DEPARTMENT OF THE INTERIOR
FRANKLIN K. LANE, Secretary
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THE GEOLOGIC STORY
OF THE
ROCKY MOUNTAIN NATIONAL PARK
COLORADO

BY

WILLIS T. LEE, Ph. D.
Geologist, United States Geological Survey

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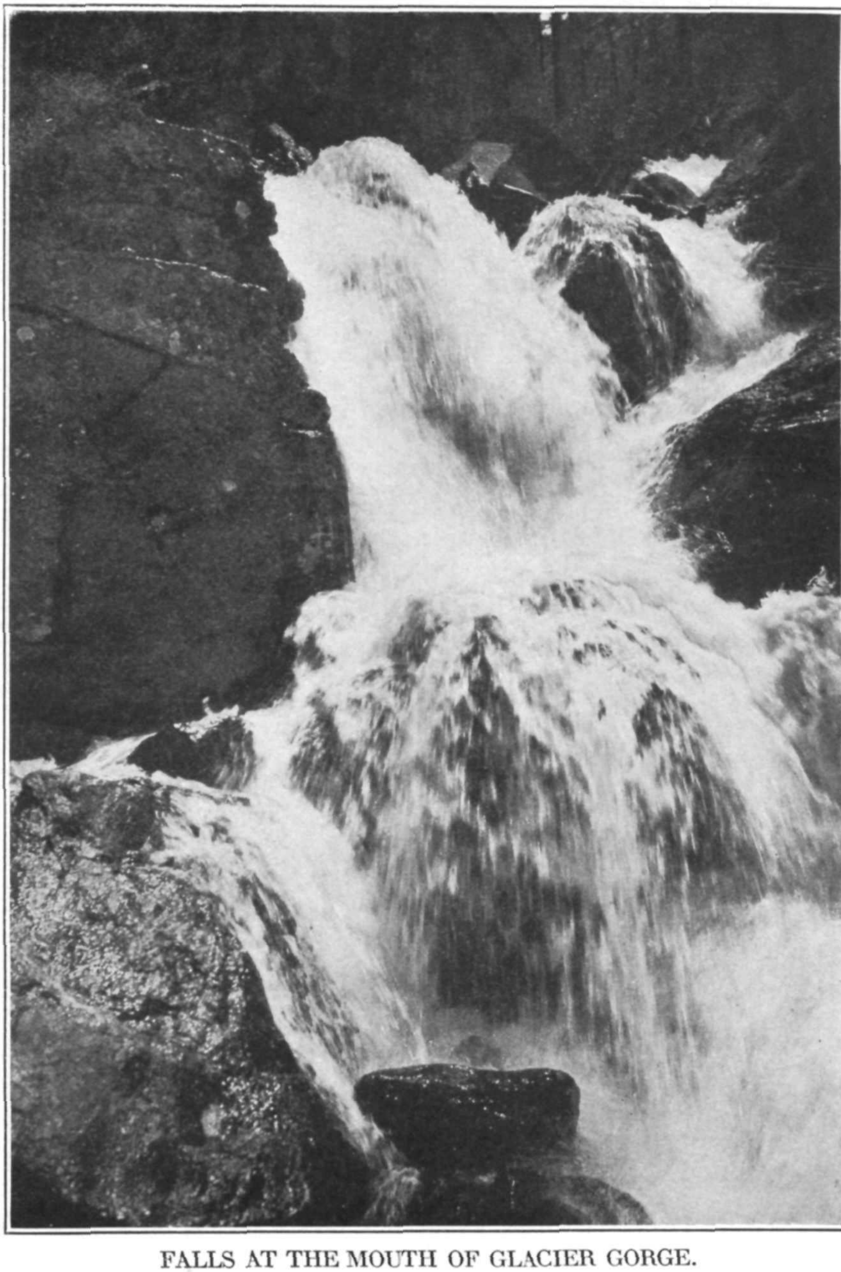
CONTENTS.

ILLUSTRATIONS.



FALLS AT THE MOUTH OF GLACIER GORGE.

Photograph by Willis T. Lee, United States Geological Survey.

THE GEOLOGIC STORY OF THE ROCKY MOUNTAIN NATIONAL PARK, COLORADO.

By Willis T. Lee, Ph. D.

INTRODUCTION.

LOCATION AND CHARACTER.

On January 26, 1915, a particular section of the Rocky Mountains chosen as representative of the noblest qualities of the mountain region was set aside as the Rocky Mountain National Park.

This park covers an area of approximately 398 square miles, situated in the high mountains of the Front Range in north-central Colorado, about 50 miles in a straight line northwest of Denver. Altitudes within it range from 8,000 to 14,255 feet above sea level. The mountains are of such height that during the greater part of each year they are spangled or completely covered with snow. Hence the Front Range is often called the Snowy Range.

Denver, the metropolis of the western plains, through which most of the visitors pass on their way to the Rocky Mountain National Park, is only 50 miles from Estes Park, the gateway. The park is within 30 hours of Chicago and St. Louis and is much closer to Kansas City and many other great centers of population in the central part of the United States. Probably no other national playground is more easily reached by a large number of people.

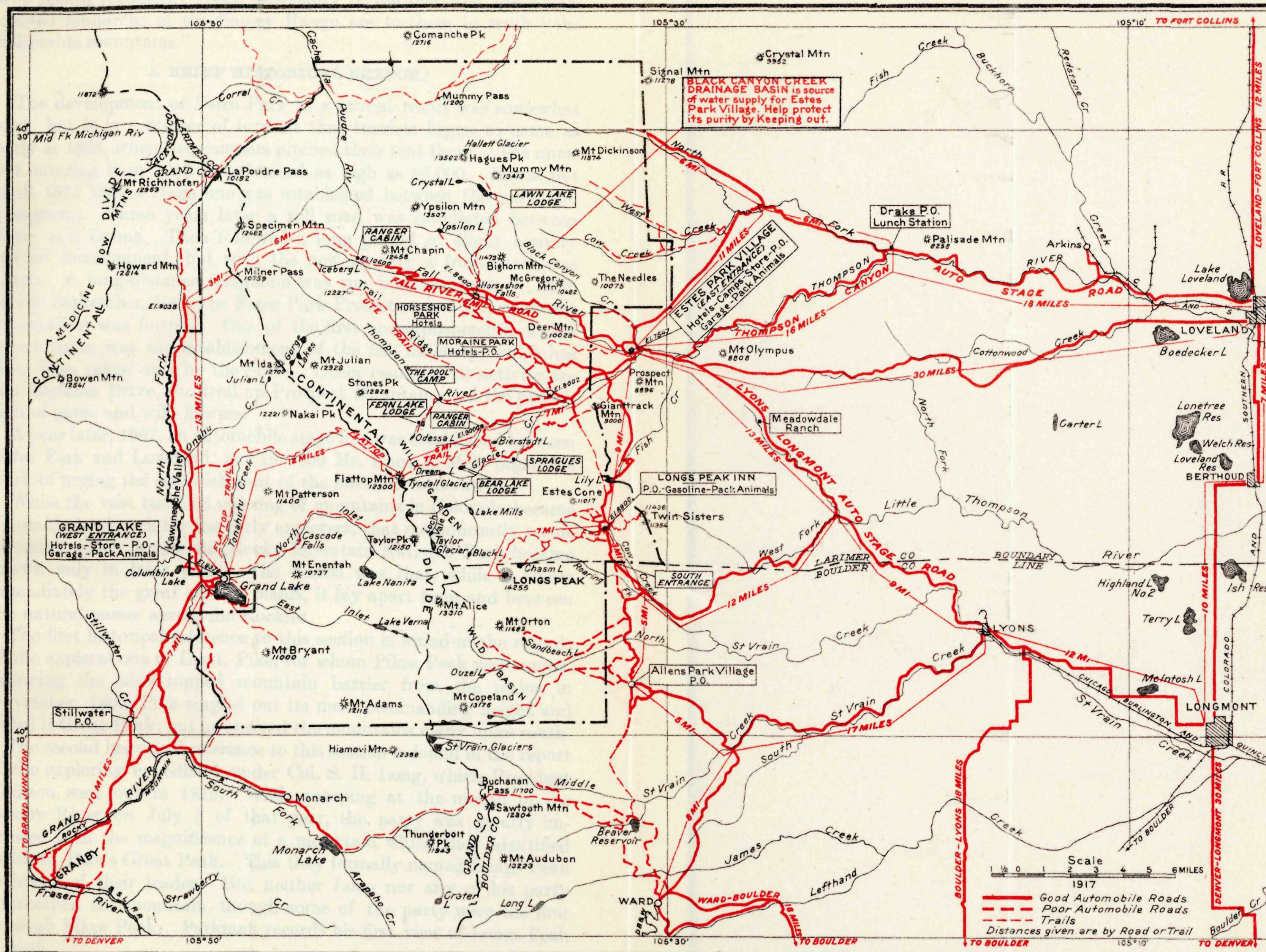
The appeal of this park to the tourist is varied, and few fail to find satisfaction here. In it are accommodations for visitors of every kind, from the man who wants the conveniences of the modern hotel to the one who wishes to throw off restraint and to live for a time the care-free life. Here he may bivouac by rock and stream in the primeval forest or obtain the comforts of modern life in easy reach of perpetual ice, where cool breezes from the snow fields render delightful the bright summer days and make welcome the warmth of the camp fire on the clear, cool evenings.

