springs and other towns around the base of the upland, thus limiting its availability for military training. There are also a considerable number of guest ranches and other tourist facilities along the roads through the upland, and the residential areas of the nearby towns extend well up the mountain flanks from the plains to the east. However, for military activities such as rock climbing classes and marches in which the location of troops can be closely controlled, the Pikes Peak area has been very convenient.

The road net in the vicinity of Pikes Peak is as good as that in the Camp Hale area. Roads give access to considerable areas usable for training in the montane and lower subalpine zones. The Pikes Peak toll road and cog railway climb the mountain from Cascade and Manitou, respectively, on Route 24, providing easy access to the high alpine zone. Jeep trails reach upper subalpine and low alpine points along the eastern margin of the highland from Route 336 and the Manitou area. There are many foot trails throughout the area. Off-trail foot travel is reasonably easy on much of the upland and its flanks.

Military observation flights in the Pikes Peak area have been made from the Fort Carson light aircraft field. Light plane landings are possible at many points in the 9,000- to 10,000-foot zone of the upland. Much of the upland is within the altitude limits of practical operation of helicopters, including all of the very rugged peak-and-canyon topography below 9,000 feet around the margins of the upland.

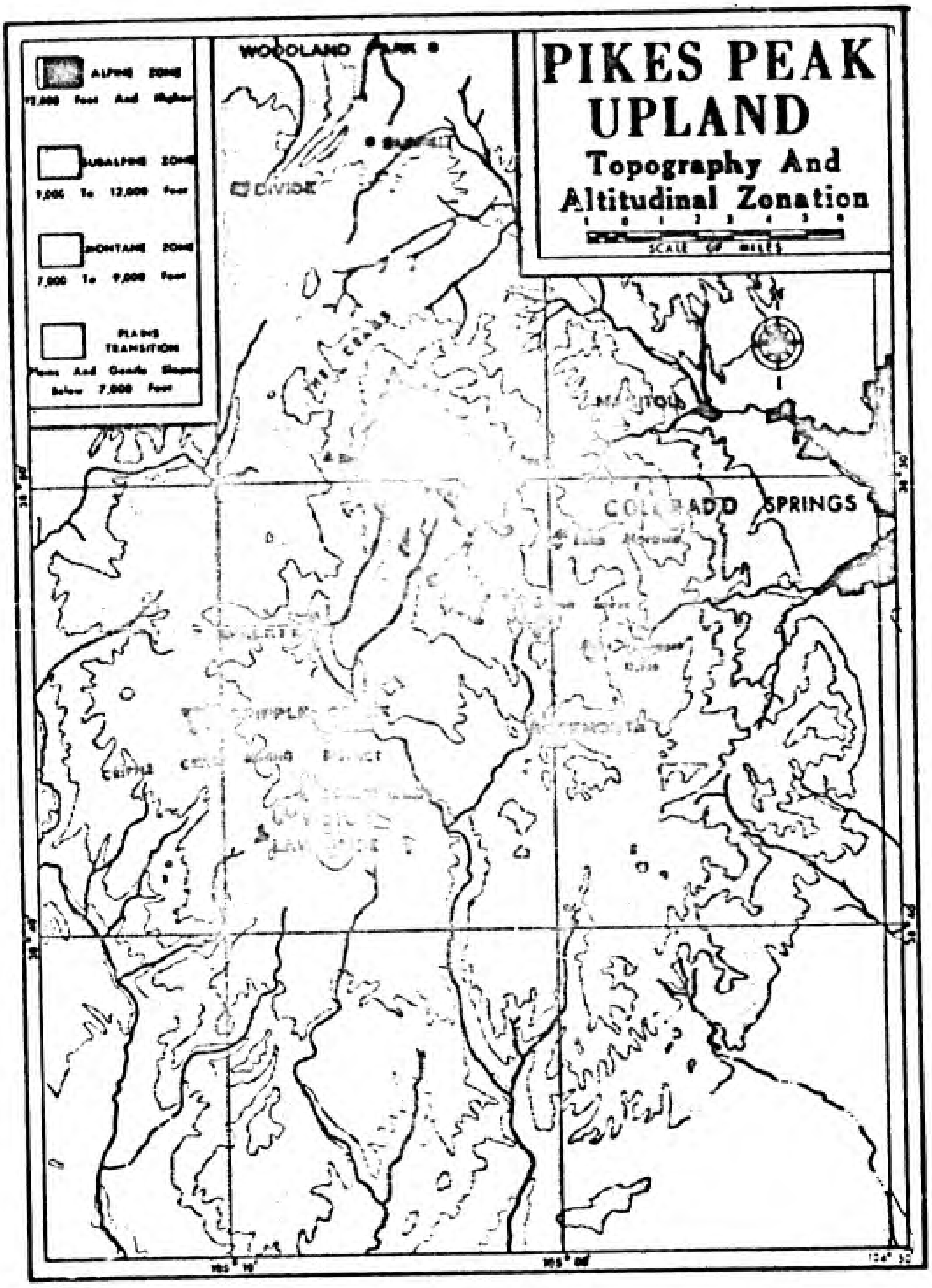

PIKES PEAK
UPLAND
Topography And
Altitudinal Zonation
SCALE OF MILES
ALPINE ZONE
12,000 Feet And Higher
SUBALPINE ZONE
9,000 To 12,000 Feet
MONTANE ZONE
7,000 To 9,000 Feet
PLAINS TRANSITION
Plains And Gentle Slopes Below 7,000 Feet
WOODLAND PARK
DIVIDE
COLORADO SPRINGS
CRIPPLE CREEK

Figure 19

a. Topography and surface types

The Pikes Peak upland is a roughly circular plateau which is about 17 miles in diameter and 9,000 to 11,000 feet high over much of its area (Fig. 19). Except to the northwest, where it falls away as a gradually descending hilly plateau surface, it is surrounded by 2,000— to 3,000-foot scarps which are carved into peaks and canyons. From the plateau surface, Pikes Peak rises to 14,107 feet in the northeastern part of the upland. Several of the spurs and outliers have summits between 12,000 and 13,000 feet high.

Except for the Cripple Creek mineralized area and a small southern peninsula of metamorphic rock, all of the Pikes Peak upland is granite. Sedimentary rocks occur only around its margins well below the plateau. As is often true in the mountains of subhumid regions, the granite here tends to decay, becoming a sandy or gravelly material (grus) which is the characteristic residual subsoil of the upland. The grus is dry and seems to be a poor source of plant nutrients. Much of it is bare of soil and vegetation, especially in the Almagre Mountain area southeast of Pikes Peak (Fig. 19).

(1) Cliffs

High, steep cliffs of ice-carved granite, suitable for rigorous tests of rock-climbing techniques and equipment, are present on the headwalls of the great glacial cirques which form the northeast face of Pikes Peak. Examples of such cirques are the Crater, the Bottomless Pit, and Glen Cove (Fig. 20). Their headwalls are 1,000-2,000 feet high and some of the sheer cliffs are several hundred feet high. Smaller cliffs have been carved on the flanks of two glacial troughs which descend southwestward from the summit ridge of Pikes Peak to the upper flats of West Beaver Creek near the upland village of Gillett (elevation 10,000 feet). Many other cliffs throughout the upland and on its flanks have been produced by the resistance to weathering of parts of the granite which are more massive and durable than the rock which surrounds them. Cliffs of this sort are usually not more than 100 or 200 feet high. They are excellent sites for training in military rock-climbing and are not so extensive as to require long detours by troops marching cross-country. Granite cliffs and towers at approximately 7,000 feet in North and South Cheyenne Canyons are frequently used for rock-climbing classes because they are steep, firm rock and are easily reached from Fort Carson.

Fig. 20. Glen Cove headwall on Pikes Peak, one of a number of glacially steepened cliffs along the northwest flank of the peak.

Special care should be used when climbing on the headwalls of the cirques of Pikes Peak to avoid zones of rockfall which exist where the cliffs lie below extensive creeping rubble masses near the summit.

(2) Rubble masses

The summit rubble field of Pikes Peak is a classic example of a felsenmeer (Fig. 21). It is a broad dome of angular granite blocks having no soil in their interstices and

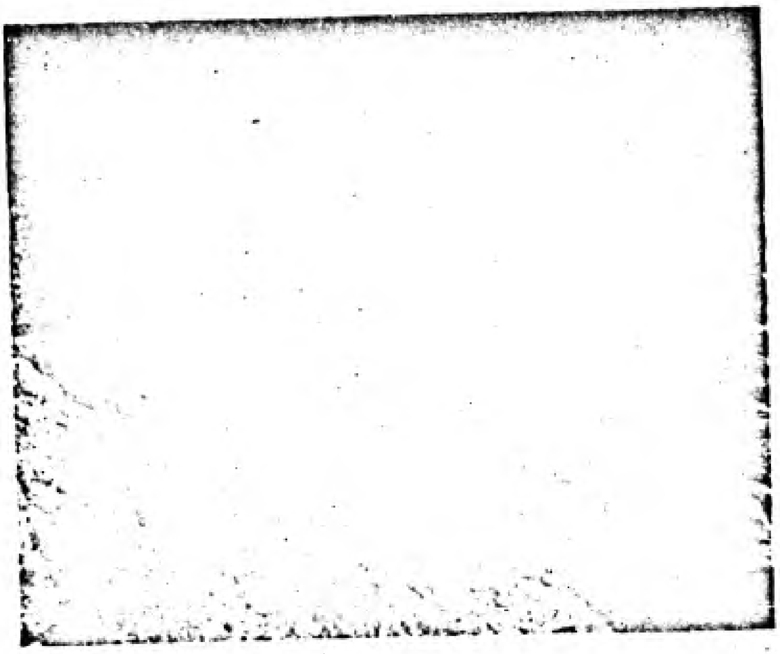


Fig. 21. The summit felsenmeer on Pikes Peak. A view southward along the route of the cog railway.

only a few visible pockets of grus. The rubble sheet covers not only the summit but also a considerable part of the south and west sides of the mountain. In places its lower margins are tongue-like rubble masses which are or have recently been very slowly over-riding the soil-covered slopes below. In other places the rubble has gradually accumulated soil as it has moved down-slope and has no definite downhill margin. Most of the other high ridges on the Pikes Peak upland are similarly capped and partly flanked by felsenmeer.

Talus slopes at and above the plateau level in the area also creep actively just as they do near Camp Hale. As in the Camp Hale area, deep accumulations of talus below cliffs give rise to rock glaciers in some instances. In the cirques on the northeast face of Pikes Peak, active rock glaciers are absent, apparently because small glaciers have occupied the cirques too recently to allow heavy talus accumulation. Glacial moraines have given rise to rock glaciers well down-valley from the cirques, however. These moraine-derived rock glaciers are now overgrown with forest.

Fig. 22. Limber pine on a droughty south-facing slope mantled with disintegrating granite rubble, Almagre Mountain. In the valley is a sedge bog ringed by subalpine meadow growing on small alluvial fans, surrounded by spruce-fir forest.

As in the Camp Hale area, rubble masses which creep downward onto increasingly steep slopes tend to create unstable situations in which care must be used to avoid setting in motion boulders which might injure persons below. As already noted, felsenmeers above cliffs are likely to cause occasional rockfalls spontaneously. The downhill (snout) end of any active rock glacier is also likely to be an area of unstable boulders and should be traversed cautiously if at all.

(3) Rubble soils and other steep soil surfaces

Mountainside soils on Pikes Peak are generally thin and droughty because they are formed from grus (Fig. 22). In most parts of the region they have nevertheless become normal rubble soils similar in many ways to those described in the Camp Hale section. Near Almagre Mountain, however, there are many slopes on which the

granite has decayed so heavily that there is very little rubble at the surface of the grus. Practically rubble-free grus also accumulates as cones at the base of many such slopes. Even on rubble-free slopes the grus is so well drained that the mantle, considered as a whole, is quite stable at all seasons. The surface of the barren grus slopes is loose, however, its texture being that of coarse sand or fine gravel. Movement across steep slopes of such material is somewhat laborious. Frost has a strong effect on grus slopes even though it does not disturb them deeply. Needle ice forming just below their surface dislodges the uppermost particles at such a rate that road cuts and other artificial depressions fill up rapidly. Grus is easily worked by road-building equipment and makes a reasonably good surface for jeep trails.

(4) Alluvial fans

A considerable part of the surface of the Pikes Peak upland at the plateau level (9,000 to 11,000 feet) is made up of moderately steep to gently sloping alluvial fans formed of material washed down from the slopes of the hills and lower mountainsides. The fans have a fairly smooth, rock-free surface of fine soil over gravel and rubble. A good deal of hay is grown and harvested on these fans near the 9,000-foot level (Fig. 23).

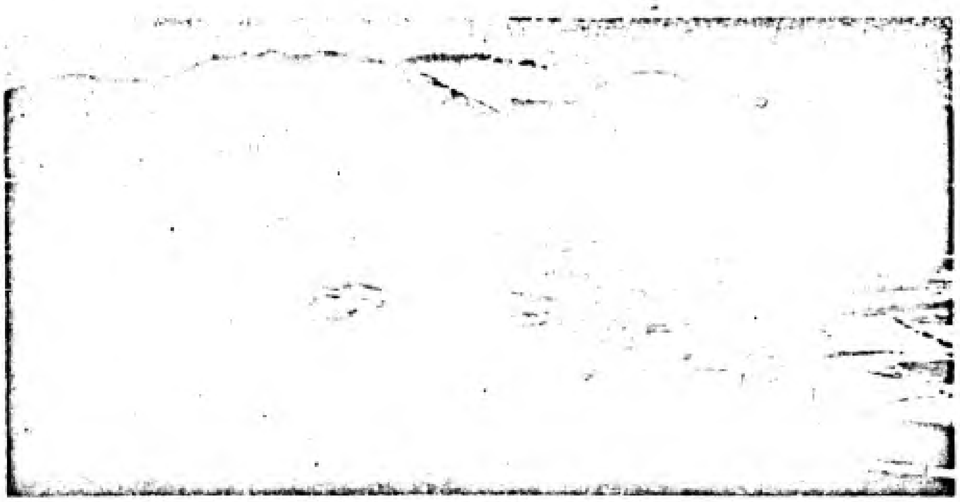


Fig. 23. The Pikes Peak upland. A view southeastward toward the summit of Pikes Peak (elevation 14,107 feet) from near the upland village of Divide (9,000 feet).

The belt of chaparral along the lower edge of the montane forest near Fort Carson grows on remnants of another zone of alluvial fans which were once part of the margin of the Great Plains. The fans now stand somewhat above the plains level and are much eroded, but considerable areas of their upper surfaces remain locally. Like the plains to the east and the alluvial fans of the upland to the west they have fine soil without much surface rubble.

At the base of the upland south of Fort Carson and partly within it is a foothill zone formed of alluvial fans higher than those discussed above, now so deeply eroded that little of their old upper surface remains.

(5) Moist soils and bogs

Poorly drained ground is much less extensive in the Pikes Peak area than near Camp Hale. On Pikes Peak there are no poorly drained steep slopes such as those which occur in some high basins near Camp Hale. Stream margins which in the Camp Hale area would be boggy are usually firm, though often moist. Except where precipitation is exceptional, the few bogs near Pikes Peak are sedge bogs, found in certain subalpine valleys which have unusually low gradients. Moist areas near the Seven Lakes basin and Lake Moraine have willow bogs similar to those which are widespread near Camp Hale.

Willow bogs are a barrier to foot and vehicle movement just as they are at Camp Hale. The scarcity of stream-bank bogs elsewhere in the Pikes Peak upland means that stream crossings are generally easier than near Camp Hale. The sedge bogs described above are consistently surrounded by a rim of alluvial deposits over which movement is possible either on foot or by vehicle, permitting easy detours around the bogs.

b. Vegetation

(1) Alpine vegetation, subalpine meadow, and short-grass steppe

Three types of low vegetation occupy well-drained, soil-covered ground in the Pikes Peak region at different altitudes, each type passing into the next by gradual transition.

(a) The open-ground vegetation which dominates the nearest lowlands also occurs on sunny slopes up to the middle of the subalpine zone. On the Pikes Peak upland this vegetation is short-grass steppe, dominant on the adjacent Great Plains. The equivalent vegetation at Camp Hale is sagebrush, which is dominant downstream in the Eagle River and Colorado River valleys.

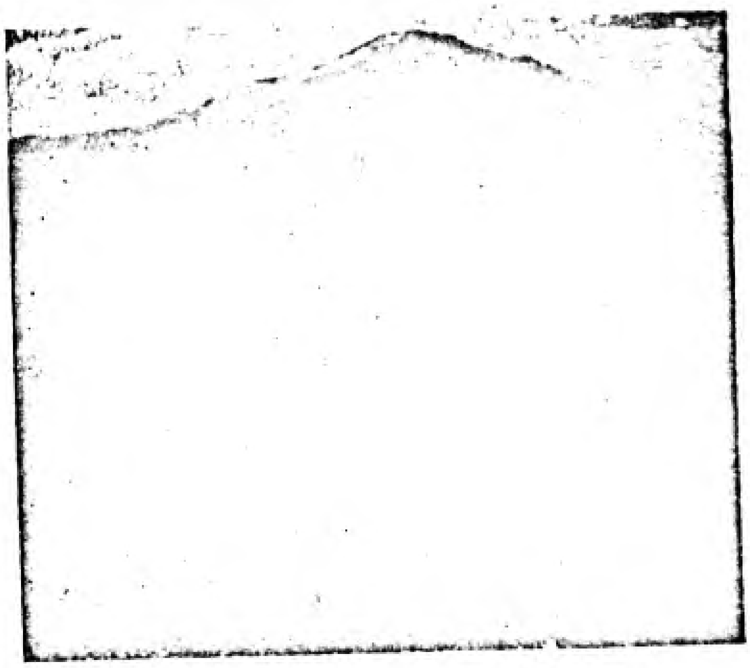


Fig. 24. A view of Pikes Peak across the southeastern part of the Pikes Peak upland, taken from Almagre Mountain. In the foreground is a sedge meadow. Felsenmeer is developing from a shattered outcrop at the right.

(b) Moisture becomes more abundant in the middle and upper subalpine zone of the Pikes Peak region and the steppe grassland gives way to meadow similar to the subalpine meadows of the Camp Hale area.

(c) As the meadows continue upward into the alpine zone the dense, tough Kobresia sedge turf (dry sedge meadow) described in the section on Camp Hale becomes the dominant vegetation. Small patches of this sedge meadow are found on Pikes Peak as high as 13,000 feet (Fig. 24).