The naturalist may find plant and animal life of all zones, from Temperate to Arctic. The artist has an inexhaustible supply of landscapes, ranging in character from mountain crag to flowery glade. The weary in mind or body find new vigor, while the vigorous have inexhaustible opportunities of testing their endurance.

For glorious, sunny days and cool, restful nights the Rocky Mountain National Park can not be surpassed. The weather is dependable. The crisp, sparkling atmosphere, laden with the pungent breath of pine and spruce, is a never-failing delight to the experienced and to the amateur alike. Here the oppressive heat of lower altitudes and damper climates is unknown, and mosquitoes need not be thought of, for the nights are too cold for them. There is an abundance of dead and down firewood for the great, roaring campfires, around which the cool evenings may be spent spinning yarns and telling stories of adventure which no one need believe. Thunderstorms are of frequent occurrence, but little rain falls. The storm soon passes, and usually its most conspicuous result is the wonderful cloud effects which so delight the heart of the artist. The streams are fed by the melting snow of the high mountains, and their waters are clear, cool, and healthful.

Like Bunyan's pilgrims, who in the course of their progress came to the "delectable mountains," the modern pilgrims are coming in increasing thousands to find their hearts' desire in the delectable mountains of the Snowy Range in the Rocky Mountain National Park. They come afoot and awheel, some with blankets and provisions on their backs, many on motorcycles, and great numbers in automobiles. Occasionally a horse-drawn vehicle is seen. But, however they come, it is with eyes fixed on the glowing peaks with feverish impatience to reach the wonderland of the dreams that have illumined the weeks and months during which their vacation plans were forming.

Whether they come in May or November, the general result is the same. The tourist of early summer is charmed by the great snow banks of the white-crested mountains and enthusiastically watches as they disappear and flowers spring into bloom in their place. Many of the plants push their tender stalks through the last remnants of the snow and burst into bloom while the ice actually covers their roots. The midsummer visitor is equally enthusiastic over the flowery glades, the spicy fragrance of the forest, the magnificence of the views obtained during the long excursions, and the exhilaration of venturesome climbing. The late visitor declares that the fall is supreme, when the air is crisp and the trout are hungry; when the frosts are painting the aspen-covered slopes, and the fleecy cover of the peaks is extended lower and lower with each recurring storm, until the whole range is covered for its winter sleep with a mantle of glistening white. But, comes the tourist early or late, the constantly increasing number of visitors and the great number of those



MAP OF ROCKY MOUNTAIN NATIONAL PARK

who return repeatedly speak eloquently of the fact that the white-crested monarchs of the Snowy Range are to them in truth "the delectable mountains."

A BRIEF HISTORICAL SKETCH.[1]

The development of Estes Park as a tourist resort was somewhat slow, but it is a matter of interest that tourists began to come as early as 1865, when two campers pitched their tent there. The number entering it in 1916 is estimated as high as 86,000. It was not until 1874 that a stage line was established between the park and Longmont. Three years later a toll road was completed between Estes and Lyons. Then followed a long period of slight activity toward development, but with the new century a fresh start was taken. A long-distance telephone was run into the park in 1900, and in September, 1906, the Estes Park Protective and Improvement Association was formed. One of the first accomplishments of this organization was the establishment of the fish hatchery, which has since been taken over by the State. Other results of its activity are the Highline Drive, the trail up Prospect Mountain, and the protection of game and wild flowers.

A year later, 1907, an automobile stage line was established between Estes Park and Loveland, and in 1909 Mr. Enos A. Mills began his work of urging the establishment of the national reservation.

While the vast tumbled massing of mountains in Colorado became a notable landmark for the early explorers, that magnificently scenic grouping which is now the Rocky Mountain National Park became known only in later years. The reason was that, while it fronts immediately the great eastern plains, it lay apart from and between the natural passes across the Rockies.

The first historical reference to this section is found in the records of the explorations of Lieut. Pike, for whom Pikes Peak was named. Scanning the snow-topped mountain barrier from the plains in November, 1806, Pike singled out its most commanding height and called it Great Peak; but he entered the mountains many miles south.

The second historical reference to this section is found in the report of the exploring expedition under Col. S. H. Long, which President Madison sent out in 1819. While camping at the mouth of the Poudre River on July 3 of that year, the party was greatly impressed with the magnificence of a mountain which they identified as Lieut. Pike's Great Peak. This they formally named Longs Peak in honor of their leader. But neither Long nor any of his party approached the mountain, though some of the party were the first to climb Pikes Peak. Parkman records his first view of Longs Peak in 1845.

[1] This sketch was prepared at my request by Mr. Robert S. Yard, of the National Park Service.

The early trappers knew the mountains, which then were fairly alive with game, great and small. Enos Mills states that Kit Carson was probably the first white trapper to visit them. Carson camped in the valleys to the east probably in 1840.

The first settler came in 1860. He was Joel Estes, from whom the broad valley was afterwards named Estes Park. He built a cabin on Willow Creek in the foothills. At that time there were numerous remains of former Indian residents in the valleys, but no Indians. For many years after that the region was visited by trappers, who followed the deer and elk and trapped the beaver in the valleys and shot the bear and mountain sheep in the rocky fastnesses of the great mountains. Settlers came slowly. In 1868 arrived James Nugent, afterwards widely celebrated as "Rocky Mountain Jim."

The superb commanding height of Longs Peak naturally tempted the early comers. In 1864 William N. Byers, founder of the Rocky Mountain News, made the first attempt to climb it. This was unsuccessful, as were all other attempts until August 23, 1868, when Mr. Byers accomplished the feat. With him were Maj. J. W. Powell, who, the following year, made his celebrated first exploration of the Grand Canyon, W. H. Powell, L. W. Keplinger, Samuel Gorman, Ned E. Farrell, and John C. Sumner.

In 1871 the first regular guide on Longs Peak, the Rev. E. J. Lamb, made his first ascent. He descended by the east precipice, a dangerous feat which Enos Mills repeated in 1903.

The exceptionally fine hunting through this entire region caused Earl Dunraven in 1872 to attempt the acquisition of a great preserve. Men were hired to file claims which he afterwards acquired; but these claims proved invalid. But he maintained a ranch in the Estes Valley for some years.

In 1874 Albert Bierstadt visited the region as Earl Dunraven's guest. Some of his most celebrated paintings are the fruit of this visit. This same year the first stage line was established between Estes Park and the village of Longmont, on the plains at the eastern edge of the foothills. Immediately thereafter many came to stay.

The first formal hotel was built by Earl Dunraven upon a site chosen by Bierstadt. This was destroyed by fire. The Dunraven properties were acquired by Mr. F. O. Stanley, who by the erection in 1909 and 1910 of handsome modern hotels costing half a million dollars gave Estes Park its first big impetus as a summer resort. In recent years many hotels of many kinds have been built in the eastern valleys, and last year 86,000 persons found roofs to cover them. Meantime many miles of valley road were laid out, giving access to beauty spots in the glens and gorges between the rocky knees of the great range, and trails were built into the heart of the mountains and across the range to Grand Lake, which meantime had become a prosperous resort on the west side.

In 1915 Congress set apart 358 square miles of the front range, with Longs Peak for the culminating center, as the Rocky Mountain National Park. In 1917 Congress added more than 40 square miles to this territory, bringing its boundary within a short distance of the village of Estes Park.

IN THE DAYS OF THE ABORIGINES.

The Arapahoe Indians once claimed the Rocky Mountain National Park as a part of their domain, and many of their place names are interesting and significant. An effort has been made, particularly by the Colorado Mountain Club, to preserve these names. Some of the Arapahoes, now old men who had visited the park in their youth, were brought back recently and questioned as to names of places and the legends connected with them. The story of their visit has been written by Oliver W. Toll. Unfortunately this story had not been published at the time the present account was written. However, the manuscript was kindly loaned by Miss Harriet Walcott Vaille, secretary of the Colorado Mountain Club, and from it were taken the notes explaining the Indian names scattered through the following description.

ACCESSIBILITY.

The value of a public park largely depends on the use that may be made of it. In accessibility the Rocky Mountain National Park is favorably situated. It contains mountain scenery of the highest order of beauty and grandeur and at the same time is the most easily reached by a large number of people of all our national playgrounds. (See fig. 1.) Its gateway from the east is the village of Estes Park, situated within the mountains in a beautiful valley of the same name. Its gateway from the west is Grand Lake.

There are several ways of reaching Estes Park (see Pl. I, in pocket) from the plains lying east of the mountains. Three routes are extensively used—the Thompson Canyon Road from Loveland to Estes Park, the Lyons-Longmont Road between Lyons and Estes Park, and the road from Ward northward by way of Allens Park and Longs Peak.

From Estes Park and the several hotels and lodges situated just outside the boundary of the national park many of the points of interest may be reached by automobile, and the tops of the highest mountains may be reached by a day's travel on foot or on horseback. It is no uncommon thing for a traveler to breakfast at a hotel or lodge on one side of the range, walk or ride over the Continental Divide, and dine on the other side. For general accessibility it will be difficult to find a high mountain resort of the first order that will quite compare with the Rocky Mountain National Park.

A GENERAL OUTLOOK.

The Snowy Range lies in a north and south direction. The gentler slopes are to the west, and at altitudes below timber line they are so heavily forested that few good views can be obtained from the trails. On the east the descent from the Continental Divide is precipitous. Here barren slopes, craggy peaks, and precipices are so numerous that magnificent and unobstructed views are to be obtained everywhere. In many places east of the divide forests have been destroyed by fire, and only the dead trunks remain, some standing, others fallen, to indicate their departed glory; but although the wholesale destruction of these splendid forests is regrettable it is not without its compensation, for many a wonderful landscape has been opened to view in this way which would be obscured by living forests. Also the weirdness of these spectral remains lends a melancholy charm to many a scene and adds variety to the galaxy of interesting spectacles.

East of the mountain crest gorges with walls 1,000 or even 2,000 feet high are common, and between the gorges stand the bold summits in infinite variety of form. As seen from the east, the range rises in daring relief, craggy in outline, snow spangled, and awe inspiring. In stalwart nobility, in calm dignity, and in the beauty and grandeur of varied scenery the mountain group that culminates in Longs Peak (14,255 feet) is unsurpassed. The lover of mountains who feels the inspiration of its imposing stateliness may be pardoned if in his enthusiasm he calls this "the top of the world," as local enthusiasts are prone to do. Many a less imposing place has been so called. There are probably few other scenic regions which combine mountain outlines so bold with qualities of beauty so refined.

The Longs Peak group of summits, loftiest and most imposing in the park, is not the only group worthy of special mention. There is in the northern part of the park an assemblage of mountains culminating in Hagues Peak (13,562 feet), which is scarcely less imposing In this tumultuous mass are some of the most majestic peaks and one of the finest glaciers in the park.

To the south of Longs Peak the country grows even wilder. The range here is a succession of superb summits. The southern boundary of the park unfortunately cuts arbitrarily through a splendid massing of noble snow-covered mountains. The St. Vrain Glaciers, with their surrounding ramparts, a spectacle of grandeur, lie outside the park, and still farther south the Continental Divide increases in splendor to Arapahoe Peak and its well-known glacier. It is to be hoped that the park will be extended southward to include Arapahoe Glacier, which is the southernmost living glacier in North America.

The west side of the range, gentler in its slopes and less majestic in its mountain grouping, is a region of loveliness and wildness diversified by innumerable streams and lakes of great charm. Grand Lake, which has railroad connections near by, is the largest and deepest lake in the park. It is the center of a growing cottage and hotel population and is destined to become a place of much importance upon the completion of the Fall River Road, which will connect the east and west sides across the Continental Divide.

The mountains of the Snowy Range are very rugged and are cut by deep canyons and steep-walled gorges into an infinite variety of sharp peaks, pinnacled spurs, and crested or serrated ridges. Geologically they are "young mountains" and exhibit all the bold, daring, and attractive characteristics of youth. The Rocky Mountain National Park is in the very heart of the Rockies, and the barren crags and granite cliffs seen in all parts of it make its name eminently appropriate.

The majestic monarchs in the center of the range are flanked by less commanding summits, arranged in order of prominence, down to the rank and file near the foothills, where mountains are so numerous that those which would be exploited in a less imposing presence as scenic wonders are not even named. These, like the more stalwart giants near the crest of the range, are separated by gorges whose walls rise almost vertically hundreds and in some cases thousands of feet. In many places precipices rise in daring relief and craggy outline 1,000 feet or more from relatively level floors. In the higher gorges many of these floors are covered during much of the year with snow or are occupied by frozen lakes. At lower altitudes they are forested or carpeted with grassy turf and beds of wild flowers. At the higher altitudes there are many rock-bound lakes, some occupying basins at the bottom of the gorges, others perched high in the craggy sides of precipices in most unexpected places. These high-altitude lakes range in color through many shades of green and blue. Because the shades vary from time to time these lakes have been called the "gems of the mountains," and their changing color is likened to the varying aspect of jewels.

In the gorges and in many of the broader valleys are found conspicuous evidences of ancient glaciation. Great moraines have been formed by glaciers carrying bowlders and smaller fragments of rock down the valleys and heaping them in great ridges at the sides and end of the ice. In many places the rocks were polished by the ice passing over them. Striated surfaces are found where the bottom and sides of a gorge were scratched by rock fragments held frozen into the moving ice, like a graver's tool clamped in a lathe. Lake basins were gouged out of the solid rock by the moving ice.

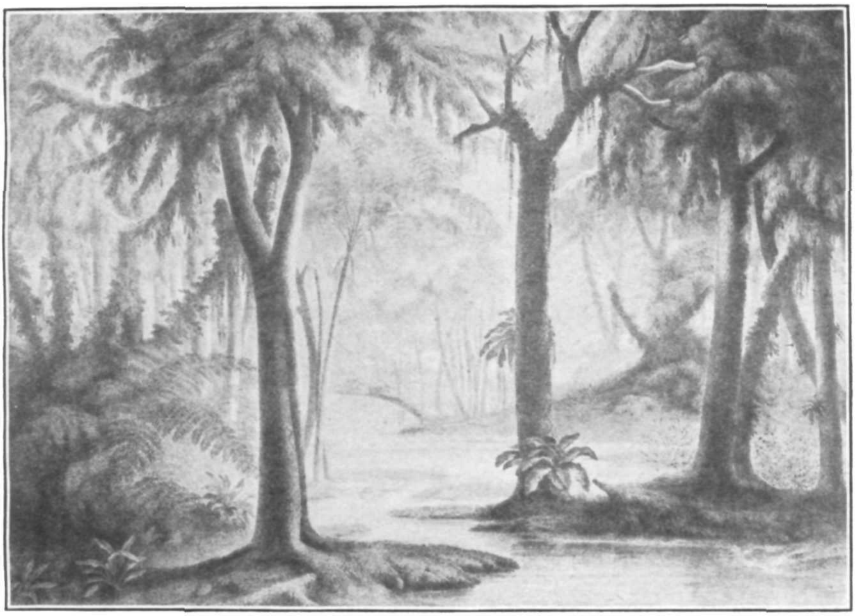
For easily read records left by ancient glaciers the Rocky Mountain National Park is almost unique. In few other places do these evidences so intrude themselves upon the eye. The great moraines, such as the long ridge south of Moraine Park, which rises 800 feet or more above the floor of the valley, are so prominent and sharply outlined that even the untrained observer notices that they differ in character from the neighboring hills. The rounded bowlders, the polished and striated surfaces, and the perfectly outlined moraines make this region a primer of glacial geology, whose lessons may be read so easily that no one need miss them. Also in this park there are small living glaciers, samples of the great masses of ice which filled the gorges in past ages. These assist the observer in his effort to realize the grandeur of long ago. We may reconstruct in imagination the great streams of ice which existed here during the Great Ice Age by magnifying these living glaciers many thousands of times until they fill the hollows between the mountains and extend many miles down the valleys. (See Pl. VIII, p. 30.)

The lower slopes of the mountains are wooded wherever they are not too precipitous for trees to take root; in some places the forests have been destroyed by fire, but the higher slopes are barren, for trees do not grow here above an altitude of 11,500 feet. Near this elevation, known as timber line, the struggle for existence is severe and gives rise to many curious and intensely interesting forms of growth, commonly known as timber-line trees. On the slopes above timber line may be found a flora sufficiently varied and unusual to delight the heart of the botanist as well as of the ordinary lover of flowers and plants. Here also may be found the descendants of the arctic plants which were driven southward during the Great Ice Age. Some followed the retreating glaciers northward as the climate moderated; others found a climate sufficiently cool for their needs on the high mountains.

THE MAKING AND SHAPING OF THE MOUNTAINS.

GEOLOGY AND SCENERY.

The Rocky Mountain National Park is noted chiefly for variety of mountain landscape. The land forms result from the action of stream and frost and ice. A study of the park, therefore, is chiefly a study of geography. Furthermore, geographic development, or the shaping of the landscape is dependent on the character of the rocks; thus a knowledge of geology is needed to interpret the scenery. For this reason the geologist is appropriately called upon to describe the park. For the description it seems desirable to place our "once-



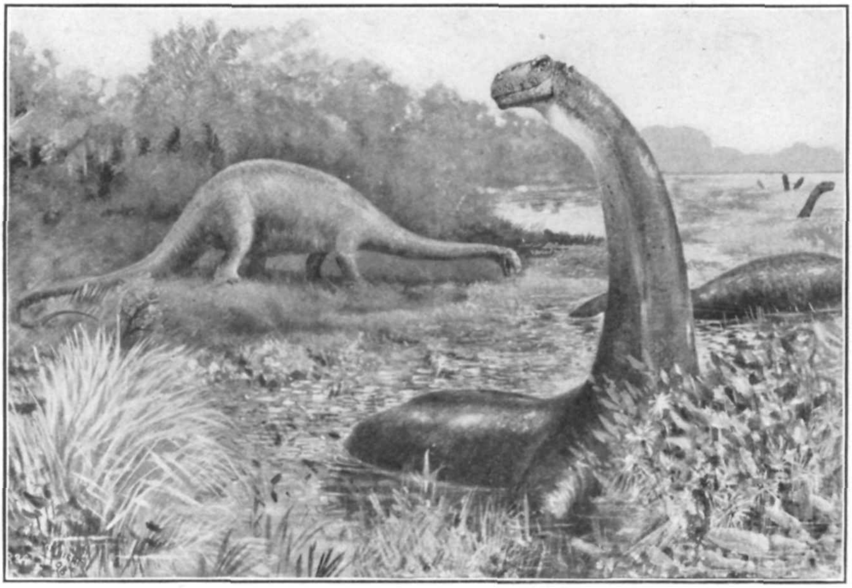
A. A CARBONIFEROUS LANDSCAPE.