Because less snow falls in winter on the slopes of Pikes Peak than at similar elevations near Camp Hale and because most snow that falls above timberline is blown off, the alpine slopes of the upland accumulate less soil moisture and have less water from melting snow in spring than the alpine slopes above Camp Hale. This and the droughty character of the granitic soil are presumably the reasons why moisture-loving types of alpine vegetation are much less abundant on Pikes Peak than near Camp Hale. Such vegetation is found only along well-defined drainage lines on Pikes Peak. Dry sedge meadow is extensive, however, apparently being adequately watered by precipitation in late spring

and summer.

Pikes Peak and the rest of the eastern flank of the Colorado Rockies have short-grass steppe vegetation in sunny, open areas below the middle of the subalpine zone. The presence of this vegetation type rather than sagebrush is apparently related to the well-defined summer maximum of precipitation. The western flank of the range, where sagebrush grows in similar situations, has little or no more precipitation in summer than at other seasons. Besides requiring more moisture during the summer, grass is more closely confined to fine soils than sagebrush. In addition to its occurrence on the high plateau, short-grass steppe reappears as the dominant vegetation type on the lower slopes of the upland and on the plains to the east.

Military vehicles can move freely over most of the slopes occupied by steppe grasses as well as over many subalpine meadows. Some subalpine meadows and many alpine meadows are too steep and rocky for vehicles but others are traversable. Troops will require cleated soles or their equivalent on steep meadow slopes in moist weather. Otherwise no difficulties may be expected in crossing such slopes on foot.

(2) Aspen forest

As at Camp Hale, aspen on the Pikes Peak upland normally occupies positions intermediate between shady slopes which support conifers and sunny slopes covered by steppe or meadow. Locally it may occupy shady slopes in a subalpine area, usually where such slopes are gentle and have been logged off in the past, as is the case near Cripple Creek. In other subalpine areas aspen may occupy sunny slopes, usually where such slopes are too rocky to be dominated by steppe grasses.

In the upper montane zone, aspen is often found in pure stands on sunny slopes which would otherwise have steppe grass or open conifers. Where sunny slopes are particularly rocky, aspen may be mixed with ponderosa pine; open areas of steppe grasses may then be entirely absent. Where part of a slope is in aspen and the rest grass, the aspen is often in circular clumps 50 yards or more in diameter.

(3) Coniferous forest

Subalpine forest of Engelmann spruce and subalpine fir is important on the Pikes Peak upland between about 9,000 and 12,000 feet, but is much less commonly dominant than in the same zone at Camp Hale. Steppe grasses, subalpine meadow, and aspen are each almost as extensive as spruce-fir in this zone, and stands of limber and foxtail pine are also common (Fig. 22). Limber and foxtail pines are trees of especially windy, sunny, or well-drained sites. They are common on ridges, though not in extensive mountainside stands as on Pikes Peak, throughout the eastern flank of the Colorado Rockies.

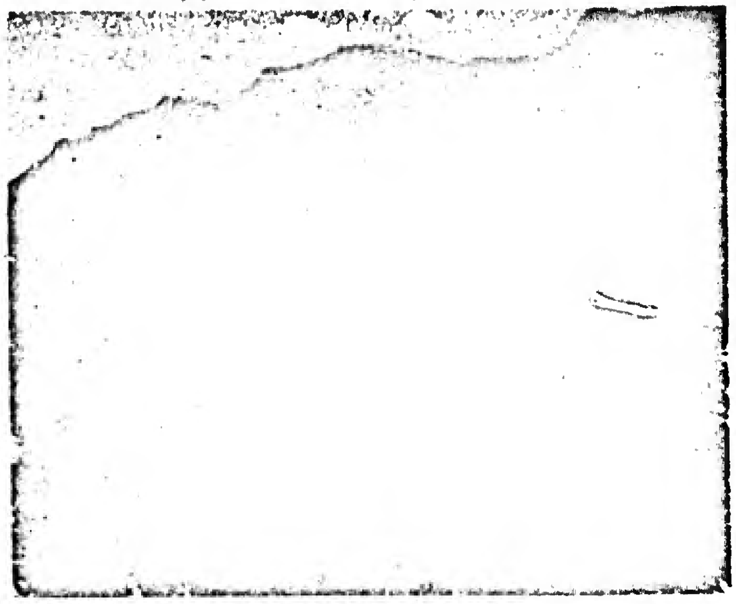


Fig. 25. Montane forest of ponderosa pine and Douglas fir, on the outer scarp of the Pikes Peak upland near Colorado Springs. Oak scrub in the foreground is part of the narrow belt growing between the coniferous vegetation and the grassland of the Great Plains near Fort Carson.

They are much less common on the western flank of the range, including Camp Hale. Stands of Douglas fir and lodgepole pine also occur in the lower subalpine zone, mostly on old burns.

The transition from subalpine to montane forest in the Pikes Peak upland nearly coincides with the irregular but fairly well defined boundary which exists near the 9,000-foot level between the lower edge of the plateau zone of the upland and the rugged plateau margins below that elevation. Below 9,000 feet, forest is much more abundant than on the plateau because the slopes are too steep and rocky for well-developed grassland. The dominant trees of the montane zone are ponderosa pine and Douglas fir (Fig. 25). In the upper part of that zone Douglas fir is dominant on most shady slopes. Sunny slopes have mixed growths of ponderosa pine, Douglas fir, aspen, and steppe grasses. The conifers are usually in open stands on such slopes. Lodgepole pine is common on old burns. Dense stands of small lodgepole pine and aspen are barriers to troop movement.

Spruce and subalpine fir follow stream banks well down into the montane zone because by their moistness, and because of the cold air which drains down them, particularly at night, such sites resemble a subalpine environment.

At lower altitudes in the montane zone, ponderosa pine is commonly mixed with Douglas fir on shady slopes but completely dominates sunny slopes, usually in open stands. Steppe grasses are the normal vegetation under stands of ponderosa pine but are often merely scattered among the rocks of the steep slopes rather than forming real grassland. Cottonwoods commonly occupy stream banks in this zone.

Scattered mats of dwarf conifers (krummholz) similar to those found at timberline above Camp Hale grow on felsenmeers at timberline on Pikes Peak and adjacent summits. The description given in the Camp Hale section applies equally well to the Pikes Peak krummholz.

c. Climate

(1) General

The climate of the Pikes Peak mountain training area is even more varied than that of the Camp Hale area because of the greater range in elevation. It also has distinctive regional characteristics which to some extent contrast with those of the Camp Hale area. In part these special characteristics are due to the position of Pikes Peak on the eastern flank of the Colorado Rockies, compared with Camp Hale's position on the western slope. In part they are due to the isolated position of the mountain and its surrounding upland, cut off from the main range by South Park.

Four weather stations are used as a basis for describing the climate of the Pikes Peak area (Fig. 19). Colorado Springs is at the eastern base of the upland, not far from Fort Carson, the climate of which it represents well. Lake Moraine is a station at 10,265 feet in a basin on the east slope of Pikes Peak. The Pikes Peak summit station is at an elevation of 14,111 feet. Cripple Creek is at 9,503 feet in a valley near the western margin of the upland. Data for Colorado Springs, Lake Moraine, and Pikes Peak are presented in Tables V to VII, and in graphs in Appendix B.

Spring and summer come earlier at Colorado Springs and Fort Carson than on the upland. Since our attention is primarily on the upland, however, the months will be grouped into seasons as they were in the discussion of Camp Hale climate. That is, winter is described as lasting four months, and summer is correspondingly reduced to a 2-month period.

TABLE V

MEAN AND EXTREME TEMPERATURE IN PIKES PEAK TRAINING AREA (°F)

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Ann
Colorado Springs, 6,098 feet, 53- to [illegible]-year record													
Absolute max.	73	74	78	82	92	101	97	98	95	87	78	72	101
Mean daily max.	43	44	51	58	66	77	82	80	74	63	52	44	61
Mean	29	31	38	46	54	64	68	67	60	49	38	31	48
Mean daily min.	17	16	25	33	41	50	54	54	46	36	25	18	35
Absolute min.	-32	-26	-16	1	15	30	37	34	20	- 6	-16	-27	-32
Lake Moraine, 10,265 feet, 57-year record													
Absolute max.	56	56	61	65	70	85	82	82	75	71	60	62	85
Mean daily max.	31	31	34	41	50	61	66	64	59	50	40	33	47
Mean	20	21	24	31	40	50	54	53	47	38	28	22	36
Mean daily min.	9	10	13	21	29	38	42	41	36	26	17	11	24
Absolute min.	-34	-37	-30	-12	- 3	14	27	24	8	-10	-19	-24	-37
Pikes Peak, 14,111 feet, 13-to 15-year record													
Absolute max.	30	29	43	39	47	63	64	62	55	47	33	30	64
Mean daily max.	8	10	14	21	30	40	48	46	39	28	16	12	26
Mean	2	4	8	13	22	33	40	38	31	22	11	6	19
Mean daily min.	- 4	- 3	1	7	16	26	34	33	26	15	5	0	13
Absolute min.	-33	-37	-29	-21	- 8	2	18	15	6	-17	-36	-37	-37
Cripple Creek, 9,508 feet, 12-year record													
Absolute max.	57	60	61	69	75	79	83	83	79	73	65	64	83
Mean daily max.	34	36	40	48	57	66	72	70	66	56	43	38	52
Mean	22	23	27	36	44	52	59	57	51	42	30	25	39
Mean daily min.	9	10	14	23	31	39	45	44	37	29	17	12	26
Absolute min.	-25	-27	-22	-11	11	19	27	28	15	-1	-14	-16	-27

TABLE VI

MEAN AND EXTREME PRECIPITATION IN PIKES PEAK TRAINING AREA (INCHES)

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Ann
					Colorado Springs, 6,098 feet, 70-year record								
Max.	1.0	1.9	3.0	6.8	8.1	5.1	6.6	7.1	4.6	3.4	2.3	2.5	
Mean	0.2	0.4	0.7	1.6	2.2	1.8	2.8	2.4	1.1	0.6	0.4	0.3	14.5
Min.	0	0	T	0.1	0.1	0	0.3	0.5	0	0.0	0.0	T	
					Lake Moraine, 10,265 feet, 58-year record								
Max.	1.8	3.4	4.0	16.6	7.0	7.5	8.2	9.0	6.2	5.1	3.4	6.5	
Mean	0.7	0.9	1.7	3.1	2.9	2.5	4.2	3.9	1.6	1.4	0.8	0.7	24.4
Min.	T	0.1	0.2	0.7	0.5	0.1	1.3	0.9	0.1	0.1	T	T	
					Pikes Peak, 14,111 feet, 15-year record								
Max.	4.3	3.9	4.7	13.1	12.3	3.5	8.1	11.3	3.8	4.6	7.8	4.6	
Mean	1.6	1.5	2.1	3.6	3.8	1.6	4.2	3.8	1.7	1.7	1.9	2.6	30.1
Min.	0.1	0.4	0.4	0.4	0.4	0.6	0.4	0.2	0.4	0.2	0.1	0.2	
					Cripple Creek, 9,508 feet, 12-year record								
Max.	1.6	2.0	3.6	4.7	6.3	4.6	9.1	5.9	3.8	2.7	2.5	2.7	
Mean	0.5	0.5	1.1	1.5	1.9	1.5	3.7	3.0	1.3	0.8	0.5	0.5	36.8
Min.	T	T	0.1	0.2	0.1	T	T	0	0	T	0	T	

TABLE VII

MEAN AND EXTREME SNOWFALL IN PIKES PEAK TRAINING AREA (INCHES)

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Ann
					Colorado Springs, 6,098 feet, 6-year record								
Max.	8	9	15	12	3	T	T	*	1	6	6	4	
Mean	4	3	6	4	1	T	T	T	*	2	3	2	25
Min.	*	*	3	1	T	T	0	0	0	T	T	1	
					Lake Moraine, 10,265 feet, 14-to 21-year record								
Max.	34	29	46	101	75	11	2	T	13	33	20	24	
Mean	13	17	25	36	22	2	*	T	2	9	11	10	147
Min.	2	6	3	5	5	T	0	0	0	0	2	0	
					Cripple Creek, 9,508 feet, 9-to 11-year record								
Max.	21	32	22	30	6	3	0	0	4	12	12	10	
Mean	10	12	11	16	3	*	0	0	1	4	6	5	68
Min.	*	2	1	T	0	0	0	0	0	0	2	0	

T= trace
*= 0.1 to 0.5 in.

(2) Winter Climate (December, January, February and March)

Winters are comparatively mild at Colorado Springs and Fort Carson. Daytime temperatures at Colorado Springs are above freezing on about 5 out 6 days and temperatures above 70°F have occurred in each of the winter months. High temperatures occur during strong west-to-east (downslope) air movements, known as chinook winds or "snoweaters". During such winds relative humidities have been as low as 2 percent, and temperatures may rise so fast that they wipe out the normal diurnal changes, causing the highest temperature for some days to be recorded at night. Low temperatures occasionally occur at Colorado Springs. The absolute minimum temperature there is -32°F (January) and temperatures below zero must be expected most winters.

Snowfall at Colorado Springs is normally light, averaging 2 to 4 inches per month during the winter months (Table VI and Fig. 41). March averages 6 inches, and as much as 15 inches have been recorded. Some rain also occurs in winter.

At higher elevations, winters are progressively more severe and the amelioration of the chinook is less effective. Not only are temperatures lower but precipitation is heavier and snow is a regular feature of the winter environment. Lake Moraine at 10,265 feet normally has a snow cover all winter and snow depths up to 20 inches were reported in a 6-year period of record. Average winter snowfall at Lake Moraine is almost as great as at Leadville (at about the same elevation in the Camp Hale area), but minimum monthly snowfalls are considerably lighter. This indicates that snow cover is less reliable at Lake Moraine, where there has been a December without snow and as little as 2 inches of snowfall in January.

Winter snow cover is even less reliable at Cripple Creek than at Lake Moraine because snowfall is lighter and temperatures are higher. Most winter days at Cripple Creek have maximum temperatures above freezing and several days a month can be expected to have temperatures in the 40's.

Pikes Peak is one of the highest points in the United States at which regular weather observations have been taken. In the 15 years of record its temperature was never above freezing in December, January, and February. Daily minima are generally below zero but the absolute extreme of -37°F (February) is no lower than the value for Lake Moraine, and Dillon in the Camp Hale area has recorded lower temperatures in four different months. As important as the low temperatures are the chilling winds. The average wind speed in winter is greater than 20 miles per hour. Although records are not available, there is no doubt that frequent periods of gale force winds occur.

Precipitation is heavier on Pikes Peak than at the lower elevations. For the entire year, twice as much precipitation can be expected as at Colorado Springs, and during the four winter months the average precipitation is five times as great. Snowfall is heavy but most of it is blown off the mountain into the glacial cirques.

(3) Spring Climate (April, May, June)

At Colorado Springs cold snaps are infrequent and of short duration in April. An average of one day a month has temperatures that remain below freezing. Some snow can be expected but appreciable accumulation is unusual. By June temperatures near 80°F can be expected on most afternoons (Table V). Precipitation is then mostly in the form of afternoon showers associated with thunderstorms.

At elevations higher than Colorado Springs precipitation is heavier and is more often in the form of snow. The heaviest snowfalls in the two study areas occurred at Lake Moraine. In April 1942, 101 inches of snow fell there, and over 50 inches of snow fell in 3 other Aprils between 1944 and 1955 (Table VII). Temperatures in April at Lake Moraine are often above freezing and the snow melts rapidly. Snow depths of over 2 feet are unusual but they have occurred as late as May. In a freak snow storm on May 18 and 19, 1955, Lake Moraine had 7.76 (melted) inches of precipitation. The maximum snow depth on the ground from this storm was 45 inches. Most of the state had no snow on the ground at the time this depth was reported at Lake Moraine. Despite the heavy snows at Lake Moraine, it should be stressed that in some years it has had no snow cover because of lack of snowfall or because of rapid melting.

At Cripple Creek, spring snow is not as heavy as at Lake Moraine. An average of 16 inches falls in April and 3 in May. The snow does not last long; temperatures average above freezing in April and even average daily minima are above freezing by May (Table V).

On Pikes Peak the April mean minimum is 7°F and the mean maximum is 21°F. Temperatures above freezing are unusual until late May and temperatures as low as 2°F have occurred in June. Snowfall and snow depth records are not available from Pikes Peak, but the records at Lake Moraine indicate that snowfall in the vicinity of the peak is heavy in the spring. Average wind speeds in the spring are less than in the winter. Gale force winds still can be expected and will cause discomfort when associated with low temperatures.

(4) Summer Climate (July, August)

Actually, one cannot limit the summer at Colorado Springs to two months or say that there is any summer at all on Pikes Peak. Summer conditions are at their maximum in July and August at Colorado Springs. Temperatures above 80°F occur on more than half the days during these months, and an average of 12 days in this 2-month period have temperatures above 90°F. Nights are cool with temperatures usually below 60°F.

Precipitation is at a maximum because of a high rate of occurrence of thunderstorms during summer. Thunderstorms occur on more than half the days in most summers, a rate of occurrence which is surpassed only in Florida and on the Gulf Coast. Hail can be expected to occur locally almost every month from June through September. Approximately 80 percent of the annual precipitation falls during these months. Periods of precipitation are brief but the daylight hours are characterized by intense radiation and clear or partly cloudy skies.

At Pikes Peak, July and August are the only months in which the temperature is above freezing more often than below. Winds are lighter, and this is the season when tourists can motor to the top with a good chance of experiencing weather which is not too hostile. July and August are wet months. Some summer snow occurs on Pikes Peak but most of the precipitation is of short duration occurring as rain associated with thunderstorms. Precipitation is also heavy at the intermediate elevations. Both Pikes Peak and Lake Moraine have an average of 4.2 inches of rainfall in July (Table VI). Cripple Creek apparently has fewer thunderstorms and slightly less rainfall.

(5) Fall Climate (September, October, November)

At Colorado Springs, the season of transition from summer to winter is marked by many clear days, moderate temperatures, and light precipitation. As the season progresses, the likelihood of cold weather increases. Minimum temperatures below freezing are rare in September but frequent by November (Table V).

Frost is expected often at Lake Moraine and occasionally at Cripple Creek in September. By November, mean temperatures average below freezing at these stations, and temperatures below zero occur occasionally. Snow falls more often than rain in November and may accumulate. Below 10,000 feet, snow is normally less heavy than in the Camp Hale area.