Showing the great barren trunks of tree ferns and treelike club mosses.

B. A MODERN LANDSCAPE IN THE ROCKY MOUNTAIN NATIONAL PARK.

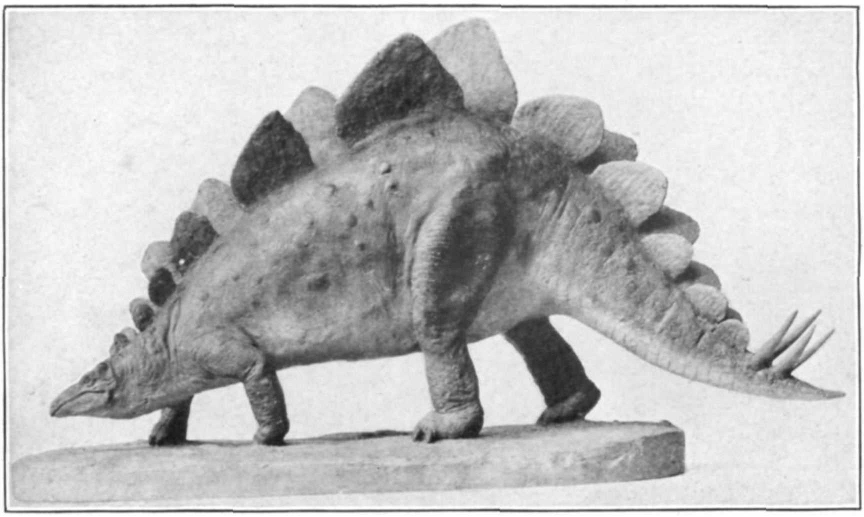
Showing spruce and pine trees in the valley of the North Fork of Grand River. Photograph by Willis T. Lee, United States Geological Survey.

FORESTS OF YESTERDAY AND TO-DAY.



A. BRONTOSAURUS (THUNDER LIZARD).

A great amphibious dinosaur from the horizon of the Morrison formation. Restoration by Charles R. Knight.



B. STEGOSAURUS.

An armored dinosaur from the horizon of the Morrison formation.

ANIMALS THAT ONCE ROAMED OVER THE SITE OF THE ROCKY MOUNTAIN NATIONAL PARK.

upon-a-time" in the story of this park in a period before the present mountains had raised their heads above the sea.

BEFORE THE ROCKIES WERE BORN.

Over the place where Longs Peak and its slightly less imposing companions stand in lofty isolation and invite the summer tourist to their cool retreats, the waves of an open sea once rolled and its tide ebbed and flowed, unhindered by rock or shoal. In this sea sported the marine monsters of long ago and on its shores wandered the grotesque creatures of the Age of Reptiles (see table of geologic time, p. 20), which lived eons before the human race began its existence.

The mountain region has had a long and varied geologic history, which reaches back to a time long antedating the birth of the present mountains. Attention will be directed only briefly to this ancient geologic history, but, as older sedimentary rocks once covered the site of the mountains, brief mention will be made of some of the principal events. Older mountains have stood where the present Rocky Mountains now stand. From one of these ancient mountain systems were derived in the later part of the Carboniferous period, or Age of Amphibians, the sand and mud which hardened into the red rocks that form the conspicuous ridges or so-called hogbacks of the foothill region east of the park.

It may be of interest to some who pass through the canyons carved in these brilliantly colored rocks to know that the red beds were formed millions of years ago, before modern plants and animals came into existence. The landscape of that ancient day must have contrasted strongly with the present landscape. In place of the modern highly specialized plants the observer in retrospective imagination sees only the lower kinds of vegetable growth, such as horsetails, ferns, and the most primitive of the flowering plants. In place of the splendid forests (see Pl. III) which now cover the mountains he would see tree ferns and huge club mosses—great barren trunks each with a few huge leafless branches. In place of the higher mammals, such as the beaver, which the tourist may see if he has patience enough to wait for these cautious creatures to appear, the highest types of animals of that far-off time were the sluggish toadlike amphibians and the most primitive of reptiles.

During long ages which followed the ancient mountains were worn down by rain and stream until a nearly flat surface extended over the region where the mountains had stood. To this plain the streams from the highlands of other regions brought sand and mud and spread them out in layers which hardened into rock. The sedimentary rocks formed at this time extended over the site of the Rocky Mountain National Park. The eroded edges of the older ones may now be seen in the foothills (see fig. 2), where the hard layers form ridges and the soft layers form valleys.

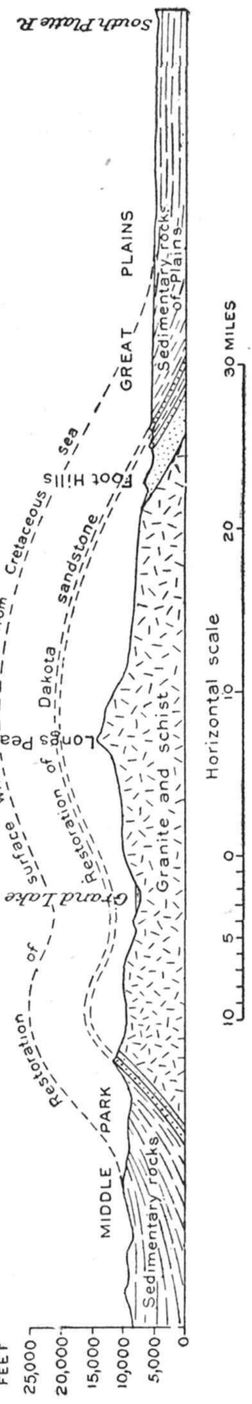


FIG. 2.—Profile section across the Rocky Mountains east and west through Longs Peak and Grand Lake, showing the present surface in solid line and the hypothetical ancient surfaces which were warped by the rise of the mountains. The single line of dots is the position which might have been assumed by the surface that emerged from the Cretaceous sea had it not been destroyed by erosion. The double line of dots is the position that the base of the Cretaceous rocks—Dakota sandstone—might have assumed had it not been eroded away.

Later, in the Age of Reptiles—that is, in the early part of the Cretaceous period (see table, p. 20)—sand and mud were spread out over this region in the form of sheets ranging in total thickness from less than 100 to more than 400 feet. These hardened into the rocks which the geologists call the Morrison formation, so called because it was first studied in detail at the town of Morrison, which is situated just west of Denver, Colo. In many respects these rocks are the most interesting of those exposed in the foothills of the Rockies. They are especially fascinating because of the fossil bones of huge reptiles found in them. It is worthy of note, in this connection, that the first fossils of the greatest of all known reptilian faunas were found in these rocks at Morrison.

During the life of these grotesque giants the country where now the hoary summits of the mountains hang among the clouds was a low-lying swampy plain somewhat similar in character to the delta of the Mississippi. Over this plain the streams migrated, forming broad flood plains, extensive swamps, and shallow migratory lakes. In these swamps and lakes and on the surrounding plains lived the huge reptiles whose bulk seems almost incredible and whose form, as depicted by those most competent to judge their character, seems beyond the power of the imagination (see Pl. IV, *B*, p. 15). The largest of these creatures were plant eaters, and some of them attained a length of 85 feet or more and a weight that has been estimated as high as 20 tons. These monsters were inhabitants of the swamps (see Pl. IV, *A*), in which many of them perished by miring. Their bones were preserved in the mud and are now found petrified in a remarkably perfect state of preservation. The leg bone of one of these monsters, 6 feet 6 inches long, is shown in figure 3.

Probably the most grotesque of all the monsters of this period was the armored dinosaur (*Stegosaurus*). It was a herbivorous or vegetable-eating creature, about 20 feet long and 10 feet high, with an extremely small lizard-like head, long hind legs, and short forelegs. It had a double row of enormous bony plates along its back and four huge spines near the end of its tail. For repulsive ugliness it seems

FIG. 3.—Leg bones of a dinosaur, showing size in comparison with the size of a man.

to be in a class of its own. Had it not been for the strong protective armor it could scarcely have survived the attacks of its carnivorous enemies, for its brain was so ludicrously small as to suggest a mentality scarcely sufficient for conscious efforts at self-preservation.

Scarcely less in bulk than these grotesque vegetarians and probably much more active and powerful were some of their carnivorous enemies, such as *Allosaurus* (Pl. V, *B*, p. 18), a monster 20 feet long, whose toes were armed with long, sharp claws adapted to catching and rending its prey, and whose jaws were well supplied with pointed fangs for tearing flesh.

In the long ago monsters such as these lived where the Rocky Mountain National Park now is—in the long ago before the mountains were brought forth, and before erosion had succeeded in carving the upheaved mass into craggy peak and rocky gorge.

In geologic history, as in human history, change is the order of progress. The swampy plains subsided, and over them the sea water

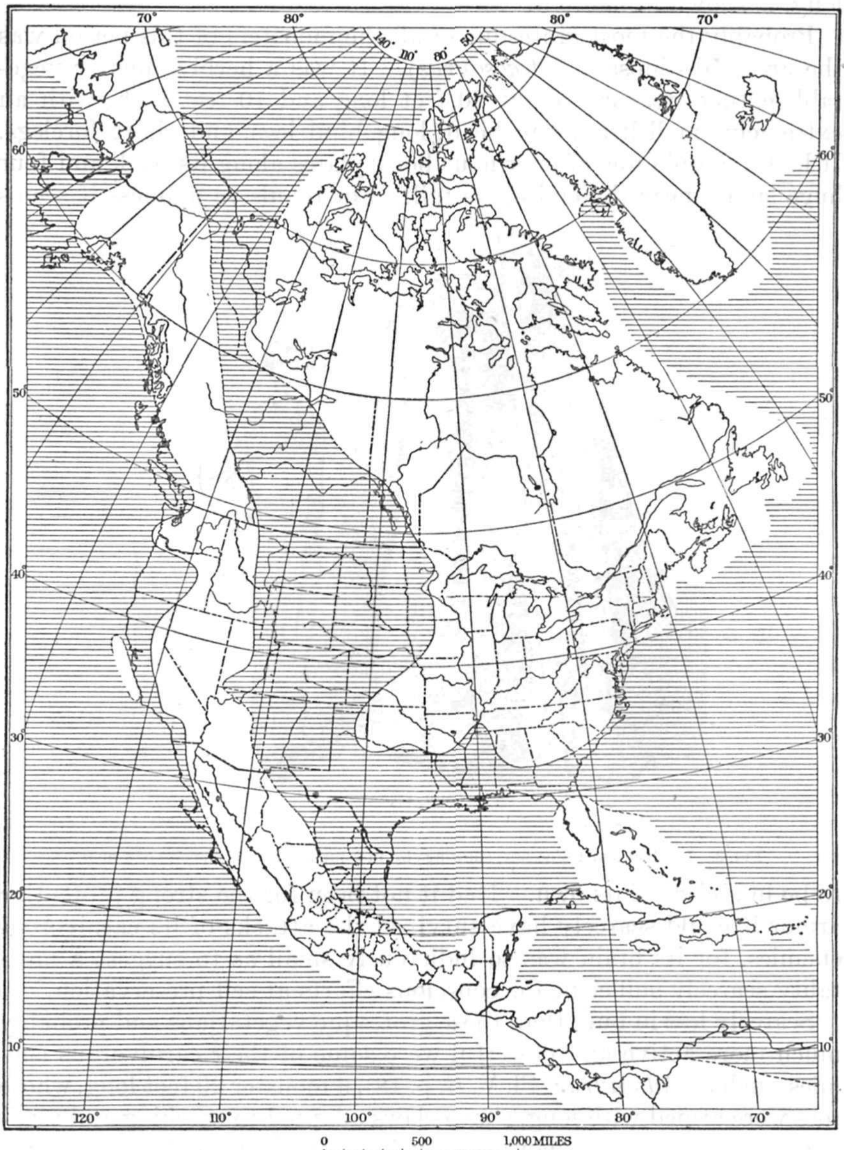
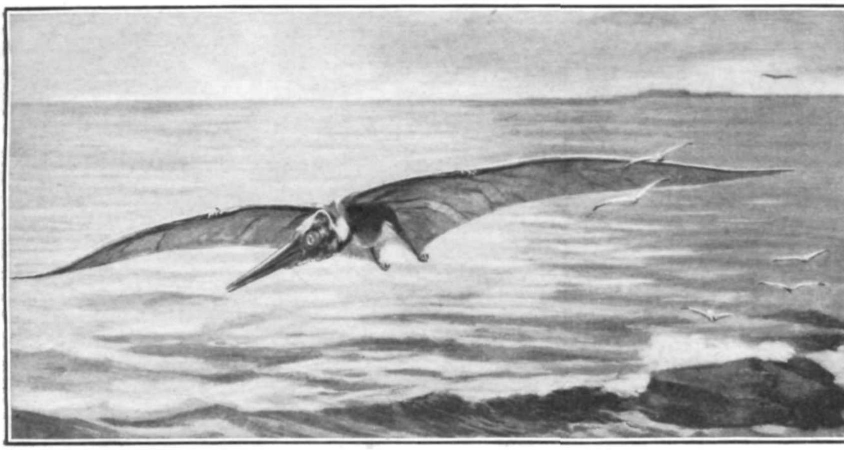


FIG. 4.—Map of North America, showing distribution of land and sea in Upper Cretaceous (Benton) time. (Area not shaded indicates land; shaded area indicates sea.)

made its way, connecting the Gulf of Mexico with the Arctic Ocean, covering the interior of North America from Utah to the Mississippi River. (See fig. 4.) In this sea sported such creatures as the great



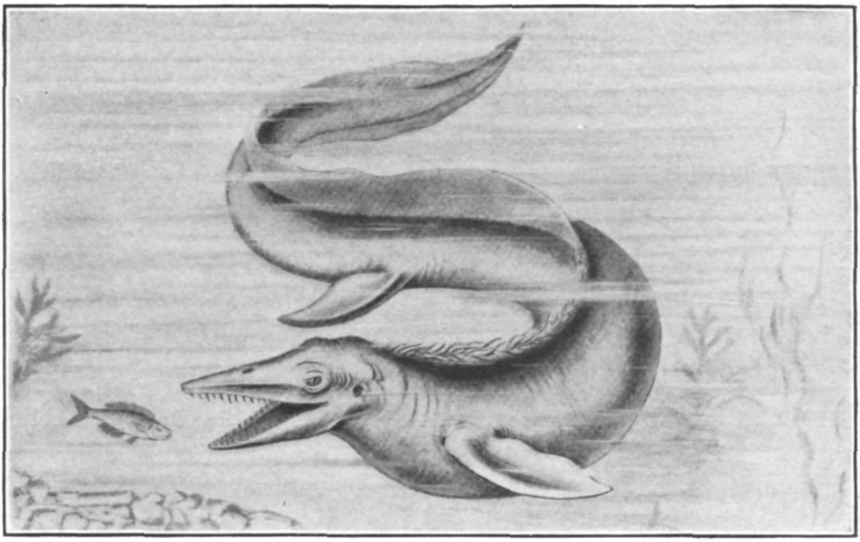
A. RESTORATION OF A PTERODACTYL (ORNITHOSTOMA).

A flying dragon measuring 18 feet from tip to tip of wings. Winged reptiles like this lived in central North America during the Cretaceous period.

B. ALLOSAURUS.

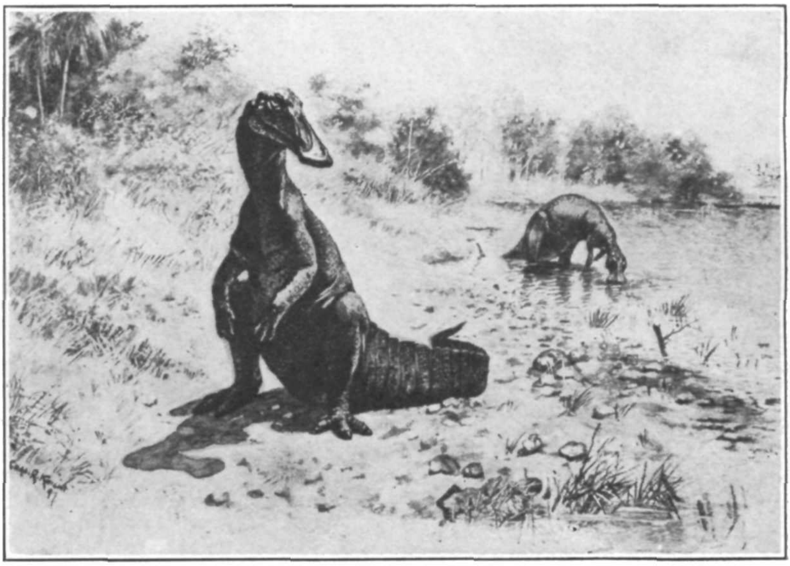
A carnivorous dinosaur preying on one of the herbivorous dinosaurs.

ANCIENT INHABITANTS OF THE ROCKY MOUNTAIN NATIONAL PARK.



A. RESTORATION OF TYLOSAURUS.

A marine lizard of Cretaceous age about 40 feet long—a "sea serpent" such as swam at one time where Longs Peak now stands. Drawn by J. Green.



B. THE SPOON-BILL DINOSAUR.

Hadrosaurus mirabilis, a reptile of Cretaceous age.

CREATURES OF LONG AGO.

Mosasaur (*Tylosaurus*) (Pl. VI, *A*, p. 19), and over its waters sailed carnivorous flying reptiles (pterodactyls), some of which had a stretch of wing of 18 feet (see Pl. V, *A*, p. 18); they were animated engines of destruction, which somewhat forcibly suggest the modern war airplanes, of which they were in a sense the prototypes.