On Pikes Peak the mean temperature is below freezing in September and down to 11°F by November. Temperatures rise above freezing on some days in September and October but in November the highest temperature on record is 33°F. The absolute minimum in November is -36°F, as low as in the winter months. Although mean precipitation for the fall months is less than in spring or summer, the record shows that in some months snow is heavy. Over 7 inches of precipitation has occurred in November at Lake Moraine, an amount greater than the maximum precipitation of any winter month but considerably less than has been reported in April or May.

4. Comparisons with other mountain areas

Physical similarities and differences between the Camp Hale and Pikes Peak regions and mountain areas in other parts of the world are a matter of considerable concern to the U.S. Army because the purpose of testing and training in the Rockies was to increase the Army's ability to operate in mountains throughout the world. The mountain regions of the world are extremely diverse physically, and though some of them resemble the Colorado Rockies in many respects, there are also great differences.

As this section will be devoted to comparing them with other mountains of the world, we should note that the Colorado Rockies are a midlatitude range rising from semiarid high plains and plateaus in the interior of the western United States. The region is characterized by clear skies, wide temperature ranges, low precipitation, and considerable areas of scant vegetation. Many ranges at similar latitudes in interior Asia resemble the Rockies in these and other respects even though the greater size of Asia, the greater height of many of its ranges, and the different orientation of its ranges from those of North America, cause great dryness in much of inner Asia and reduce the north-south flow of air masses across it.

The midlatitude position of both the Colorado Rockies and the comparable ranges in Central Asia results in marked seasonal changes in the amount of solar radiation. The Arctic has even stronger seasonality of solar radiation. The tropics have little seasonality of radiation even where mountains are high enough to have cold or cool climates. The interior position of the Colorado Rockies means that air masses reach them only after moving considerable distances overland, often losing much moisture on the way. (The dryness of the Kunlun Range in mid-Asia is an even more extreme example of such a situation). Winds from the Pacific reach Colorado only after crossing a succession of rugged ranges on which much of their moisture is dropped. Like mid-Asia, though to a lesser extent because its ranges are not as high, Colorado gets maximum precipitation on its highest mountains. Figures given in the section on precipitation show, however, that the annual fall recorded among the Colorado summits is much less than has been observed in some other mountains.

The north-south orientation of the Rocky Mountains allows frequent alternation in Colorado between air masses from north and south which have highly contrasting temperatures. Strong diurnal temperature fluctuation accentuates these extremes, producing temperature ranges which are probably about as great as those of mid-Asia.

The climatic characteristics of the mountain region of Colorado and those of comparable ranges in Asia affect not only their vegetation but also the processes of weathering and erosion which determine many of their topographic characteristics. On the other hand, there are striking topographic characteristics of the Rockies related to climate, which

differentiate them from such maritime midlatitude mountain regions as the Swiss Alps or the Cascades. The mountains of desert regions or of the humid tropics have even more distinctive climate-controlled topographic characteristics.

a. Topography

(1) Altitude and relief

Many peaks in the Colorado Rockies reach 14,000 feet. The highest, Mt. Elbert, 23 miles south of Camp Hale, rises to 14,431 feet or within 65 feet of the highest peak in the United States. Nevertheless its altitude is less than half that of Mr. Everest, falls 8,000 feet short of Mt. Aconcagua in the Andes, 5,000 feet short of Mt. Logan in Canada and Mt. McKinley in Alaska, and 1,350 feet short of Mont Blanc in the Alps.

The greatest relief which can be assigned to the Colorado Rockies is 9,000 feet because they rise from a 5,000 to 6,000-foot plateau. The Himalayas, Andes, Alaskan ranges, and the Alps, on the other hand, all rise on at least one flank from plains not far from sea level, so practically all of their height must be considered relief. The Apennines in Italy, the mountains of central Japan, and the San Bernardino Mountains east of Los Angeles all have relief equal to that of the Colorado Rockies yet do not reach altitudes much higher than 10,000 feet. On the other hand, the Olympic Mountains of northwest Washington may be cited as a range known for its ruggedness but having slightly less total relief and much less actual altitude than the Colorado Rockies.

(2) Glaciation

Glaciers were fairly extensive in the higher parts of the Colorado Rockies during the Ice Ages. They occupied most of the high valley-heads in each of the higher ranges of the state. Many high ridges were left bare at that time, however, their snow blown by wind into the valleys where it contributed to the feeding of glaciers. In the northern half of the state, glaciers pushed beyond the mountain fronts onto the floors of some of the intermontane basins, as in the upper Arkansas valley and Middle Park. A number of lake basins were left behind when the glaciers shrank. Since the last Ice Age, the glaciers have been reduced to insignificant remannts in the northern part of the east front of the range, and have disappeared entirely from the Camp Hale and Pikes Peak areas.

A very high proportion of the mountains of the world retain more glaciers today than the Colorado Rockies. Such ranges also characteristically show stronger and more extensive evidence of Ice Age glaciation. Because of their great height, even the driest ranges of mid-Asia have extensive ice. The very dry Kunlun Range seems to accumulate ice only above 20,000 feet, however.

The European Alps have roughly as much ice on their summit areas today as the Colorado Rockies had during the Ice Ages. During the Ice Ages the Alps were almost buried in ice. They had at least as much ice cover as the St. Elias Range in Alaska and the Yukon has today and in some parts must have had as much as some parts of Greenland or Antarctica now have. Ranges with both modern and Ice Age glacial systems comparable with those of the Alps, and thus more extensive than those of the Colorado Rockies, include the Canadian Rockies, the mountains of British Columbia, the northern Cascades, the New Zealand Alps, and parts of the Chilean Andes. Even the tropical Andes and the equatorial mountains of Africa have bigger icefields than the Colorado Rockies.

On the other hand, many ranges have no ice or as little ice as the Rockies. Most such ranges are of less height, except those in the tropics and sub-tropics. The Brooks Range of northern Alaska is about 9,000 feet high with about 8,000 feet of relief at 68° N. latitude but has only about as many glaciers as the Colorado Rockies.

(3) Fluvial erosion

As noted in the section on Camp Hale, many broad alpine and subalpine slopes in Colorado are almost unmarked by torrent channels, though similar slopes in more humid mountains have many such channels. This condition is due partly to relative lack of precipitation but partly due to vigorous frost action which tends to fill in such channels with coarse rubble. Rock streams and rock stripes are examples of the filling of drainage lines by frost action.

Although precipitation as well as frost diminishes at low levels in the Colorado Rockies, the lower slopes show increased effects of fluvial action relative to frost action and have developed a landscape of the familiar cliff, canyon, and benchland type familiar in the semiarid West. Frost action still has considerable effect even at the lowest levels in Colorado, however. Only in the tropics and subtropics are the lower flanks of mountain ranges free of frost.

(4) Mass wasting

Humid midlatitude mountains such as the Cascades, the British Columbia Coast Range, and the Swiss Alps, at least on their moister flanks lack the rock glaciers and other conspicuous effect of rubble creep which are so strikingly characteristic of the mountains of Colorado. Because such effects are closely related to climate (Troll 1941, 1943-44, 1948) their distribution is a matter of some interest. Rock glaciers have been noted not only throughout the southern and central Rockies but also in the drier parts of the Sierras, in various parts of Alaska, and in the White Mountains of New Hampshire. They have also been described in the Tien Shan range of central Asia, where they closely resemble those of Colorado. Similar forms are presumably present, though undescribed, in other mid-Asiatic ranges.

Midlatitude and subarctic ranges with a maritime climate (intermediate to heavy precipitation and a moderate range of temperature), such as the Alps, have rather shallow but active frost disturbance of soils near timberline, occurring mostly during the period of spring thaws. Comparatively gentle "alp slopes" consequently develop just above timberline in such humid ranges. Because the Colorado Rockies lack such alp slopes, they cannot properly be called "alpine" in a regional sense even though they have an "alpine" vegetation zone.

b. Vegetation

(1) Timberline and higher areas

Because their timberline is at an elevation of 11,500 to 12,000 feet, the Colorado Rockies have less than 3,000 feet of relief above it. The Alps have 8,000 feet of relief above timberline, the Himalayas 15,000 feet. The highest Alaskan peaks rise as much as 18,000 feet above the timberline of that region.

Abundance of precipitation makes a considerable difference in the character of alpine vegetation. Heather and other heath plants are much more important on the alpine slopes of ranges such as the Alps and Cascades than in the Rockies. The very wet Chugach Range near Whittier, Alaska, with approximately 175 inches of rain per year at sea level, has alpine vegetation which is often bog-like or, to use the Alaskan term, muskeg, even on well-drained slopes (Thompson 1954).

(2) Relationship of forest to scrub and steppe vegetation

The driest mountain areas of the world have no forest at all; such conditions exist in the Kunlun Range and most parts, at least, of the Pamirs in mid-Asia, as well as on the west slope of the central Andes. Humid ranges, on the other hand, generally support forest on all of their slopes below timberline except those which have been cleared, as they have to a considerable extent in the Alps. The Colorado Rockies represent a condition intermediate between dry and humid mountains, in which many south slopes are entirely or partly without forest, being occupied by steppe grassland or semiarid scrub vegetation. Similar contrast between north and south slopes exists in Asia in the Elburz, Hindu Kush, Tien Shan, Altai and other Mongolian ranges, the Nan Shan, and throughout eastern Tibet (Kam) as far south as the border of Yunnan (Teichman 1922).

(3) Number and type of forest zones

Most temperate zone mountains, including the Colorado Rockies, have one or more forest zones below the subalpine. In a humid subtropical or tropical range many distinct vegetation zones may occur. In subarctic ranges, on the other hand, only one forest zone is present and that is similar to the subarctic forest (taiga) of nearby lowlands. Spruce and

fir are usually dominant in North American subarctic and subalpine forests, including those of Colorado, just as they are in the Canadian taiga. In Asia, larch is very abundant both in the taiga and in subalpine forests.

Most montane forests in eastern North America and Eurasia are partly or entirely deciduous. Throughout western North America including Colorado, the montane zone is strongly dominated by conifers. Ponderosa pine, characteristic of this zone in the Colorado Rockies, is widely distributed in the montane zone of the less humid ranges of the West and is often accompanied, as in Colorado, by Douglas fir. Such forest, containing trees of only moderately large size, is found from the east slope of the Cascades northward into interior British Columbia as well as throughout the Rockies from Montana southward. Coastal montane forest on the Pacific coast of North America contains huge conifers such as western hemlock, western red cedar, and Sitka spruce, usually growing from sea level up to an elevation of 1,000 to 5,000 feet.

c. Climate

(1) Temperature.

The lowest temperatures on record outside of Antarctica are from the vicinity of the Verkhoyansk Mountains of northeastern Siberia, where an official temperature of -90°F has been recorded at a piedmont station and an unofficial temperature of -108°F was recorded at a station in an intermontane basin. This can be compared with an absolute low temperature of -60°F at Taylor Park (about 9,400 feet) in a valley tributary to the Gunnison Basin, Colorado. Extreme high temperatures do not occur in mountains, though they do occur in low intermontane basins such as Death Valley.

Because temperatures normally decline with altitude it is not possible to compare the characteristic temperatures of two ranges in simple terms. However, the formulae given in Appendix C will permit comparison of any station in the world with normal conditions at the same elevation in the Colorado Rockies. Persons making comparisons should note carefully whether inversions, if any, affect the temperature gradient of the range as a whole, as is often believed, or whether they are associated with particular basins as in the Colorado Rockies. In Colorado the higher stations within any small area may be warmest at times, as is often true near Camp Hale, but since inversions in high basins are comparable to those in low basins, the effect is to increase the thermal difference between stations at any one level rather than to wipe out the normal gradient for the range.

(2) Precipitation

The heaviest precipitation recorded in the Colorado Rockies (about 50 inches per year) is at Wolf Creek Pass in the San Juan Mountains,

150 miles south of Camp Hale. Deep valleys on the flanks of the range get as little as 10 or 15 inches. Though 50 inches cannot be considered light precipitation, other mountain regions get much more. To cite extreme cases: the northeast slope of Kauai Island, one of the mountainous Hawaiian Islands, averages 476 inches per year, and Cherrapunji, India, in the Khasi Hills south of the Himalayas, averages 418 inches per year and has had 1,042 inches in a year. Mountain stations at higher latitudes get less extreme precipitation, but Little Port Walter on the mountainous coast of southeastern Alaska averages 231 inches per year. The Santis, a summit station in Switzerland, averages 132 inches per year, and Crkvice, in the Dinaric Alps of Yugoslavia averages 183 inches per year. In general, the European Alps are intermediate in precipitation between the extreme examples cited above and the relatively dry mountains of Colorado.

Tamarack, California, at an elevation of 8,000 feet in the Sierra Nevada, has an average of 400 inches of snowfall per year and has had as much as 884 inches. It has often had as much as 30 or 40 feet of snow on the ground.

Although it is difficult to compare the characteristic precipitation of one mountain region with that of another, it is possible to compare stations elsewhere in the world with the calculated normal for the same elevation in the Colorado Rockies. For this the reader is again referred to the formulae in Appendix C. The formulae for precipitation were calculated by the same method and are based on the same stations as those for temperature, but the distributions from which the precipitation formulae were calculated are less linear and the formulae are correspondingly less reliable.

(3) <u>Wind</u>

Data are not available for world comparisons of windiness in mountain regions. A comparison can be made, however, between Pikes Peak (mean velocity 19.2 mph; altitude 14,109 feet) and Mount Washington, New Hampshire (mean velocity 37.1 mph; altitude 6,288 feet). As an isolated summit which is one of the highest in the range, Pikes Peak might be expected to have a higher mean wind speed than this; it may be concluded that the Colorado Rockies are not a particularly windy range.

5. Bibliography

Bartram, John G. 1939, Summary of Rocky Mountain Geology, Bull. Am. Assn. Petrol. Geol., 23: 1131-1152.

Bates, C. G. 1917, Forest Succession in the Central Rocky Mountains, Jour. Forestry, 15: 587-592.

———1923, Physiological Requirements of Rocky Mountain Trees, Jour. Agr. Research, 24: 97-164.

———et al. 1924, Forest Types in the Central Rocky Mountains as Affected by Climate and Soil, U. S. Dept. of Agr. Bull. 1233.

Behre, C. H.,Jr. 1933, Talus Behavior Above Timberline in the Rocky Mountains, Jour. Geology, 41: 622-635.

Brooks, C. E. P. 1951, A Selective Annotated Bibliography on Mountain Meteorology, Meteorol. Abstracts & Bibliog., 2: 916-559.

Campbell, M. R. 1922, Guidebook of the Western U. S., Part E, The Denver and Rio Grande Western Route, U. S. Geol. Survey Bull. 707.

Capps, S. R.,Jr. 1909, Pleistocene Geology of the Leadville Quadrangle, U. S. Geol. Survey Bull. 386.

———1910, Rock Glaciers in Alaska, Jour. Geology, 18: 359-375.

Cary, M. 1911, A Biological Survey in Colorado, U. S. Dept. Agr., North American Fauna, 33: 1-256.

Cox, Clare. 1933, Alpine Plant Succession on James Peak, Colorado, Ecological Monographs, 3: 301-372.

Cross, Whitman, 1894, The Pikes Peak Quadrangle, U. S. Geol. Survey, Geol. Folio 7.

Daubenmire, R. F. 1943, Vegetational Zonation in the Rocky Mountains, Bot. Rev., 9: 325-393.

Davis, W. M. 1911, The Colorado Front Range, a Study in Physiographic Presentation, Annals Assn. Am. Geog., 1: 21-83.

Gilbert, G.K. 1904, Systematic Asymmetry of Crest Lines in the High Sierras, Jour. Geology, 12: 579-588.

Ives, R. L. 1940, Rock Glaciers in the Colorado Front Range, Bull. Geol. Soc. Am., 51: 127-194.

Kendrew, W. G. 1953, Climates of the Continents (4th ed.), Oxford Univ. Press, New York.

Kesseli, John E. 1941, Rock Streams in the Sierra Nevada, California, Geog. Rev., 31: 203-227.

Laird, Harley B. 1951, Forecasting Precipitation on the West Slope of Colorado, Monthly Weather Review, 79: 1-7.

Marr, John W. 1956, Vegetation and Environment on the East Slope of the Front Range in Colorado, Final Report, Contract No. DA44-109-qm-570, Quartermaster Corps, U. S. Army (unpublished).

Patton, H. M. 1910, The Rock Streams of Veta Peak, Colorado, Geol. Soc. Am. Bull. 21.

Powers, W. E. 1935, Physiographic History of the Upper Arkansas River Valley and the Royal Gorge, Jour. Geology. 43: 184-199.

Ray, L. L. 1940, Glacial Chronology of the Southern Rocky Mountains, Geol. Soc. Am. Bull., 51: 1851-1918.

Retzer, John L. 1950, Genesis and Morphology of Soils of Alpine Areas in the Rocky Mountains, Univ. of Wisconsin (unpublished Ph. D. thesis).

Robbins, W. W. 1917, Native Vegetation and Climate of Colorado in Their Relation to Agriculture, Colorado Agr. Exp. Station Bull. 224.

Sharpe, C. F. 1938, Landslides and Related Phenomena, Columbia Univ. Press, New York.

Shaw, C. H. 1909, The Causes of Timber Line on Mountains; the Role of Snow, Plant World, 12: 169-181.

Stahelin, R. 1943, Factors Influencing the Natural Restocking of High Altitude Burns by Coniferous Trees in the Central Rocky Mountains, Ecology, 24: 19-30.

Teichman, Eric. 1922, Travels in Eastern Tibet, The University Press, Cambridge, England.

Thompson, Will F. 1954, Environmental Handbook for Whittier, Alaska, Environmental Protection Division Report No. 226, Quartermaster R & D Command, US Army, Natick, Mass.

Troll, Carl. 1941, Studien zur Vergleichenden Geographie der Hochgebirge der Erde. Bonner Universität Buchdruck, Bonn.

————1943-1944. Strukturboden, Solifluction und Frostklimate der Erde, Geologische Rundschau, Band 34, Heft 7-8: 535-694.

————1948. Der Subnivale oder Periglaziale Zyklus der Denudation. Erdkunde, Band 2: 1-21.

Tweto, Ogden. 1949, Stratigraphy of the Pando Area, Colo. Sci. Soc. Proc., 15: 147-235.

US Army, Quartermaster Rese rch & Development Command, Environmental Protection Division. 1955, Three Mountain Areas in Southwestern Wyoming. Research Study Report RER-6, Natick, Mass.

US Department of Agriculture, Weather Bureau, 1933, Climatic Summary of the United States, Section 22-24, Colorado. Washington, D.C.

US Department of Commerce, Weather Bureau. Climatological Data, Colorado (data summarized for 1940-1955). ashington, D.C.

———— Climatic Summary of the United States - Supplement for 1931 through 1952. (Climatography of the United States 11-5, Colorado). Washington, D.C.

———— Local Climatological Data with Comparative Data, 1956. Colorado Springs, Colorado. Washington, D.C.

Vanderwilt, J. W. et al. 1948, Guide to the Geology of Central Colorado, Colorado School of Mines Quarterly, vol. 43; no. 2

Westgate, L.G. 1905, The Twin Lakes Glaciated Area, Jour. Geology, 13: 285-312.

Whitfield, C. J. 1932, The Ecology of the Vegetation of the Pikes Peak Region, Ecological Monographs, 3: 75-105.

6. Acknowledgments

Colonel Donald J. Woolley, Commanding Officer of the Mountain and Cold Weather Training Command, and many of his officers were most helpful during field studies for this report in 1955. Lt. Richard Hess and Specialist Jim Dawson, assigned as field companions during traverses in the Gore, Sawatch, and Elk Mountains, were excellent mountaineers and good company. Aerial views used in this report were made during a light aircraft flight with Captain Epsaro of M&CWTC.

Acknowledgment is also made to Dr. John W. Marr and Mr. William Osburn of the Institute of Arctic and Alpine Research, University of Colorado. Mr. Osburn was a very well informed and agreeable companion during extensive reconnaissance studies in the Rockies. Dr. Marr was helpful in a number of ways and much use was made of information from his final report on Contract DA44-109-QM-570.

Dr. John Retzer of the Rocky Mountain Forest and Range Experiment Station of the U. S. Forest Service, was also most helpful. Descriptions of soils and of the relation between soils and permafrost given in this report owe much to study of Dr. Retzer's published and unpublished reports and to field study and conversation with him. He also arranged to have the facilities of the experiment station made available for several days of field study.

The physiographic diagram of Camp Hale Military Reservation (Fig. 2) was drawn by Norman J. W. Thrower, under a Quartermaster contract, using a method of landform representation developed by Mr. Thrower and Professor Arthur H. Robinson, Department of Geography, University of Wisconsin. The other maps were drafted by Messrs. Andrew D. Hastings, Jr., Aubrey Greenwald, and Roland J. Frodigh. Miss Gertrude Barry drafted the climatic graphs. The statistical analysis for Appendix C was made by Mrs. Julie Swan. The manuscript was reviewed by William C. Robison, head of the Mountain Unit, and Dr. Peveril Meigs, Chief, Regional Environments Research Branch of the Environmental Protection Research Division.

APPENDIX A: CLIMATIC GRAPHS FOR THE CAMP HALE AREA

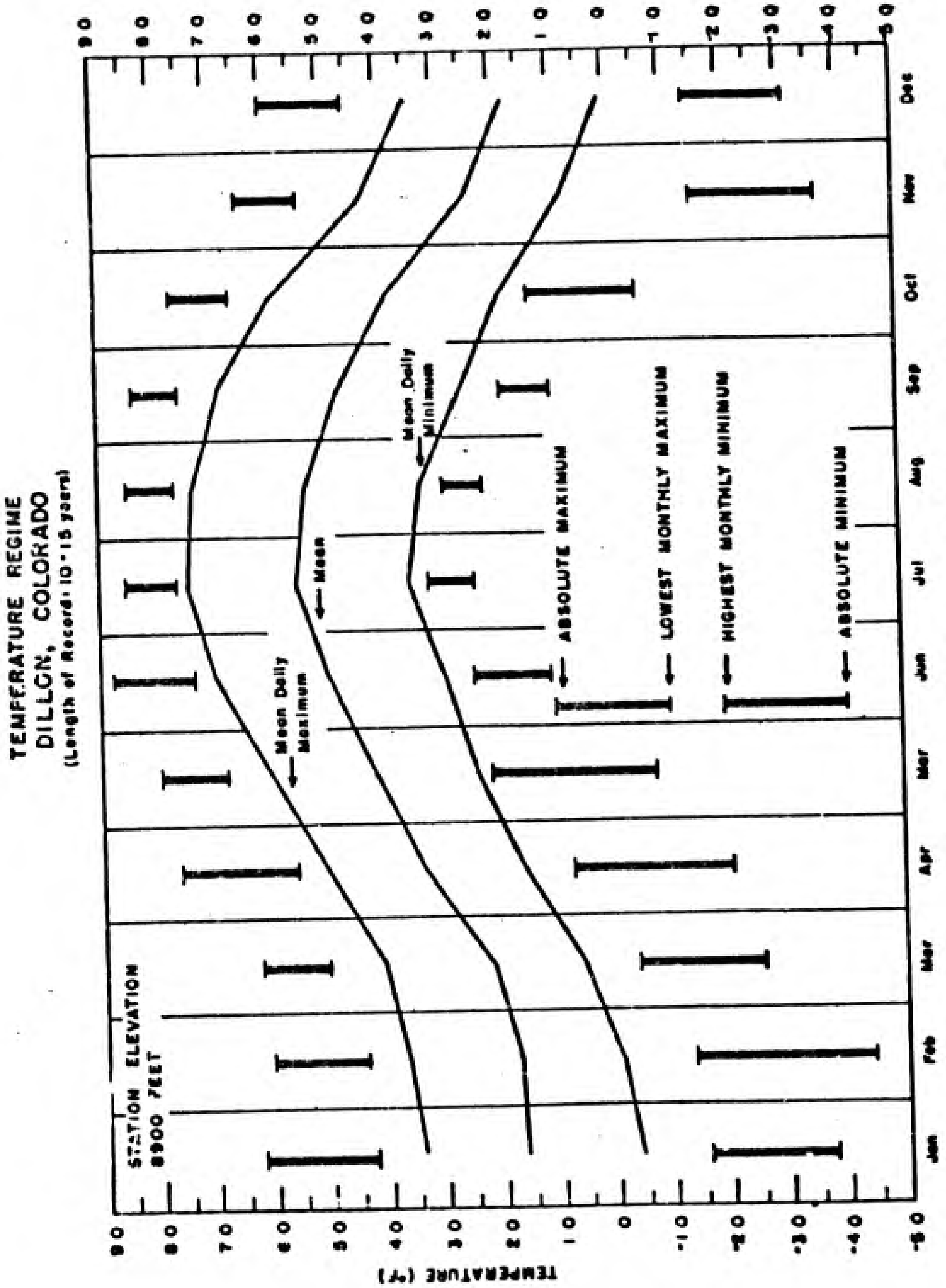

TEMPERATURE REGIME
DILLON, COLORADO
(Length of Record: 10-15 years)
STATION ELEVATION
8900 FEET
Mean Daily Maximum
Mean
Mean Daily Minimum
ABSOLUTE MAXIMUM
LOWEST MONTHLY MAXIMUM
HIGHEST MONTHLY MINIMUM
ABSOLUTE MINIMUM
TEMPERATURE (°F)
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec

Figure 26

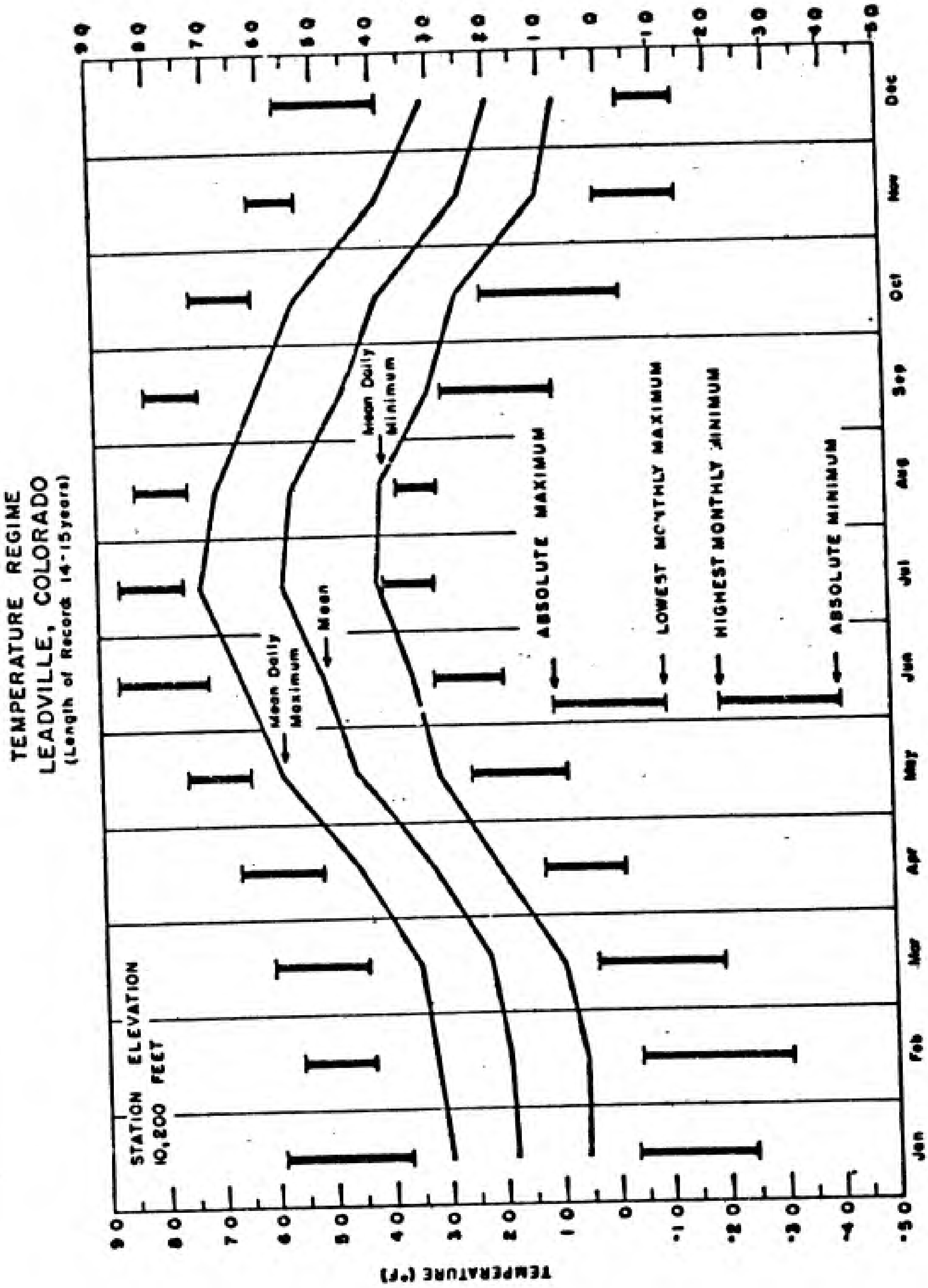

TEMPERATURE REGIME
LEADVILLE, COLORADO
(Length of Record 14-15 years)
STATION ELEVATION
10,200 FEET
Mean Daily Maximum
Mean
Mean Daily Minimum
ABSOLUTE MAXIMUM
LOWEST MONTHLY MAXIMUM
HIGHEST MONTHLY MINIMUM
ABSOLUTE MINIMUM
TEMPERATURE (°F)
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec

Figure 27

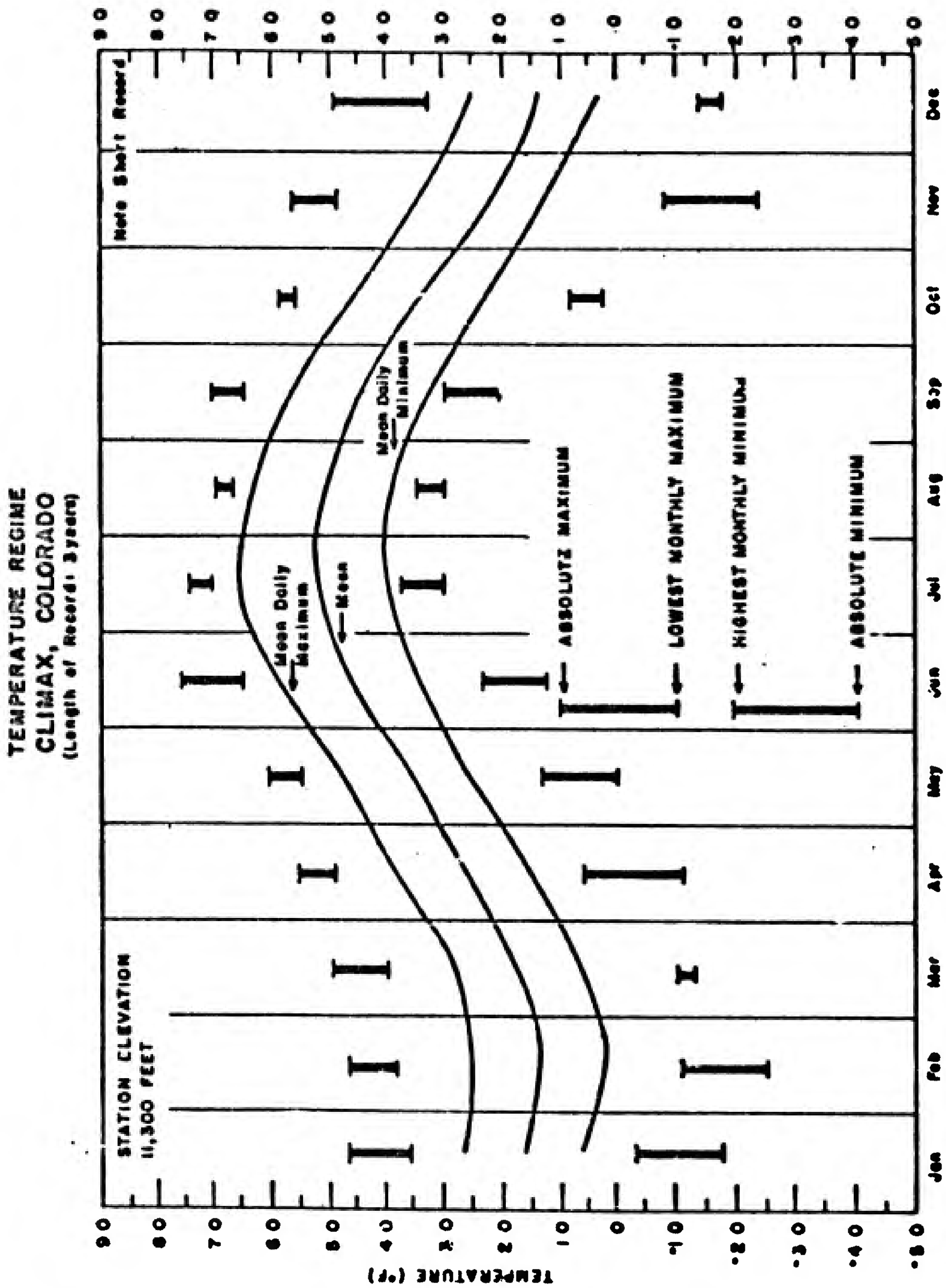

TEMPERATURE REGIME
CLIMAX, COLORADO
(Length of Record: 3 years)
STATION ELEVATION 11,300 FEET
Note Short Record
Mean Daily Maximum
Mean
Mean Daily Minimum
ABSOLUTE MAXIMUM
LOWEST MONTHLY MAXIMUM
HIGHEST MONTHLY MINIMUM
ABSOLUTE MINIMUM
TEMPERATURE (°F)
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec

Figure 28

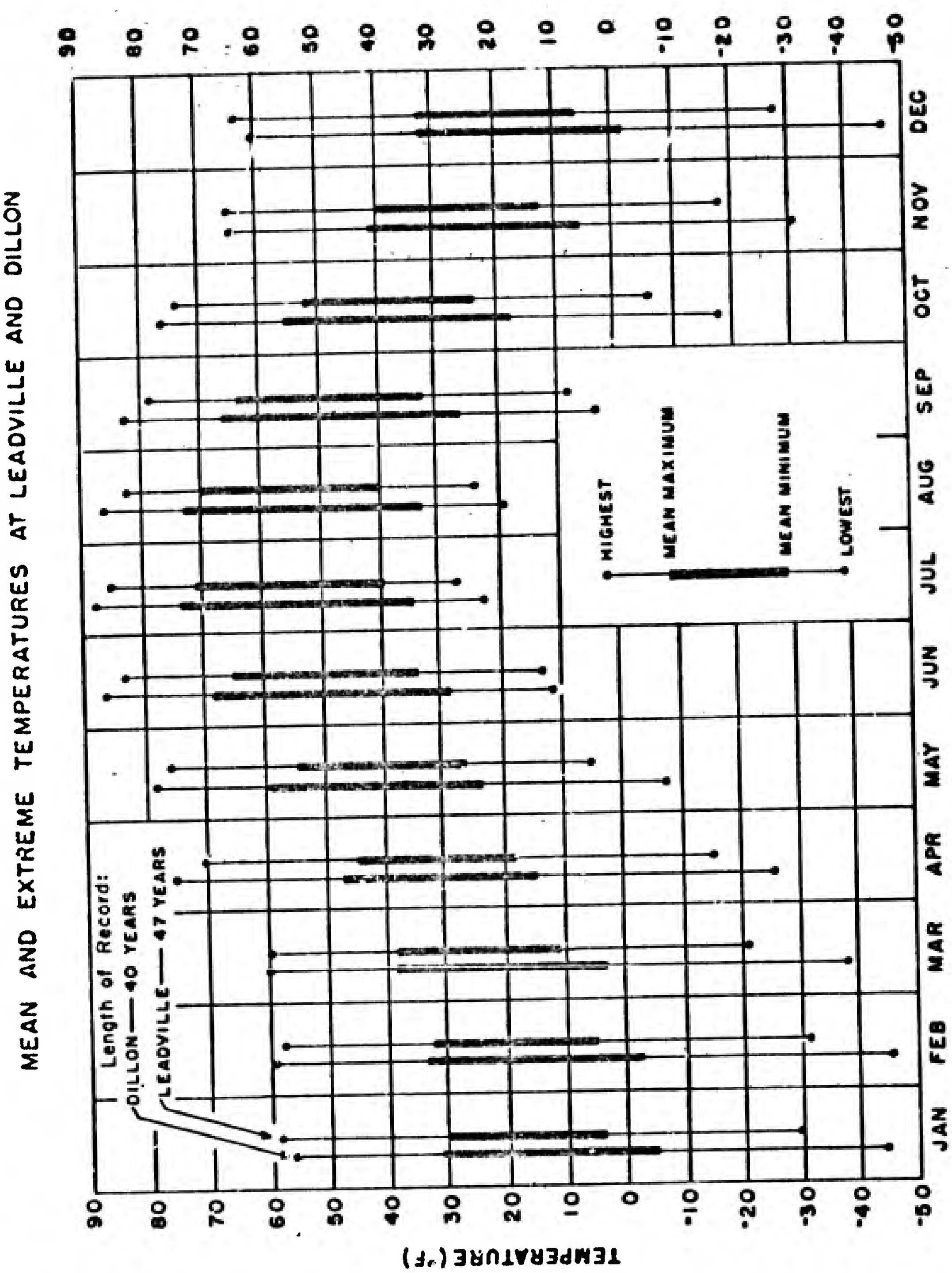

MEAN AND EXTREME TEMPERATURES AT LEADVILLE AND DILLON
Length of Record:
DILLON —— 40 YEARS
LEADVILLE —— 47 YEARS
HIGHEST
MEAN MAXIMUM
MEAN MINIMUM
LOWEST
JAN
FEB
MAR
APR
MAY
JUN
JUL
AUG
SEP
OCT
NOV
DEC
90
80
70
60
50
40
30
20
10
0
-10
-20
-30
-40
-50
TEMPERATURE (°F)