On the shores of this sea grew luxuriant vegetation which found lodgment in huge peat bogs. These deposits have been preserved for our use in the form of coal.[1] On these boggy shores lived the reptiles of that age, some of which were scarcely less grotesque than their Morrison predecessors (see Pl. IV, *B*, p. 15). With them lived birds, some of which still retained reptilian characteristics,[2] such as jaws with teeth, a character possessed by few modern birds and by these only at an embryonic stage.

The first sediments laid down in this sea were the sands and pebbles formed along the shore. As the water advanced farther and farther inland, the beach sands, washed clean by wave and tide, were buried, during a later stage when the shore had advanced and the water was deeper, by the mud which gathered over them at the bottom of the sea. This sand hardened into a very resistant layer of sandstone, which has been named Dakota. It is the rock which forms the crest of the prominent hogback or ridge just east of Lyons and a few miles west of Loveland (see fig. 2, p. 16).

The sand was buried in turn by other sand, mud, and limy ooze laid down in the sea during the Cretaceous period (see table, p. 20) to a depth of several thousand feet. These beds hardened into the shale and limestone of the plain which lies east of the foothills. The petrified shells of mollusks which lived in this sea during the Cretaceous period may be seen west of Loveland in the shaly rocks at the side of the Estes Park Road.

THE BIRTH OF THE ROCKIES.

At the end of the Cretaceous period some great readjustment took place within the body of the earth which caused worldwide changes at its surface. The disturbance stirred into life the dormant roots of the ancient mountains. The sea water sank back into the ocean basins,[3] and the bed of the sea was arched into a great dome (see fig. 2).

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[1] In the eastern and central parts of the United States nearly all of the coal is of Carboniferous age—an age which took its name from the carboniferous or coal-bearing character of the rocks—but in the Rocky Mountain region nearly all of the coal is younger than Carboniferous. The coal beds in western America are mainly of Cretaceous and Tertiary age. (See table, p. 20.)

[2] There are so many facts which indicate that birds were derived from reptiles that few paleontologists now question their ancestry. The strongest reptilian character is the jaws with teeth similar to those of the ancient reptiles. Other significant similarities are found in the skeletons. Added to these is the fact that certain modern birds during their early life have reptilian characteristics.

[3] Statements of this kind need not tax our credulity if we recall that a quantity of water equivalent to 1 per cent of the ocean would cover all the land areas of the globe to a depth of 290 feet. The water of the old Cretaceous sea would doubtless represent only a small fraction of 1 per cent of the oceanic water and when poured back into the ocean probably raised the general sea level very little.

It should not be inferred that rock movements of this kind are rapid enough to be seen or that they were accompanied by cataclysmic disturbances. Doubtless there were earthquakes occasionally, as there are now.[1] But it is probable that the great rock movements which resulted in the upheaval of the Rocky Mountains were not rapid enough to be perceptible. From a geologic point of view a change in level of 1 foot in a century for any large part of the earth's surface would be a rapid change. It is probable that had a man been living during the time of even the most rapid mountain growth he would not have detected any change during his lifetime. We speak of the "everlasting hills" as types of stability and of unchanging constancy, but they are everlasting only in a relative sense, as compared with the span of human life. Every geologist knows that the hills are constantly changing, and it is possible that these changes are going on at the present time as rapidly as they ever did.

Principal divisions of geologic time.[2]

Era.	Period.	Epoch.	Characteristic life.	Duration, according to various estimates.
				Millions of years.
Cenozoic (recent life).	Quaternary.	Recent. Pleistocene (Great Ice Age).	"Age of man." Animals and plants of modern types.	1 to 5.
	Tertiary.	Pliocene. Miocene. Oligocene. Eocene.	"Age of mammals." Possible first appearance of man. Rise and development of highest orders of plants.	
Mesozoic (intermediate life).	Cretaceous.	([3])	"Age of reptiles." Rise and culmination of huge land reptiles (dinosaurs), of shellfish with complexly partitioned coiled shells (ammonites), and of great flying reptiles. First appearance (in Jurassic) of birds and mammals; of cycads, an order of palmlike plants (in Triassic); and of angiospermous plants, among which are palms and hardwood trees (in Cretaceous).	4 to 10.
	Jurassic.	([3])		
	Triassic.	([3])		
Paleozoic (old life).	Carboniferous.	Permian.	"Age of amphibians." Dominance of club mosses (lycopods) and plants of horsetail and fern types. Primitive flowering plants and earliest cone-bearing trees. Beginnings of backboned land animals (land vertebrates). Insects. Animals with nautilus-like coiled shells (ammonites) and sharks abundant.	
		Pennsylvanian.		
		Mississippian.		
	Devonian.	([3])	"Age of fishes." Shellfish (mollusks) also abundant. Rise of amphibians and land plants.	

[1] An earthquake shock was felt in Estes Park on Jan. 6, 1903.

[2] The geologic record consists mainly of sedimentary beds—beds deposited in water. Over large areas long periods of uplift and erosion intervened between periods of deposition. Every such interruption in deposition in any area produces there what geologists term an unconformity. Many of the time divisions shown above are separated by such unconformities—that is, the dividing lines in the table represent local or widespread uplifts or depressions of the earth's surface.

[3] Epoch names omitted; in less common use than those given.

Principal divisions of geologic time—Continued.

Era.	Period.	Epoch.	Characteristic life.	Duration, according to various estimates.
Paleozoic (old life)—Continued.	Silurian.	(1)	Shell-forming sea animals dominant, especially those related to the nautilus (cephalopods). Rise and culmination of the marine animals sometimes known as sea lilies (crinoids) and of giant scorpion-like crustaceans (eurypterids). Rise of fishes and of reef-building corals.	17 to 25.
	Ordovician.	(1)	Shell-forming sea animals, especially cephalopods and mollusk-like brachiopods, abundant. Culmination of the buglike marine crustaceans known as trilobites. First trace of insect life.	
	Cambrian.	(1)	Trilobites and brachiopods most characteristic animals. Seaweeds (algæ) abundant. No trace of land animals found.	
Proterozoic (primordial life).	Algonkian.	(1)	First life that has left distinct record. Crustaceans, brachiopods, and seaweeds.	
	Archean.	Crystalline rocks.	No fossils found.	50+

[1] Epoch names omitted; in less common use than those given.

HOW THE MOUNTAINS GREW.

If uplift had occurred without erosion, a great dome, somewhat like that illustrated by the broken lines of the profile (fig. 2, p. 16), but more or less warped and broken, with surface cracked and uneven, would now stand in place of the highly varied complex of peaks, ridges, and gorges which characterize the mountain region. As a matter of fact, however, the agents of erosion began their work the moment that the rising land emerged from the sea. From that time to the present the height and the character of the mountains have been dependent on the progress of the conflict between opposing forces. One group of forces strove to elevate the mountains; the other to tear them down. Sometimes one group gained the ascendancy and sometimes the other, so that the mountains have had an eventful life. Sometimes they were high and rugged, as we now see them; at other times they were worn down to a state of low relief, in which some portions of them were nearly level and others were reduced to relatively low rolling hills having smooth, gently sloping sides.

Little need be said here about the mountain-making forces. Their origin is obscure and their manner of operation is uncertain, because they originate in the unknown interior of the earth. There are several possible ways by which the Rocky Mountains may have been formed. They may represent wrinkles on the face of the earth, caused by the shrinkage of the interior; they may have been forced up by the settling of some larger portion of the earth's mass, much as the surface of soft wax is raised near an object which is thrust into it; or they may have been raised by the intrusion of molten matter forced at great depths into the underlying rocks of the mountains.

More is known of the processes by which the uplifted mass was sculptured, because these were recorded at the surface. Although erosion began as soon as the land arose above sea level, we may be permitted for the sake of clear understanding to think of the mountains as elevated before the agents of erosion began to operate; for it is difficult to carry in the mind the two concepts with all the complex interrelations. The great dome may be thought of as the block of stone from which the sculptor is to carve a group of statuary. Chief among the graver's tools to be used are rain and stream, frost and ice. The driving forces for operating these tools are chiefly gravity and the heat of the sun. The latter may be said to work both positively and negatively. Its positive work consists largely in transforming water to vapor and raising it into the air. Its negative work, or the accomplishments due to partial withdrawal of heat, results in the fall of rain and snow, frost action, and accumulation of ice in snow fields and glaciers. Gravity works chiefly through the fall of rain and the flow of streams and of glaciers.

The rocks are softened in preparation for the graver's tools by such chemical agents as carbon dioxide and other acids from decaying vegetation. The resulting statuary is the mountains. The chips formed in digging the valleys and gorges were swept away by the streams and the glaciers. Most of these have been carried out of the mountains, but the chips most recently formed are now seen as the sand of the lakes, the pebbles of the streams, and the bowlders of the great glacial moraines.

HOW THE MOUNTAINS WERE SHAPED.