Figure 29

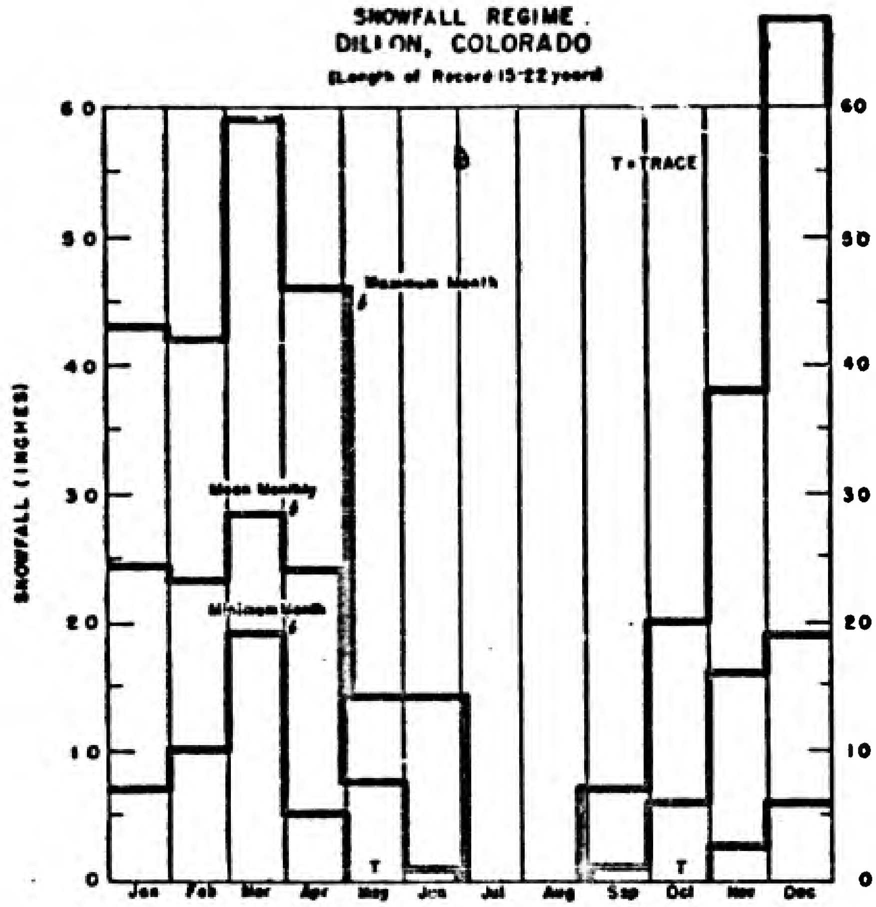


Figure 30

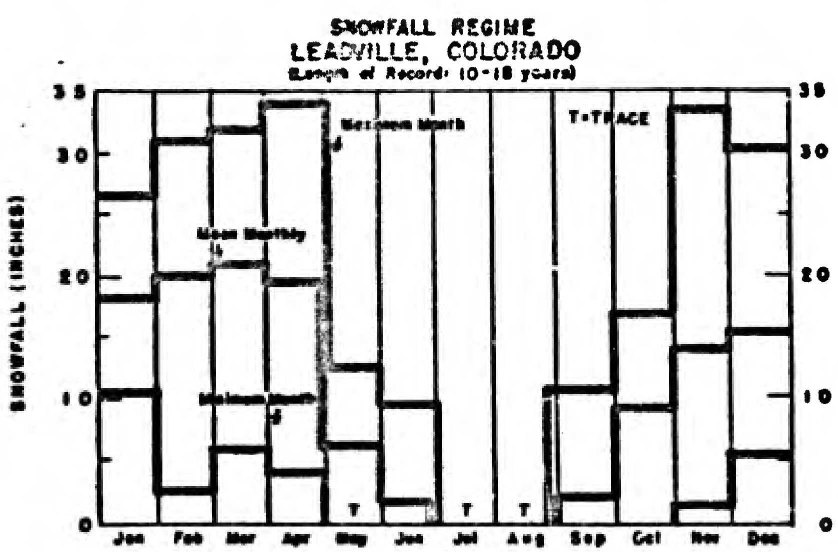
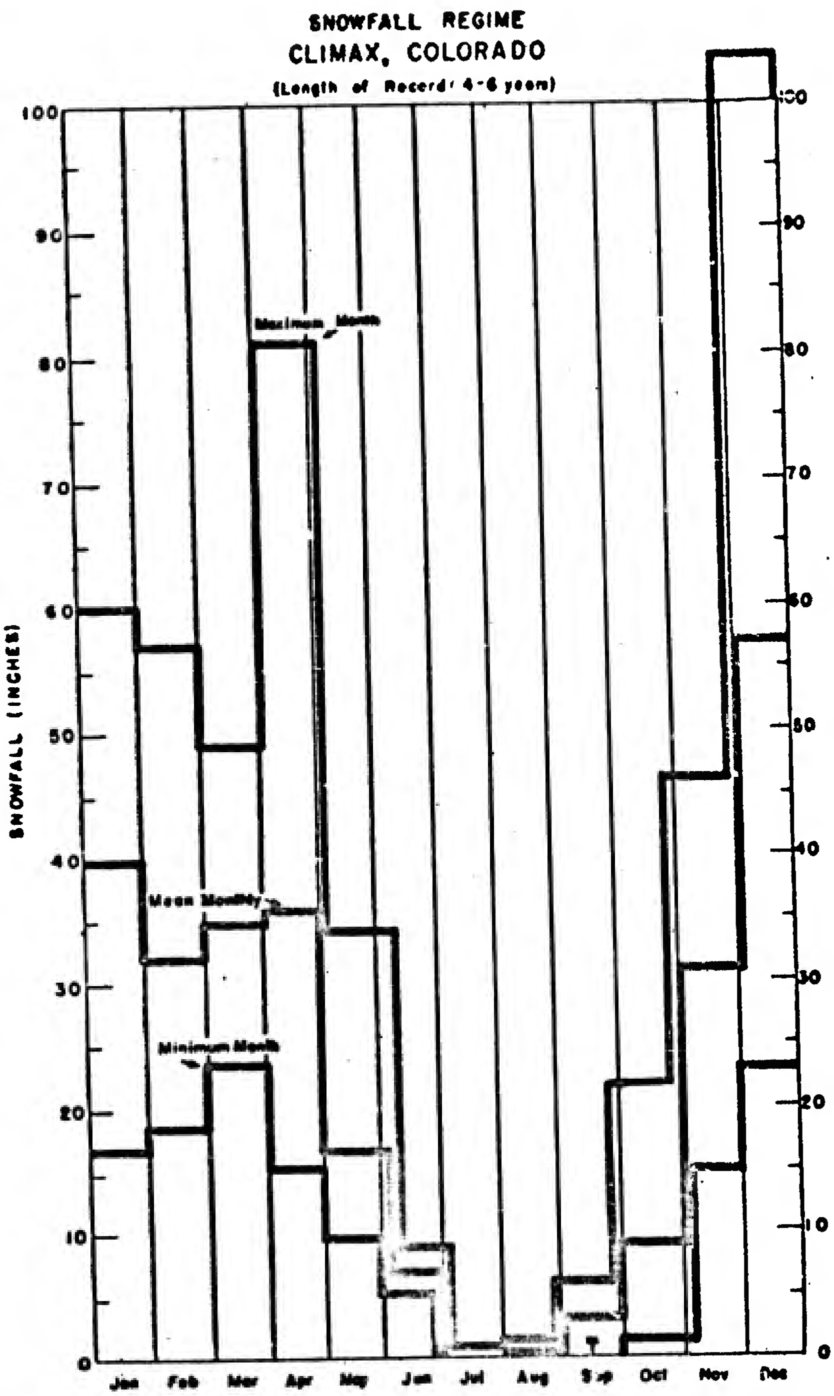


Figure 31



SNOWFALL REGIME
CLIMAX, COLORADO
(Length of Record: 4-6 years)
SNOWFALL (INCHES)
Maximum Month
Mean Monthly
Minimum Month
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec

Figure 32

PRECIPITATION REGIME
DILLON, COLORADO
(Length of Record: 45 years)

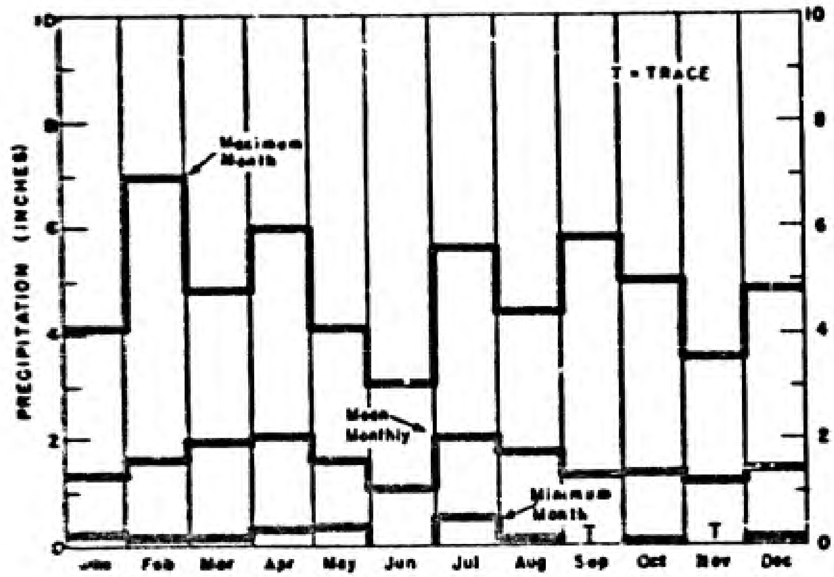


Figure 33

PRECIPITATION REGIME
LEADVILLE, COLORADO
(Length of Record: 57 years)

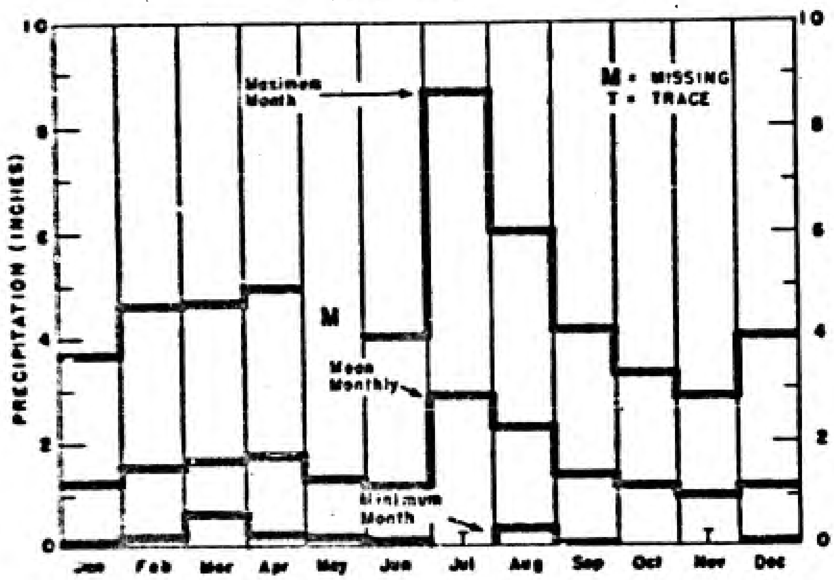


Figure 34

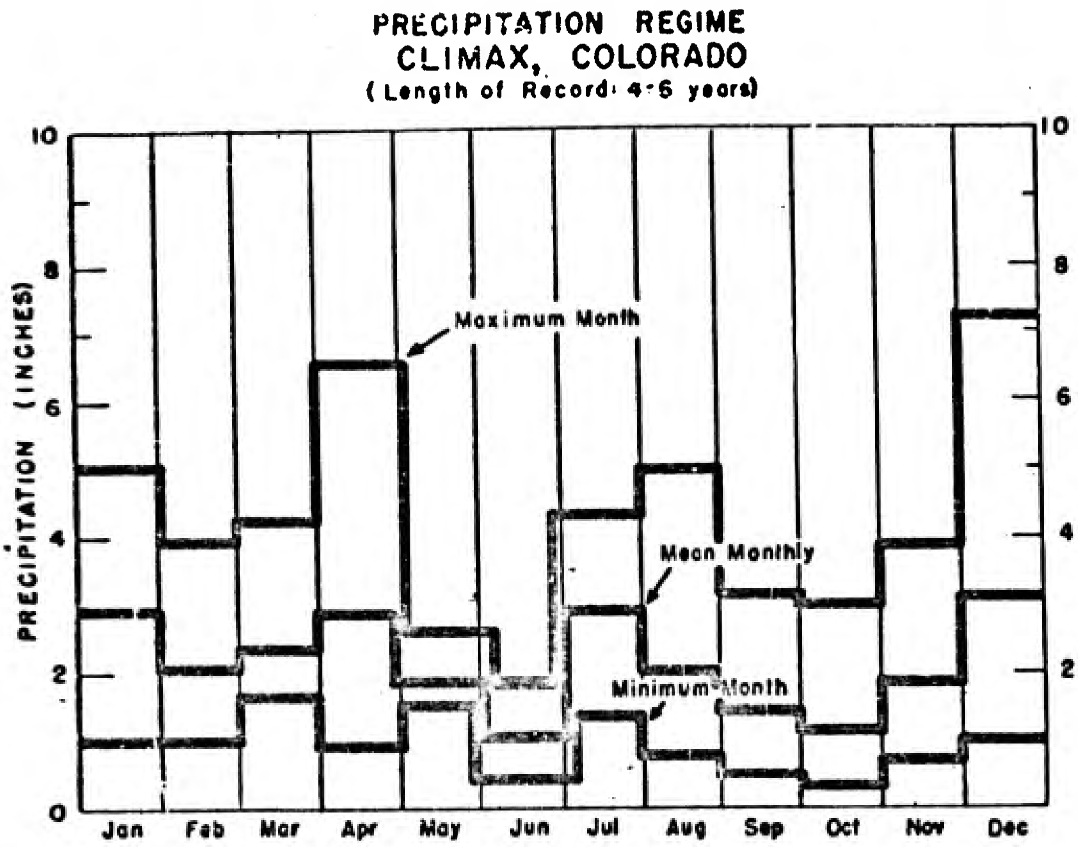

PRECIPITATION REGIME
CLIMAX, COLORADO
(Length of Record: 4-6 years)
PRECIPITATION (INCHES)
Maximum Month
Mean Monthly
Minimum Month
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec
0
2
4
6
8
10