Many people have the erroneous notion that some titanic force pushed mountains up in the form they now possess. On the contrary, the forms so much admired result from centuries of action by rain, stream, frost, and ice. To uncivilized people rugged mountains and deep canyons are repellent, for the untutored mind peoples them with evil spirits and imaginative dangers. But the thousands of cultured tourists who visit them find a satisfying contentment, and this satisfaction reaches its climax when appreciation of the magnificent results is accompanied by an intelligent comprehension of the processes by which these results were obtained. Some mountain climbers are content only with the thrill of mastering a difficult peak; others are more advanced in their appreciation. The massive vigor of the mountains incites enthusiasm and lifts the mind to higher levels. But surely the acme of satisfaction is reached when the thrill of attainment and the expansion of soul, so often experienced amid grand surroundings, is accompanied by an understanding of the forces which brought the objects of admiration into being.

Although this is not the place for a textbook description, in which the various agents of erosion are enumerated and evaluated, mention may be made of some of the principal ones and a brief sketch given of the manner in which they operate.

WORK OF RAIN.

Great results may be accomplished by forces so insignificant that they escape the notice of unobservant persons. Some who have not given the subject special thought may read with incredulity the statement that the great mountains of this national park were carved out largely by rain. But those who study land forms and the processes by which a landscape is shaped have long recognized the fact that rain is one of the principal factors in erosion. Careful observation during a storm will convince the most skeptical. Every raindrop that strikes the earth picks up a tiny load of mud, and the myriad drops collect as the muddy water of the rivulets which join to form the river that carries the great loads of mud to the sea.

But probably an equally important work accomplished by water falling as rain is done in connection with other chemical agents. Water has been called a universal solvent. In spite of the fact that we frequently refer to "pure water," there is no such thing as pure water on the face of the earth. It always contains other material in solution. If it contains certain kinds in sufficient quantity it may be called a mineral water, but in reality every spring, every well, and every stream contains mineral water.

The raindrop on its way from the cloud to the earth absorbs oxygen, carbon dioxide, and other gases, and, on penetrating the soil, it takes up vegetable acids and various other ingredients. It carries these with it into the minute crevices of the rock, where the acids produce chemical changes. The water is not so much the cause of the chemical action as it is the carrier of the chemical agents. Some of the newly formed compounds are easily soluble and are quickly taken into solution by the water; others are less soluble. Thus, by the chemical action of the rain water some parts of the rocks are dissolved out and the less soluble parts are left, held together so loosely that the rock crumbles.

The subject of the chemical action of water and its results might be expanded into volumes, for it embraces the production of soil, the construction of caves, the formation of minerals, and the deposition of metalliferous ores. However, the action which immediately concerns us in understanding how the rain helped to form the mountains is that of moisture on the granite of which the mountains consist. The granite contains a variety of minerals but is composed mainly of crystals of quartz and feldspar. The quartz is only slightly affected by the penetrating solutions. These solutions act principally on the feldspars, composed chiefly of sodium, potassium, calcium, aluminum, and silica. Of these elements aluminum and silica are only slightly soluble and are left as clay and sand when the rock breaks down. The sodium, potassium, and calcium unite with the carbon dioxide brought to them in solution by the water and form soluble salts, such as calcium carbonate. These are removed by the percolating waters. This removal, however, takes place irregularly along crevices or wherever the solutions can penetrate the rock. Hence the rock crumbles when the honeycombing process has gone far enough.

The decay of rocks seems more conspicuous in lowlands than in highlands, because the removal of waste products goes on less vigorously there than in highlands. Also from steep mountain surfaces a greater proportion of the rain water escapes as surface run-off. On such precipitous mountains as those of Rocky Mountain National Park chemical action is doubtless near the minimum, while the mechanical forces of disintegration, represented by stream, frost, and ice, are at their maximum.

WORK OF FROST.

Probably the most efficient of the mechanical agents of erosion, especially in the high mountains, is frost. It is well known that water expands on freezing, and it is equally well known that the expansive power of freezing water is almost irresistible. So potent is this force that it has no difficulty in splitting granite asunder and pushing great blocks of it from the cliffs. One of the dangers of climbing in the high mountains arises from falling rocks. Water fills a crack in the face of a precipice, freezes at night, and loosens a mass of rock from the face of the cliff. The ice melts during the day, and the next night the expansion of the freezing water pushes the loosened mass farther from the parent cliff. The process is repeated again and again until there finally comes a time when the mass is pushed to a position from which it falls when released by the melting ice. Many a mountain climber has hastily sought shelter from such falling rocks and counted himself fortunate when they went skirtling harmlessly to one side of him on their way down the mountain side. At altitudes where the ice melts slowly, this danger is minimized. Naturally it is increased on a warm day, when the ice holding the hanging masses melts rapidly.

The loosening of these rocks illustrates the action in the less spectacular but far more important work of frost. All rocks are porous.

some more so than others. Water makes its way into the pores—into the large ones under the force of gravity and into the smaller ones under the force of capillary attraction. In some of the spaces thus filled the water is so confined that when it freezes and expands it breaks the rock asunder. When this process is repeated often enough the rock crumbles. The finer it is broken up the better opportunity have the chemical agents of operating upon it. Thus the frost and the chemical solutions cooperate in transforming the rocks to soil.

Probably every tourist in the Rocky Mountain National Park has noticed the pink angular gravel which covers the surface and makes excellent roads but which makes walking difficult where it is too deep. This material is due chiefly to the action of frost on the granite. The pink fragments are crystals of feldspar, a crystalline mineral in the granite which has the property of parting in two directions nearly at right angles to each other. For this reason when the rock breaks up under the action of frost the feldspars break into angular fragments having flat, glistening faces, which sparkle in the sunlight—the cleavage faces of the crystal.

WORK OF STREAMS.

Methods of work.—The chemical work of solutions in disintegrating the rocks and the mechanical work of frost in breaking them up would have little effect in shaping the mountains if the products of their activity were not carried away. A relatively small amount of this work is done by wind, but the disposal of rock waste falls mainly to the streams. It is their function to receive the solutions of mineral matter and the smaller fragments of rock and to transport them to the sea. If the particles are small enough they remain suspended for a time, rendering the water turbid, and may be transported for long distances down a stream before finding temporary lodgment along its course. The larger pieces of broken rock, such as bowlders, pebbles, and sand, take shorter journeys. They are moved along the bed of the stream always farther and farther downstream until they are ground to powder. Also in the course of their passage they scour the rocks passed over. The streams do actual cutting by rolling pebbles along the bottom and by scouring their beds with the mud and sand held in suspension, but in ordinary cases the mechanical work of streams is subordinate to their work of transportation. In streams where muddy water passes through rock channels, such, for example, as the Colorado River in its passage through Grand Canyon, the abrasive work is at a maximum, while in streams where the water is clear its abrasive work is reduced practically to nothing. A notable example of this is seen at Niagara Falls, where the clear water passes over the rocks without so much even as keeping them free from unicellular plants which grow on their surface and form a green coating.

Ordinarily streams are inspected when the water is clear and doing little work, but the cutting is accomplished principally during times of flood when the water is muddy. Particles of mud and grains of sand are carried downstream in endless procession, each particle doing its minute part in cutting away the rock. Some, on gazing into a magnificent gorge in the rocks, are content with the enigmatical statement that it was "gnawed out by the tooth of time." Others are interested in knowing that the teeth which did the gnawing were the grains of sand set in the jaws of every flood.

Maj. Powell, who conducted the famous exploration of the Grand Canyon, had implicit faith in the ability of these minute grains to accomplish great results. Many have marveled at the temerity shown by him and his daring associates in entering a canyon with walls a mile high, from which there was no exit except at the mouth, without knowing what falls were likely to be encountered. But Powell had observed that the water of Colorado River is always muddy and his mental insight had convinced him that waterfalls are not to be expected in a muddy river. Such falls as may have existed there at one time had long ago been worn down by the myriads of sand grains which had passed over them. His faith in the efficiency of these minute agents of erosion was such that he staked his life on their accomplishment.

But even in a stream which is perpetually muddy, like the Colorado River, the abrasive work is subordinate to the work of transportation. Water descends in the form of rain so quietly that we think little of the work that it may accomplish. Parts of the rain water gather in streamlets and pick up small particles of mud and sand that lie in its way and join other streamlets similarly laden to form a brook. The water of the stronger current of the brook gathers still more of the loose material and carries it along in its passage down the river on its way to the sea. Other parts of the rain enter the rock and dissolve portions of it, as already described, and these in time find their way downstream, together with the mud. Every year the streams of the United States carry to the sea about 270,000,000 tons of dissolved mineral matter and 513,000,000 tons of suspended matter, such as silt and mud.

The rate at which streams work is influenced by many conditions, such as their rapidity of flow and the character of the country drained by them. On an average the surface of North America is lowered at the rate of 1 foot in about 9,000 years. It has been estimated that if this erosive action of the streams of the United States could have been concentrated on the Isthmus of Panama it would have dug in about 73 days the canal which has just been completed after 10 years' work with the most powerful appliances yet devised by man.

Streams of park exceptional.—Every visitor to the Rocky Mountain National Park has observed that the streams are remarkably clear. They carry little mud, for although the force of the descending water is great its grinding action on the rocks is slight because of the want of particles held in suspension. These energetic streams are accomplishing relatively little at present toward the shaping of the mountains. They constitute an exception to the general rule, and there is a special reason for this exception. The rocks along the streams are only slightly disintegrated. Most of them have a fresh, hard surface. The reason for this lies in the recent glaciation which is described in the following section under work of ice. The ice removed the soft weathered parts, and the time that has elapsed since the glaciers disappeared has not been long enough for the rocks to decay to such an extent that they furnish large quantities of mud and sand. However, it has not always been thus, nor will it always remain thus. In time the fresh faces of the glaciated rocks will weather and the normal conditions of an unglaciated region will be reestablished.