Figure 35

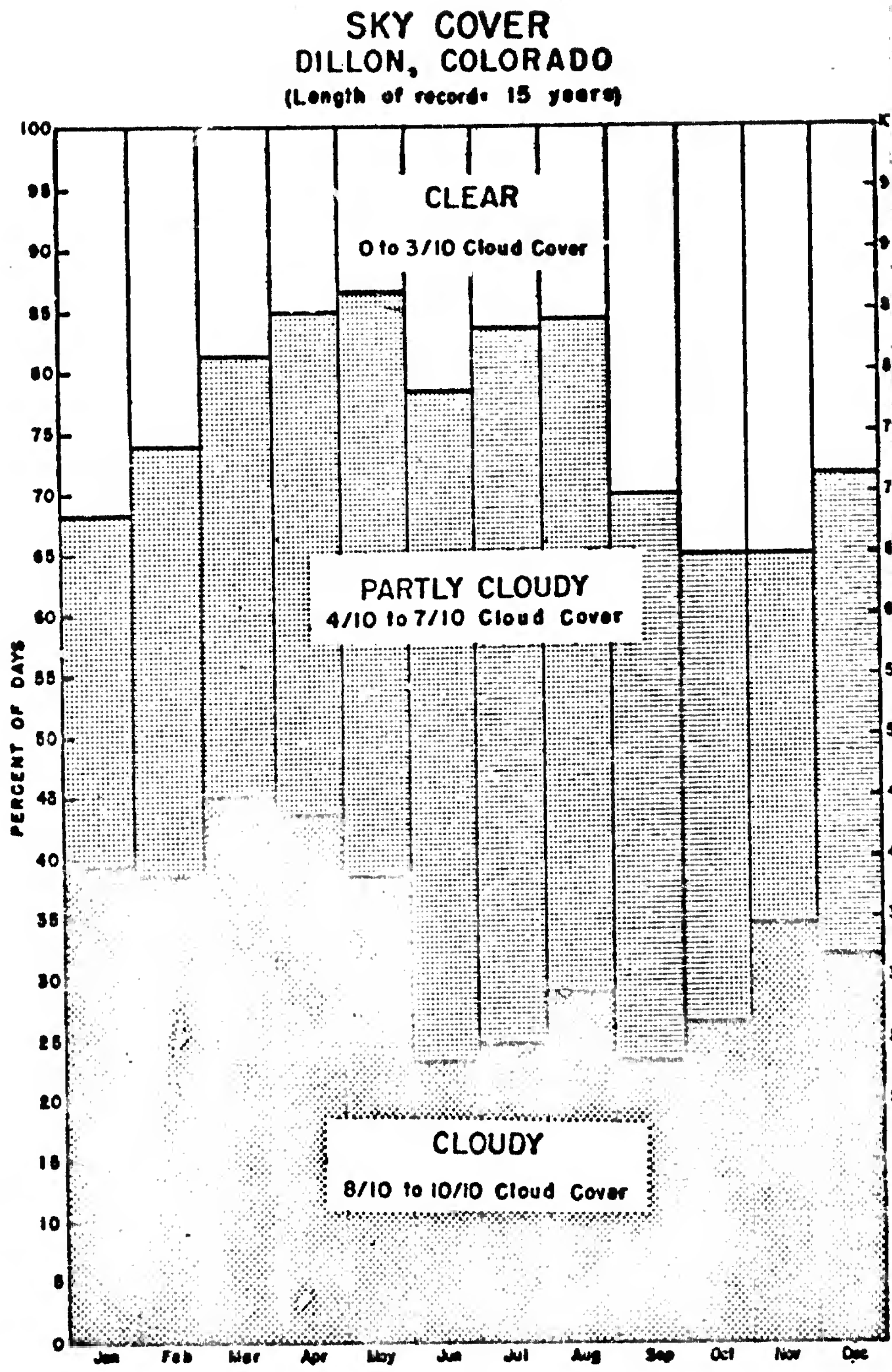
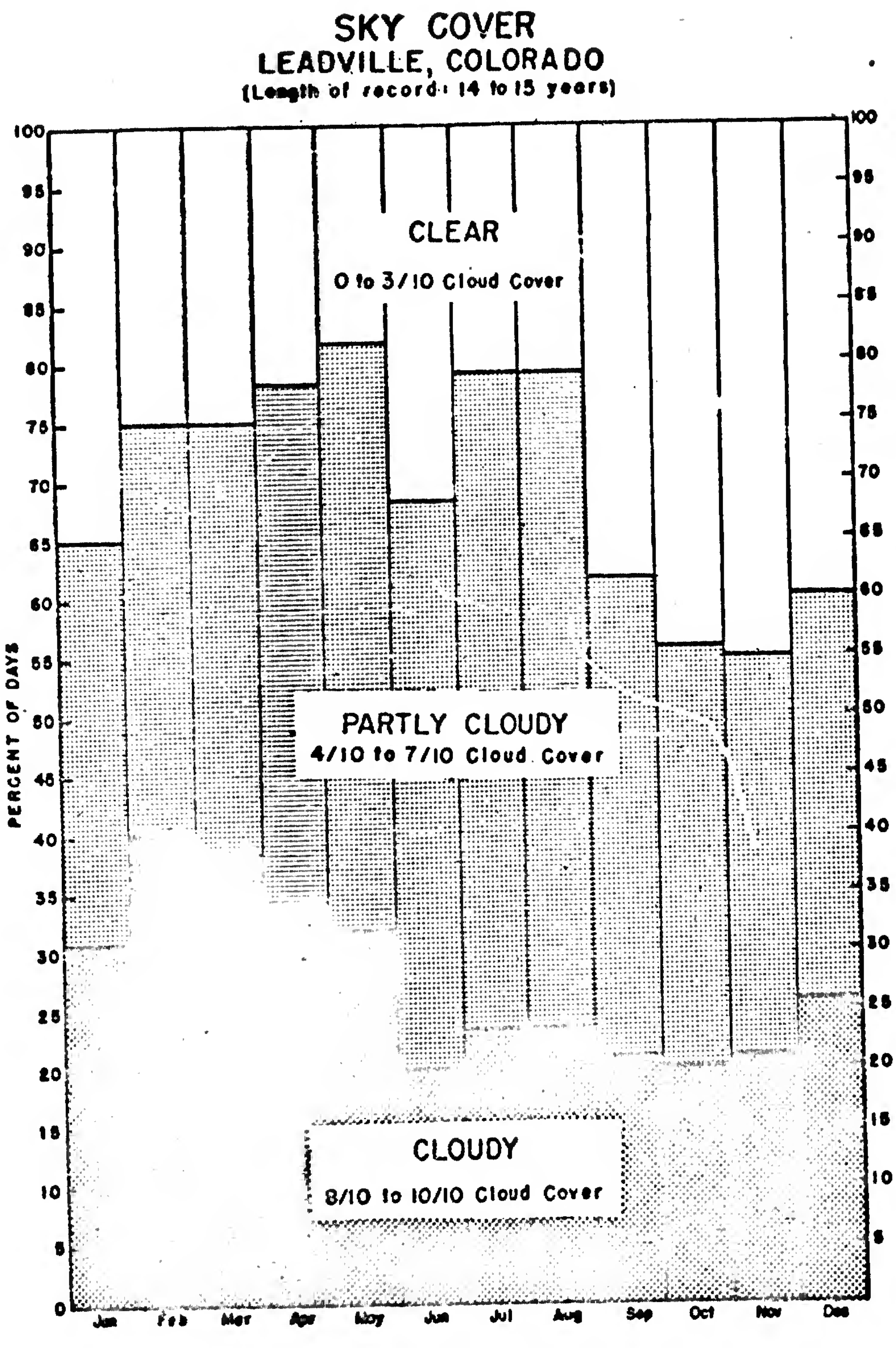

SKY COVER
DILLON, COLORADO
(Length of record: 15 years)
CLEAR
0 to 3/10 Cloud Cover
PARTLY CLOUDY
4/10 to 7/10 Cloud Cover
CLOUDY
8/10 to 10/10 Cloud Cover
PERCENT OF DAYS
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec

Figure 36



SKY COVER
LEADVILLE, COLORADO
(Length of record: 14 to 15 years)
CLEAR
0 to 3/10 Cloud Cover
PARTLY CLOUDY
4/10 to 7/10 Cloud Cover
CLOUDY
8/10 to 10/10 Cloud Cover
PERCENT OF DAYS
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec

Figure 37

APPENDIX B: CLIMATIC GRAPHS FOR THE PIKES PEAK AREA

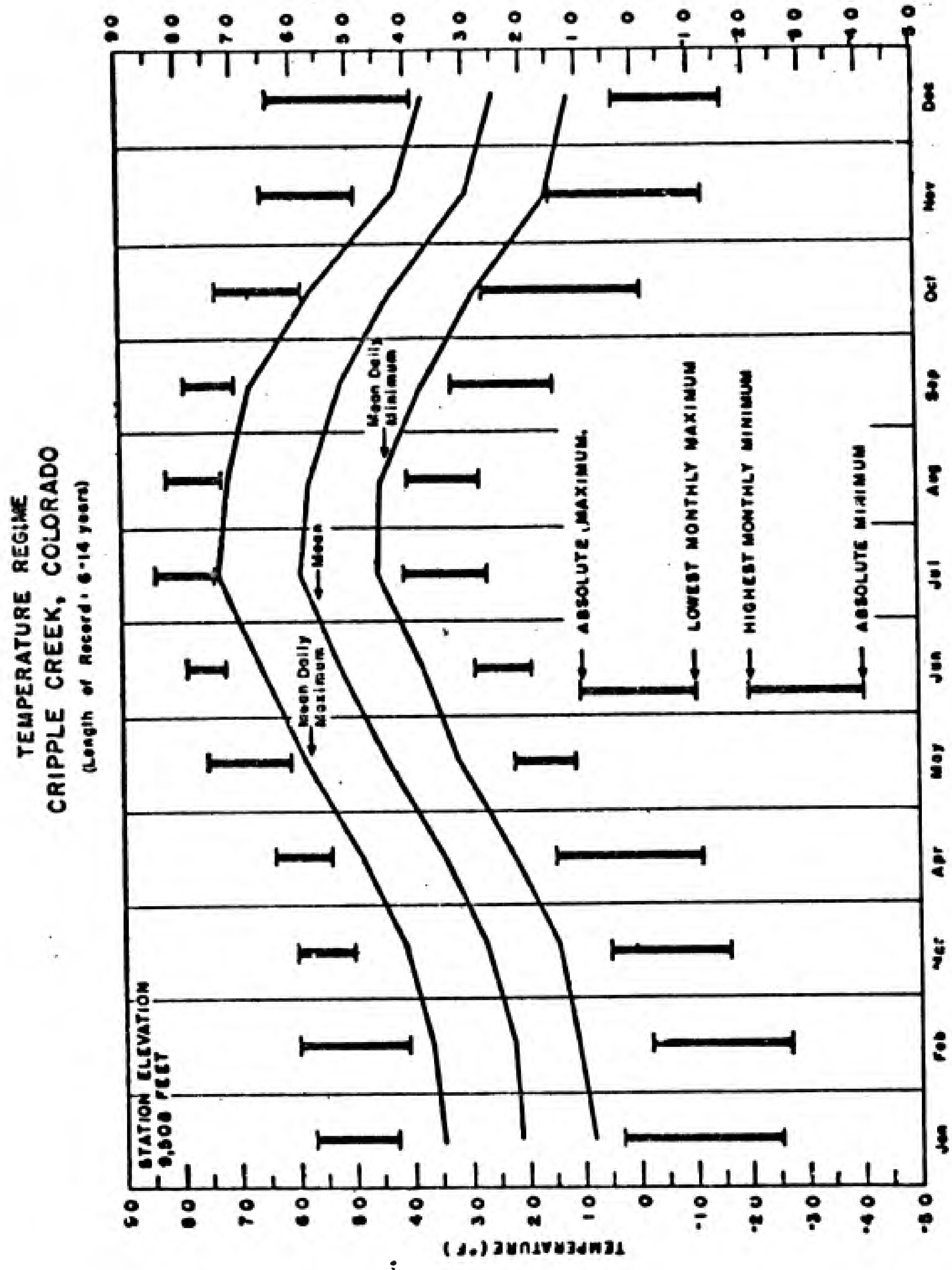

TEMPERATURE REGIME
CRIPPLE CREEK, COLORADO
(Length of Record: 6-14 years)
STATION ELEVATION 9,508 FEET
ABSOLUTE MAXIMUM
LOWEST MONTHLY MAXIMUM
HIGHEST MONTHLY MINIMUM
ABSOLUTE MINIMUM
Mean Daily Maximum
Mean
Mean Daily Minimum
TEMPERATURE (°F)
Jan Feb Mar Apr May Jun Jul Aug Sep Oct Nov Dec

Figure 38

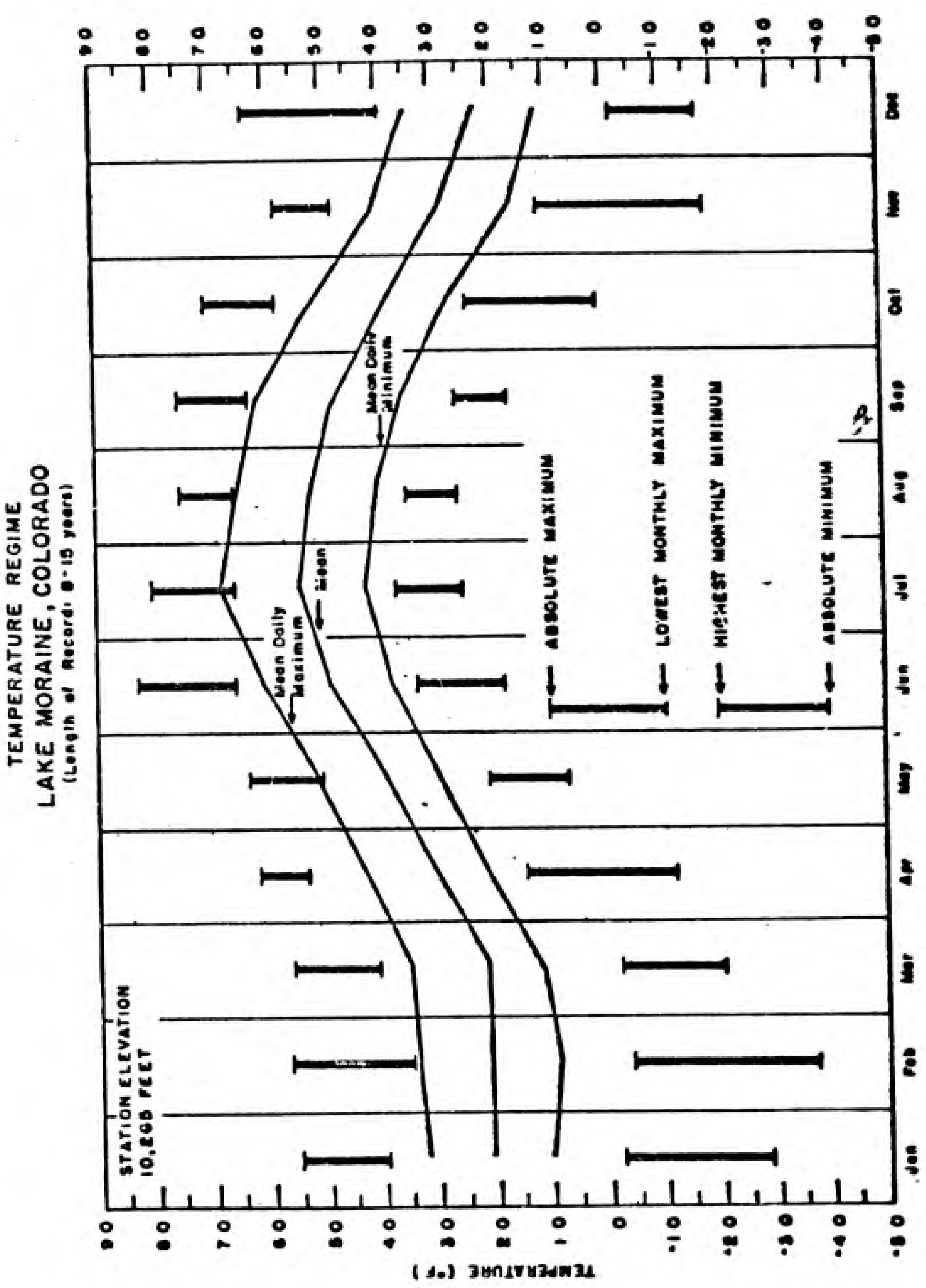

TEMPERATURE REGIME
LAKE MORAINE, COLORADO
(Length of Record: 8-15 years)
STATION ELEVATION
10,265 FEET
TEMPERATURE (°F)
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec
Mean Daily Maximum
Mean
Mean Daily Minimum
ABSOLUTE MAXIMUM
LOWEST MONTHLY MAXIMUM
HIGHEST MONTHLY MINIMUM
ABSOLUTE MINIMUM
90
80
70
60
50
40
30
20
10
0
-10
-20
-30
-40
-50

Figure 39

MEAN AND EXTREME TEMPERATURES AT COLORADO SPRINGS, LAKE MORAINE AND PIKE'S PEAK

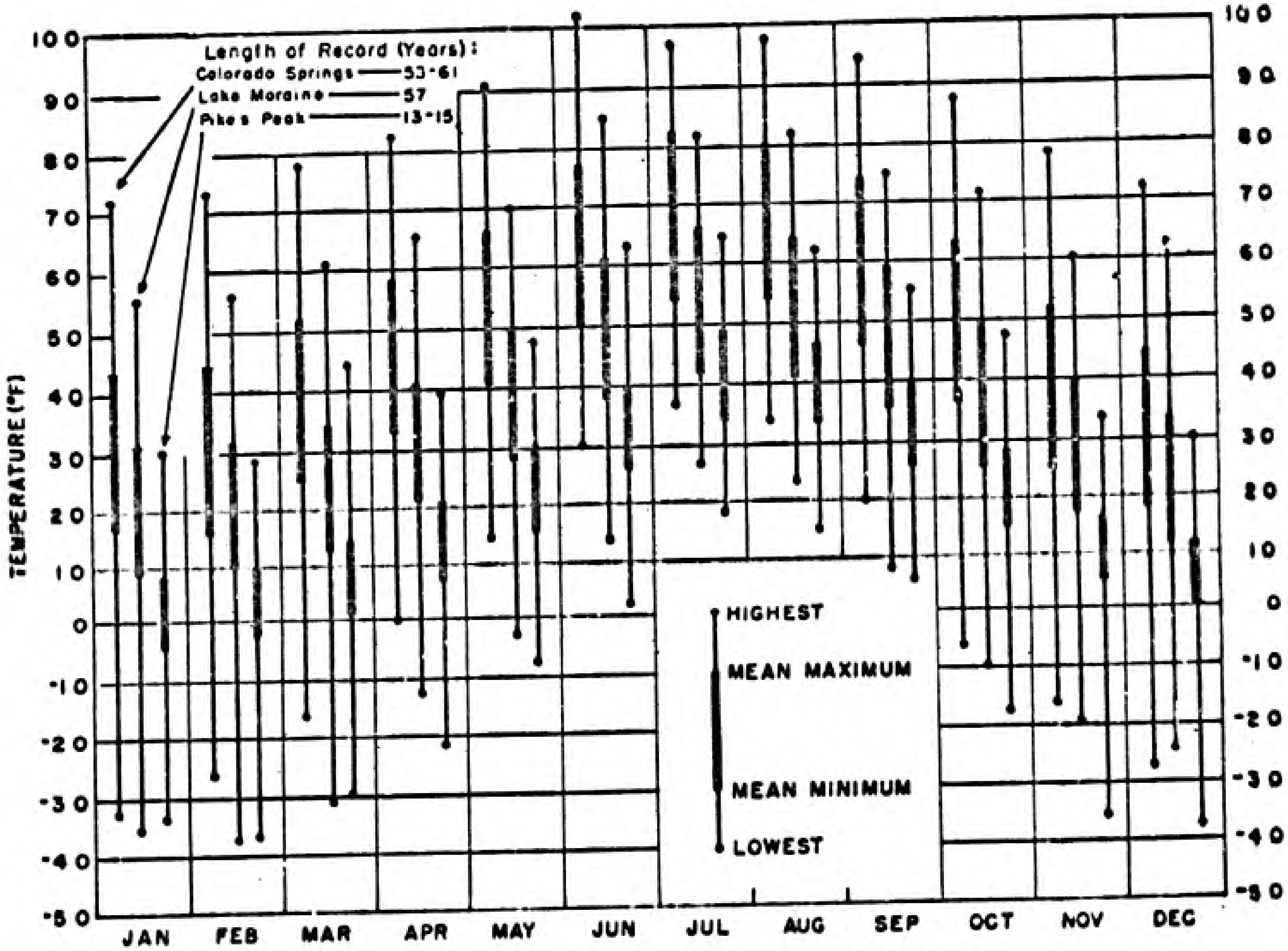


Figure 40

SNOWFALL REGIME
COLORADO SPRINGS, COLORADO
(Length of Record - 7 years)

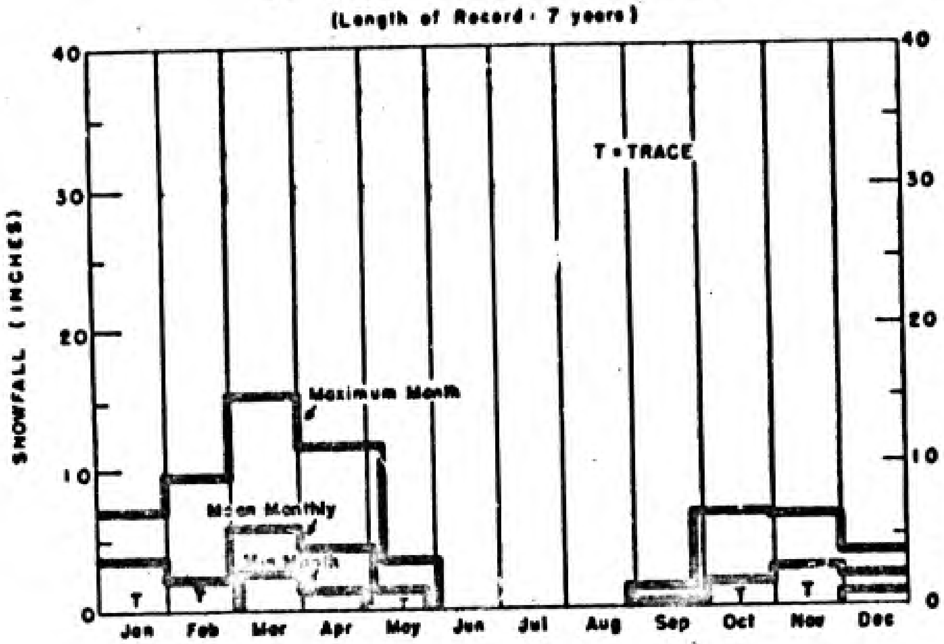


Figure 41

SNOWFALL REGIME
CRIPPLE CREEK, COLORADO
(Length of Record - 9 - 10 years)

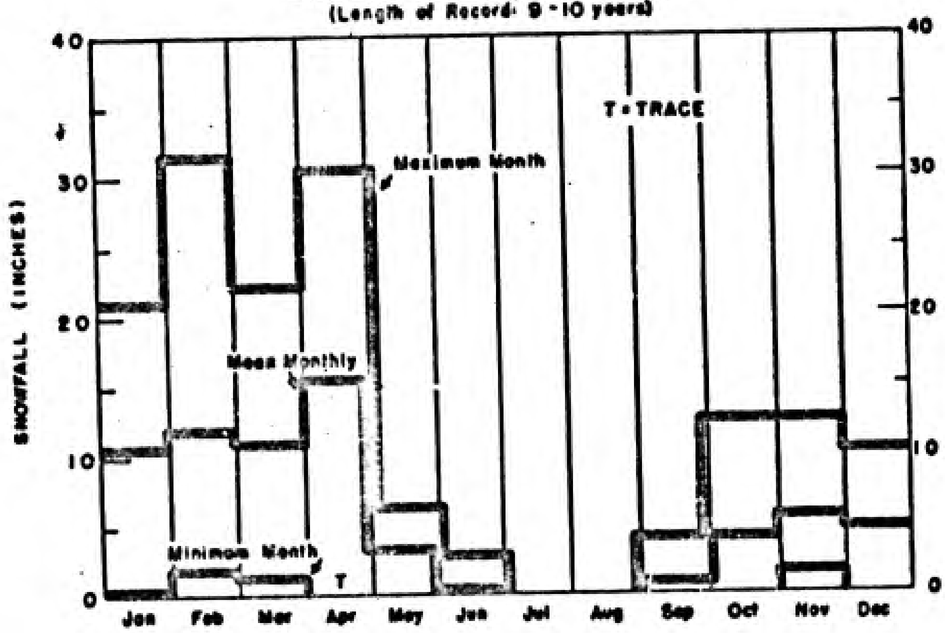
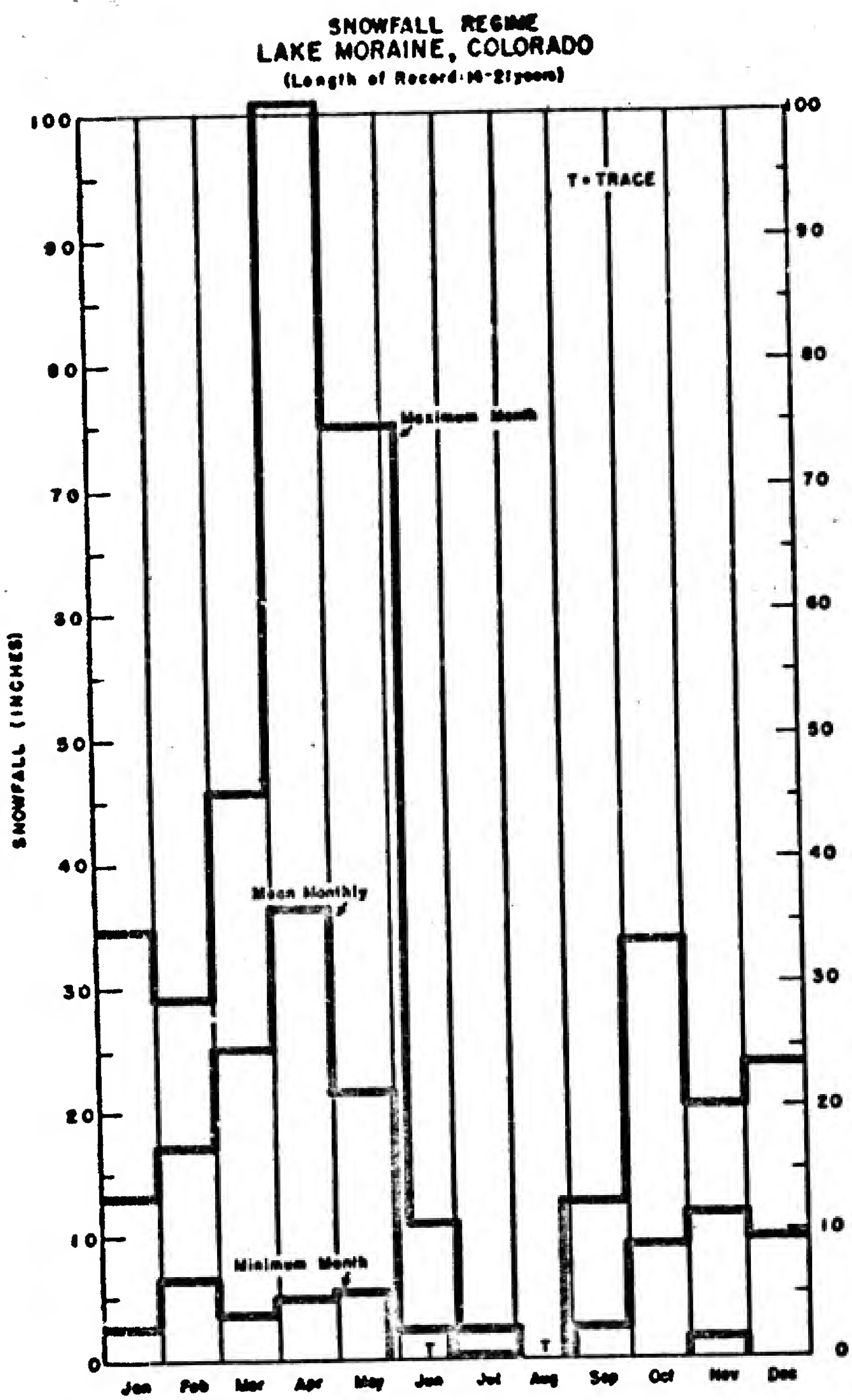


Figure 42



SNOWFALL REGIME
LAKE MORAINE, COLORADO
(Length of Record: 16-21 years)
100
90
80
70
60
50
40
30
20
10
0
SNOWFALL (INCHES)
T = TRACE
Maximum Month
Mean Monthly
Minimum Month
T
T
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec

Figure 43

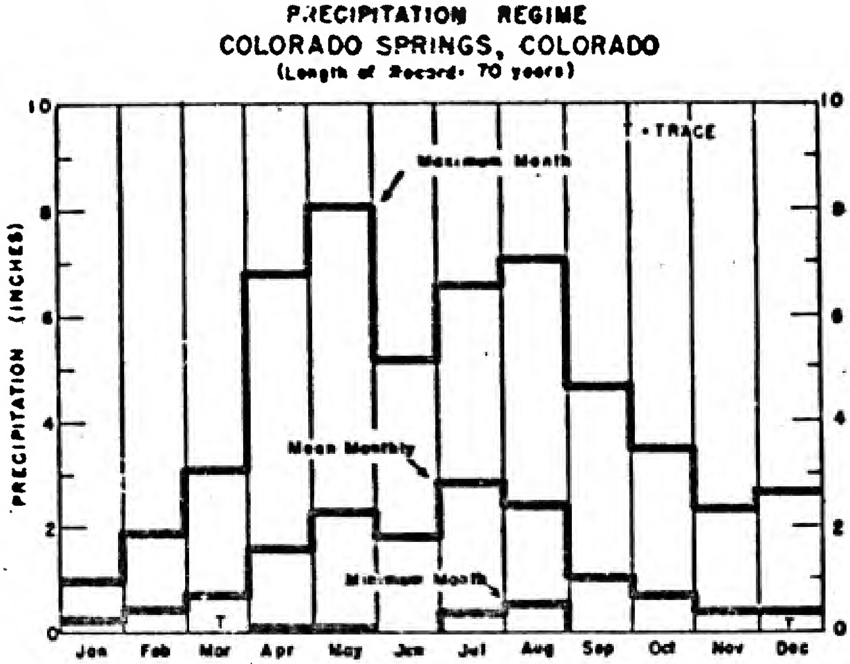


Figure 44

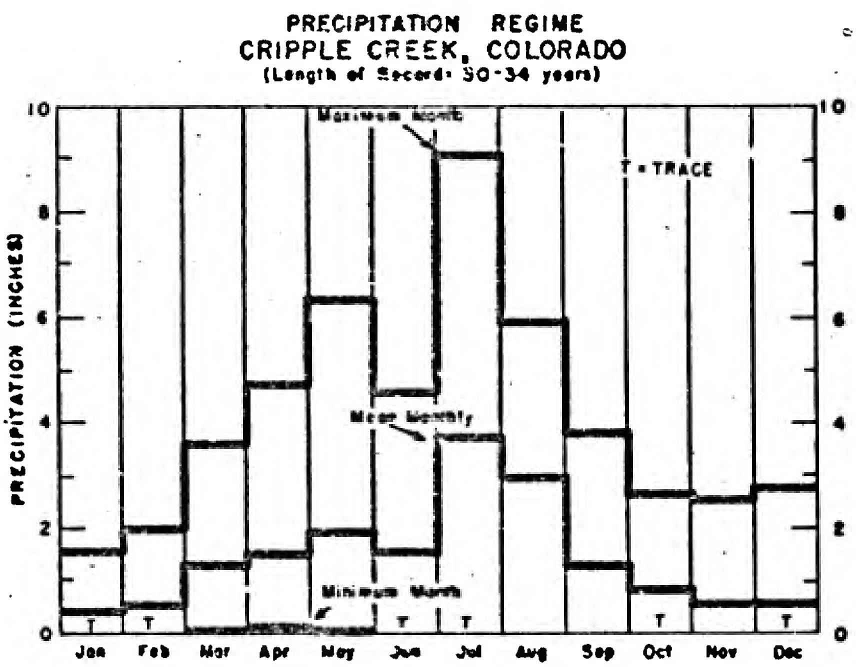


Figure 45

PRECIPITATION REGIME
LAKE MORAINE, COLORADO
(Length of Record: 58 years)

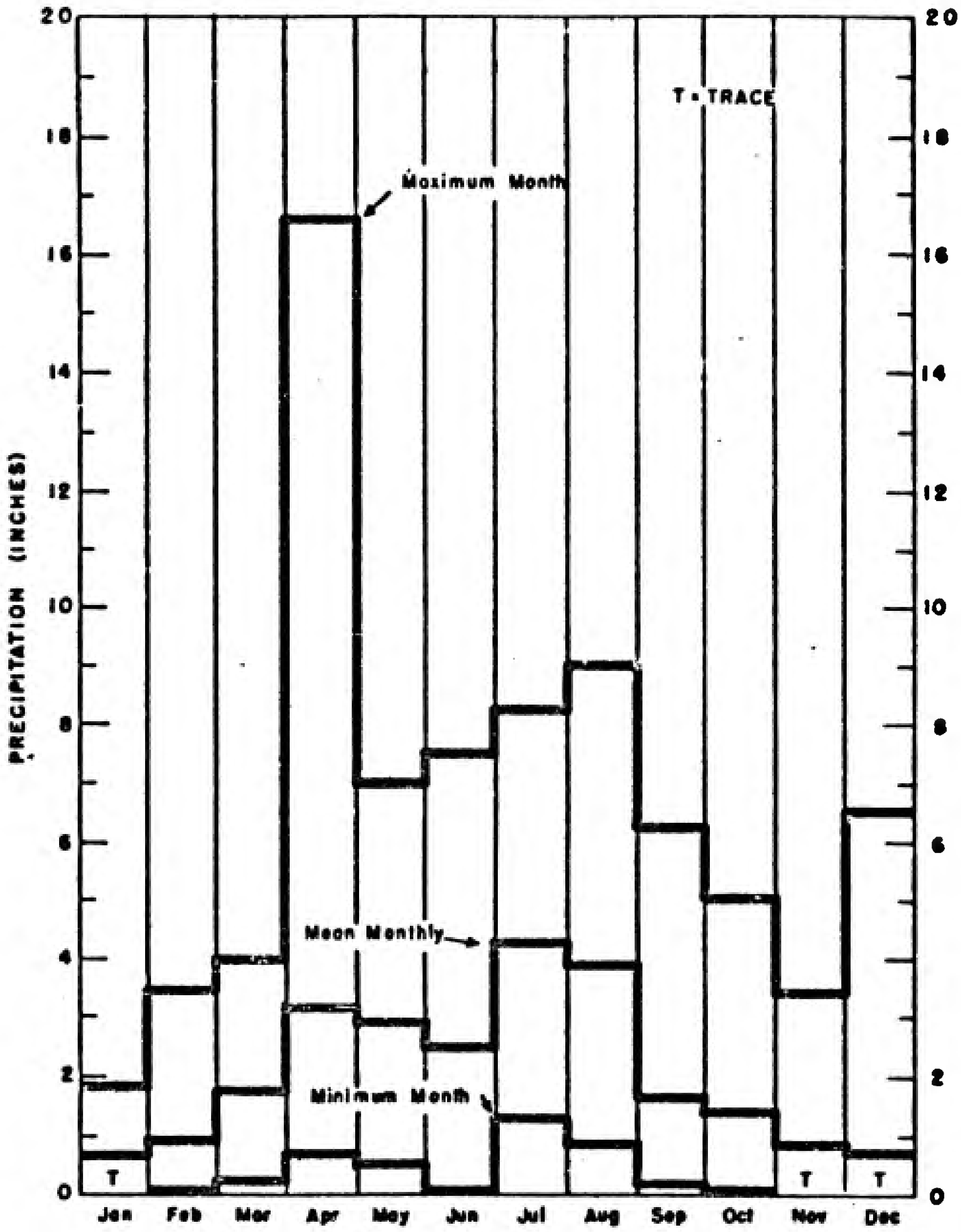


Figure 46

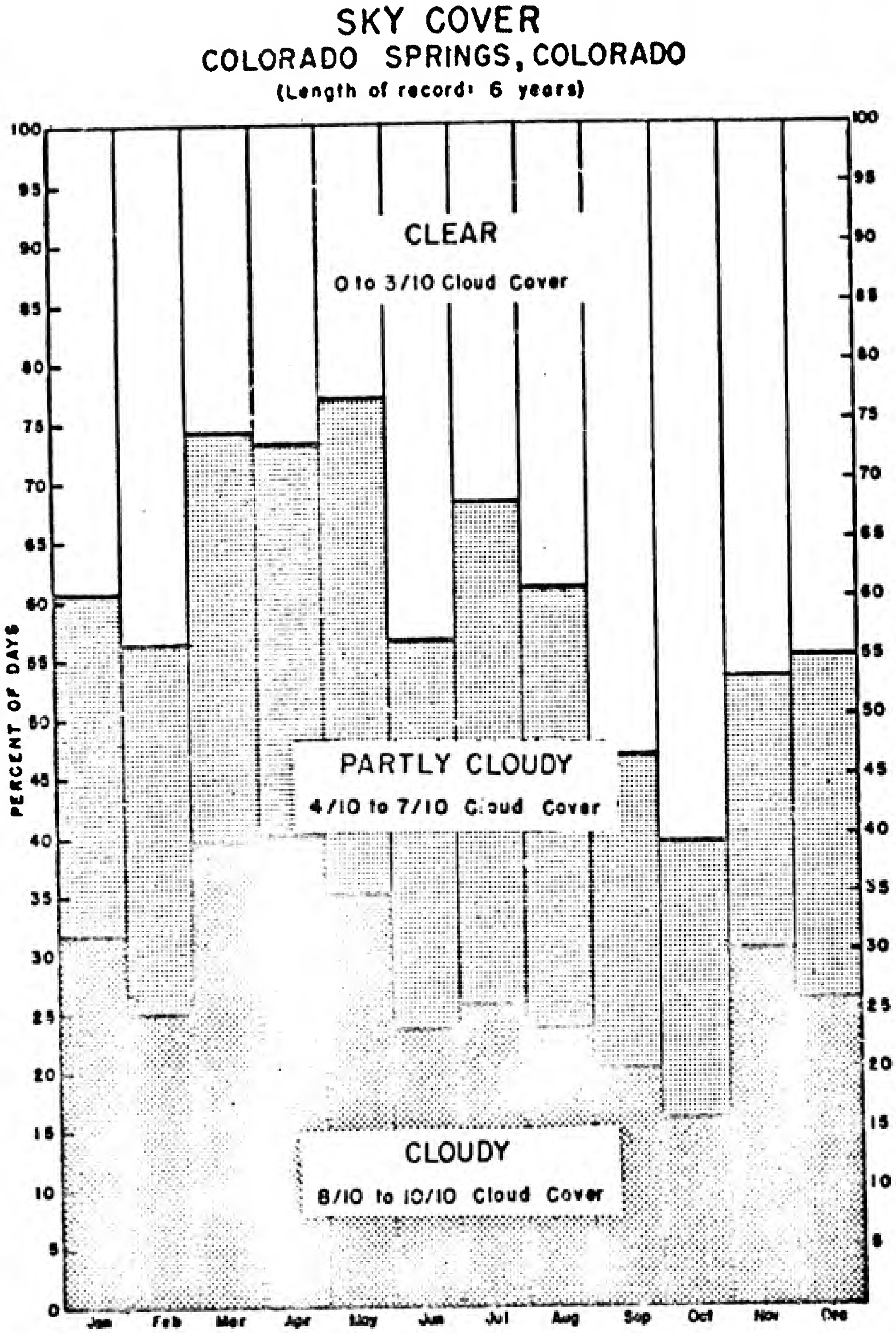

SKY COVER
COLORADO SPRINGS, COLORADO
(Length of record: 6 years)
CLEAR
0 to 3/10 Cloud Cover
PARTLY CLOUDY
4/10 to 7/10 Cloud Cover
CLOUDY
8/10 to 10/10 Cloud Cover
PERCENT OF DAYS
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec

Figure 47

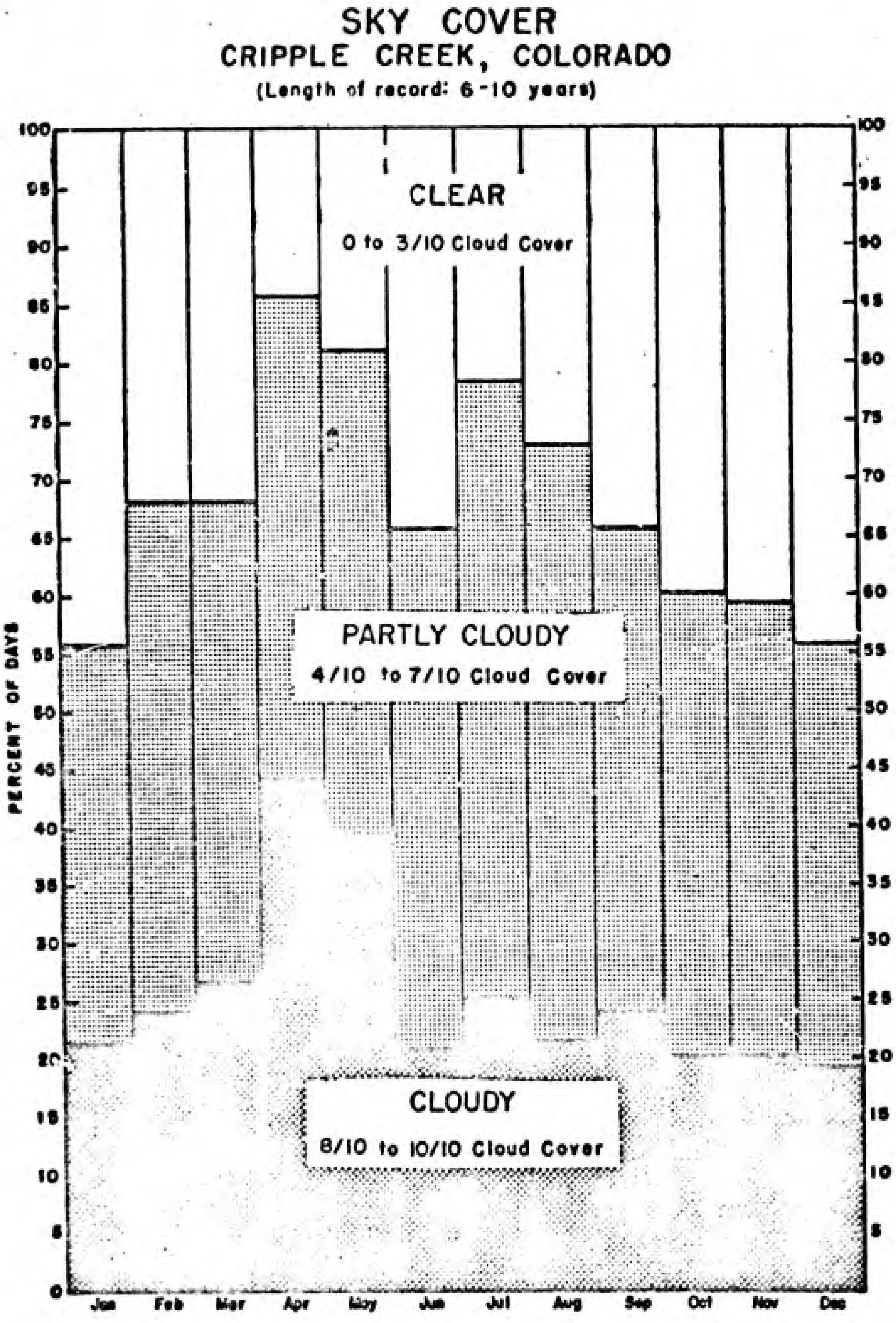

SKY COVER
CRIPPLE CREEK, COLORADO
(Length of record: 6-10 years)
CLEAR
0 to 3/10 Cloud Cover
PARTLY CLOUDY
4/10 to 7/10 Cloud Cover
CLOUDY
8/10 to 10/10 Cloud Cover
PERCENT OF DAYS
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec

Figure 48

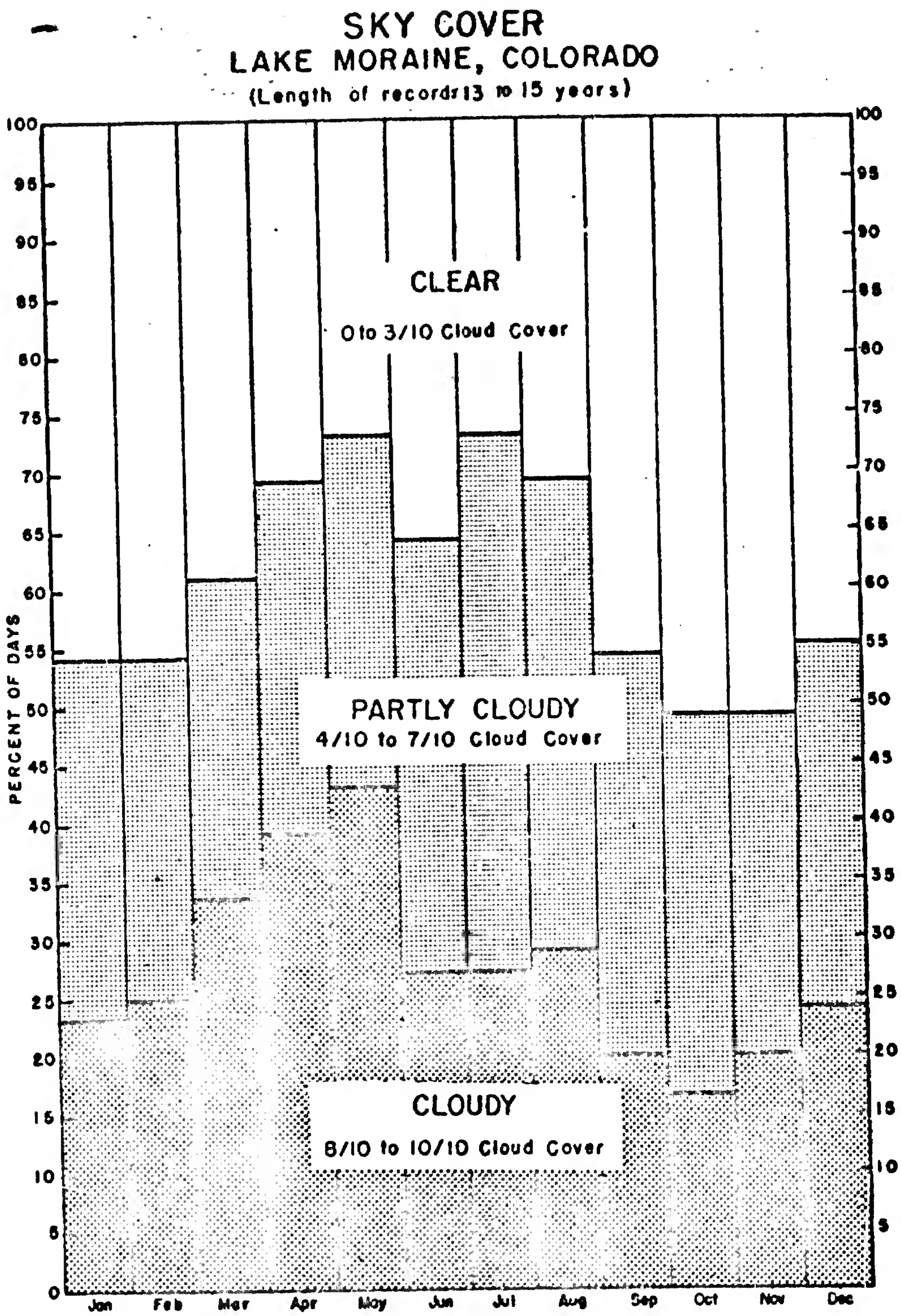

SKY COVER
LAKE MORAINE, COLORADO
(Length of record: 13 to 15 years)
CLEAR
0 to 3/10 Cloud Cover
PARTLY CLOUDY
4/10 to 7/10 Cloud Cover
CLOUDY
8/10 to 10/10 Cloud Cover
PERCENT OF DAYS
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec

Figure 49

APPENDIX C

LINES OF BEST FIT OF MEAN TEMPERATURE AND PRECIPITATION FOR THE EAST AND WEST SLOPES OF THE COLORADO ROCKIES

(Temperature in F degrees; Altitude in feet; Precipitation in inches)

	EAST SLOPE	WEST SLOPE
July temperature:	Temp. = 94.10 - .00395 Altitude	Temp. = 96.92 - .00470 Altitude

S is essentially the same for the two regions and amounts to 1.84 degrees for the two taken together.
K values are significantly different between the two regions.

	EAST SLOPE	WEST SLOPE
January temperature:	Temp. = 52.64 - .00345 Altitude	Temp. = 45.28 - .00393 Altitude

S is essentially the same for the two regions and amounts to 3.54 degrees for the two taken together.
K values are significantly different between the two regions.

	EAST SLOPE	WEST SLOPE
Summer precipitation:	Precip. = 2.76 + .000443 Altitude S = 1.55	Precip. = .43 + .000502 Altitude S = .59

K values and S values are significantly different between the two regions.

	EAST SLOPE	WEST SLOPE
Autumn precipitation:	Precip. = 2.64 + .000063 Altitude	Precip. = 2.91 + .000116 Altitude

S is essentially the same for the two regions and amounts to .77 inches for the two taken together.
K values are significantly different between the two regions.

	EAST SLOPE	WEST SLOPE
Winter precipitation:	Precip. = .34 + .000237 Altitude	Precip. = .18 + .000501 Altitude

S is essentially the same for the two regions and amounts to 1.10 inches for the two taken together.
K values are significantly different between the two regions.

	EAST SLOPE	WEST SLOPE
Spring precipitation:	Precip. = 5.79 + .000088 Altitude S = 1.79	Precip = .68 + .000511 Altitude S = 1.13

S values are significantly different between the two regions.

Differences as large as those cited as significant will occur by chance 1 time out of 20. Example: The mean temperature for July at 10,000 feet on the east slope of the Colorado Rockies can be predicted by substituting the altitude in the first formula above, giving: Temp. = 94.10 - .00395 (10,000) or 54.6°F. This agrees closely with the observed value at Sugarloaf Reservoir at that altitude, 54.8°F. Temperatures are generally less predictable in winter in the Colorado Rockies because of local temperature inversions. The predicted mean for Sugarloaf Reservoir in January is 18.1°F., compared with an actual value of 14.4°F.

NOTES: S = Standard deviation of the data from the lines of best fit
K = The first constant in each formula

APPENDIX D: GLOSSARY

Absolute maximum (or minimum) temperature: Highest (or lowest) air temperature recorded at a meteorological station over the period of record.

Alluvial: Deposited by running water.

Alluvial fan: A fan-shaped or cone-shaped deposit of detritus at the mouth of a gorge or canyon.

Alp: A mountain meadow of a type common in the European Alps. Most alps are less steep than either the glacially oversteepened forested slopes below or the cliffs, if any, that rise above them.

Alpine: (1) Reminiscent of the European Alps. (2) Pertaining to the region above timberline in mountains.

Avalanche: Intermittent snow drainage from mountain slopes, often dangerous.

Buttress: A short ridge extending at an angle from the main ridge of a mountain. Its height is considerably less than that of the main ridge.

Chaparral: Dense, woody, broadleaf evergreen brush or low trees, common in summer-dry regions such as western United States.

Chinook: A wind warmed adiabatically by descending a slope or mountain range. A foehn wind.

Cirque: A valley-head basin formed by glaciation.

Cliff: A slope exceeding the angle of repose; i.e., so steep that detritus falls freely to the base.

Coniferous: Cone-bearing. Most coniferous trees, such as pine, spruce, and fir, are evergreen.

Deciduous: Shedding all the leaves annually. All deciduous trees native to Colorado are broadleaved, as the birch, aspen, and alder.

Detritus: Any loose material resulting from the weathering of rock.

Divide: A ridge-crest between two watersheds.

Erosion: The process of detritus removal by natural agencies such as running water, ice, or wind.

Felsenmeer:* A field of angular boulders derived from underlying bedrock by intensive frost action, usually occurring at high altitudes or latitudes.

Glaciation: Modification of the landscape by glacial erosion.

Glacier:* A body of ice originating on land by the recrystallization of snow or other forms of solid precipitation and showing evidence of past or present flow.

Gneiss: A form of metamorphosed granite having parallel dark and light bands.

Grus: Loose granular material produced by the weathering of granite.

Igneous rock: Rock which solidified from a molten magma.

Intrusive rock: Igneous rock which solidified before reaching the surface of the earth.

Kobresia: A genus of sedge, forming dense sod at high elevations.

Krummholz: Stunted, gnarled trees, usually coniferous, forming low mats at timberline.

Mean daily maximum temperature: The average of the highest air temperature recorded each day in a given period at a meteorological station.

Mean daily minimum temperature: The average of the lowest air temperatures recorded each day in a given period at a meteorological station.

Mean temperature: The average of daily maximum and minimum temperatures, or, when available, of hourly or bi-hourly temperatures, during a given period at a meteorological station.

Montane: Pertaining to the altitudinal zone immediately below that occupied by subalpine vegetation. In the Pikes Peak area the montane zone extends from approximately 7,000 to 9,000 feet elevation.

---

* Interpretations of many of the terms listed in this glossary vary with different authors. The definitions given here are in each case the meanings used in the present paper. Definitions marked by an asterisk (*) are as given in the Glossary of Arctic and Subarctic Terms, ADTIC publication A-105, Research Studies Institute, Maxwell Air Force Base, Alabama, September 1955.

Moraine: Material carried or laid down directly by glaciers without the intervention of running water or other geologic agencies.

Outcrop: Bedrock exposed at the surface.

Perennial: Existing continuously for more than one year.

Permafrost:* A thickness of soil, superficial deposit, or bedrock of variable depth beneath the surface of the earth in which below-freezing temperature has existed for a long time. Also called "perennially frozen ground."

Precipitation: Moisture falling from the air to the earth's surface. It may be in the form of rain, snow, hail, or some modification of them.

Rock glacier: A mass of angular rock fragments in a cirque, valley, or valley head, whose form may resemble that of a glacier.

Rock stream: A ribbon of rubble extending down a subalpine slope or following the bed of a steep subalpine valley.

Scarp: An oversteepened slope of considerable linear extent, usually without gaps permitting level passage.

Spur: A ridge extending at an angle from the main ridge of a mountain, often moderately long but not connecting at a high level with another mountain.

Steppe: Temperate grassland comparable to that of southern Russia.

Subalpine: Pertaining to the first altitudinal zone below timberline, with its characteristic vegetation.

Subalpine fir: A species of fir (Abies lasiocarpa) common in the subalpine zone in Colorado.

Subarctic:* (1) Pertaining to the region between the midlatitudes and the Arctic. (2) The region covered by the boreal forest, bounded on the north by the tree line and on the south by a zone in which the coniferous forest is gradually replaced by a midlatitude type of vegetation such as steppe or mixed forest.

Sublimation: The passage of moisture directly from the frozen to the vapor state and vice versa.

Talus: Rubble accumulated at the base of a cliff by free fall from its face.

Timberline: The uppermost limit of tree growth in a given area.

Watershed: The catchment area of a river or lake.

Weathering: The process by which rock is broken down into detritus by atmospheric and biotic agencies and gravity.

UNCLASSIFIED

AD 209640

Armed Services Technical Information Agency

ARLINGTON HALL STATION
ARLINGTON 12 VIRGINIA

FOR MICRO-CARD CONTROL ONLY

2 OF 2

NOTICE: WHEN GOVERNMENT OR OTHER DRAWINGS, SPECIFICATIONS OR OTHER DATA ARE USED FOR ANY PURPOSE OTHER THAN IN CONNECTION WITH A DEFINITELY RELATED GOVERNMENT PROCUREMENT OPERATION, THE U. S. GOVERNMENT THEREBY INCURS NO RESPONSIBILITY, NOR ANY OBLIGATION WHATSOEVER; AND THE FACT THAT THE GOVERNMENT MAY HAVE FORMULATED, FURNISHED, OR IN ANY WAY SUPPLIED THE SAID DRAWINGS, SPECIFICATIONS, OR OTHER DATA IS NOT TO BE REGARDED BY IMPLICATION OR OTHERWISE AS IN ANY MANNER LICENSING THE HOLDER OR ANY OTHER PERSON OR CORPORATION, OR CONVEYING ANY RIGHTS OR PERMISSION TO MANUFACTURE, USE OR SELL ANY PATENTED INVENTION THAT MAY IN ANY WAY BE RELATED THERETO.

UNCLASSIFIED