Stripping of the mountains.—Through the long ages during which the mountains have been struggling to rise vast quantities of rock waste have been carried from them by the streams. In the dim past, after the close of the Cretaceous period, as soon as they had lifted their heads from the sea, they were attacked by rain, streams, and chemical solutions, so that even though the vertical movement totaled many thousands of feet the mountains may not have been greater at any time in the past than they are now.

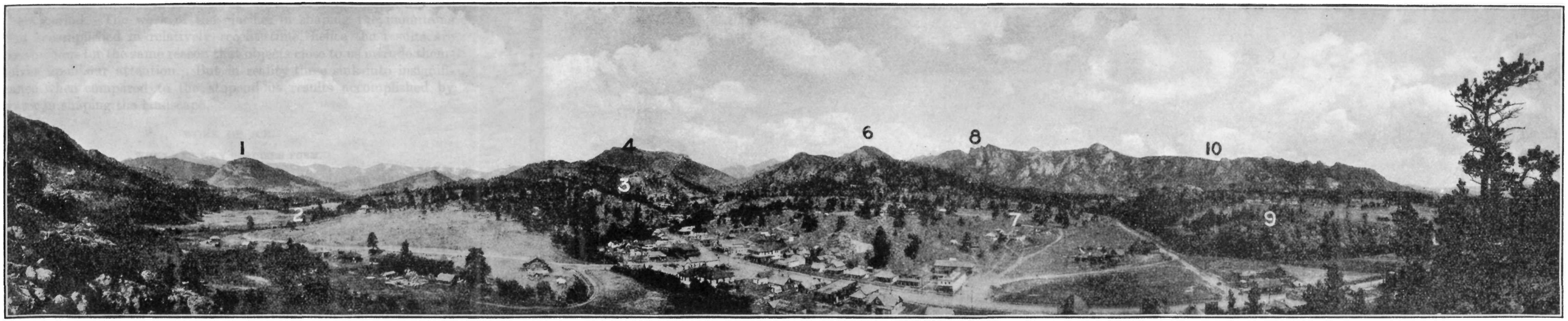
The first work of erosion was the removal of the relatively soft sedimentary rocks which at first extended over the site of the growing mountains. These rocks were thousands of feet thick, and their removal was no small task. Also the task was made difficult and the time of its accomplishment lengthened by floods of molten rock poured out on the surface. These were removed, together with the sedimentary rocks. During this early period of erosion not only were the thousands of feet of sedimentary rock and the sheets of hardened lava removed, but the underlying crystalline rocks were themselves deeply eroded. Some time early in the Tertiary period (see table of geologic time, p. 20) the forces of erosion seem to have prevailed over the mountain-making forces, and the young mountains were reduced to a rolling plain, known technically as a peneplain, or an "almost plain," and to relatively low hills with gently inclined slopes and broad, shallow valleys. The highest hills of that day may have stood 2,000 feet or even more above the general level of the peneplain. Few definite statements can be made concerning this old plain until it is studied in detail.

An old plain of erosion.—Later, when the mountains were raised still farther, the peneplain was lifted and the rising mass of rock was again deeply carved into mountains and valleys, but the raised surface has not been entirely destroyed. So many remnants of it remain that from a distance the tops of the mountains have the appearance of forming an even-crested ridge (see Pl. VII). Remnants of it remain on Flattop Mountain (Pl. IX, p. 34) and in many other places near the top of the range. It shows conspicuously near the head of Forest Canyon (Pl. XXII, *B*, p. 54) and above Hallett Glacier (Pl. XVI, *B*, p. 49). But the largest and most plainly recognizable remnant stretches out several miles on either side of Flattop Mountain. This ancient plain will be referred to so often in the descriptions which follow that a name for it seems desirable, and I propose to call it the Flattop Peneplain. A characteristic view of it is given in Plate IX (p. 34). If this high-altitude plain were now restored from such remnants as remain, it would seem as if the surface was very uneven. Mountains of considerable height rise steeply from the general level (see Hallett Peak, Pl. IX, p. 34), but it is not now known how many of the irregularities of the surface are due to incomplete erosion when the old plain was formed and how many of them are due to faulting and to warping of the surface during the process of elevation.

About the time that this ancient plain was forming the volcanic forces again were busy, and floods of molten rocks similar to those previously mentioned were poured out on the surface. These hardened on cooling into resistant rocks, and nearly all were eroded away; but one large mass remains in Specimen Mountain, which consists of beds made up of lava flows, fragmental igneous rock, and bowlders of the older mountain rock.

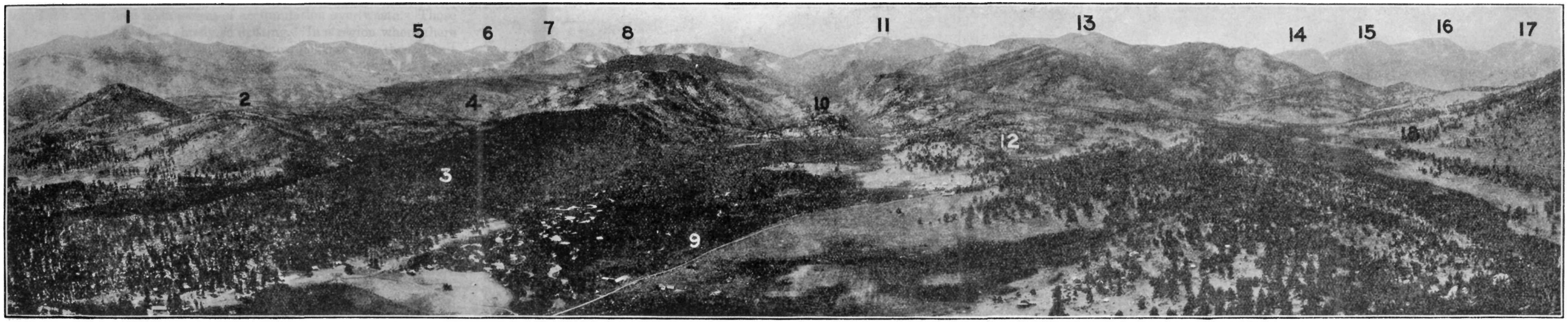
Many periods of uplift.—There were several stages of mountain uplift, alternating with long periods of relative cessation of movement, during which the erosional forces gained ascendancy over the elevating forces. During one of the long periods of erosion the mountain region was reduced in many places to a nearly plane surface. This surface has been studied in the regions south of the Rocky Mountain National Park, where it has been called the Rocky Mountain Peneplain. The mountains of Estes Park rise to a general level (see Pl. VII), which may be a part of this peneplain. Still later streams cut deeply into this plain, forming the present broad valleys, such as Estes Park, and shaping the mountains into something like their present form.

Thus the mountains were shaped and the valleys dug mainly by water. The final shaping of the high peaks and the excavating of the gorges in the sides of them were done by ice. The glacial cirques, the rock-walled gorges, the pinnacled summits, the crested ridges, and many of the other greatly admired features of the landscape are the result of the intensive action of the ice during a relatively



A. VIEW FROM PROSPECT MOUNTAIN WESTWARD OVER ESTES PARK.

Showing the near-by mountains rising to a level which is essentially the same as that of the so-called Rocky Mountain peneplain of areas farther south. 1, Gianttrack Mountain; 2, Thompson Canyon; 3, Oldman Mountain; 4, Deer Mountain; 5, Fall River; 6, Castle Mountain; 7, Black Canyon; 8, The Needles; 9, Stanley Hotel; 10, Twin Owls.



B. VIEW FROM THE HILL AT MORAINE PARK, WHICH APPEARS IN THE VIEW ABOVE, BETWEEN GIANTTRACK MOUNTAIN AND DEER MOUNTAIN.

Showing the melting basin of Thompson Glacier (Moraine Park) with its lateral moraines in the foreground and the high range beyond, at whose relatively even crest are numerous remnants of an old plain here called the Flattop peneplain. 1, Longs Peak; 2, Bartholf Park; 3, South Moraine of Thompson Glacier; 4, Moraine of Bartholf Glacier; 5, Taylor Peak; 6, Otis Peak; 7, Hallett Peak; 8, Flattop Mountain; 9, Moraine Park; 10, Gorge of Thompson Glacier; 11, Stones Peak; 12, North Moraine of Thompson Glacier; 13, Trail Ridge; 14, Mount Chapin; 15, Mount Chiquita; 16, Ypsilon Mountain; 17, Mount Fairchild; 18, Highline Drive.

PANORAMAS OF ESTES PARK AND OF THE HIGH MOUNTAINS TO THE WEST.

Photographs by Frank W. Byerly.

short period. The work of the glaciers in shaping the mountains was accomplished in relatively recent time, hence the results are conspicuous for the same reason that objects close to us intrude themselves upon our attention. But in reality these sink into insignificance when compared to the stupendous results accomplished by water in shaping the landscape.

WORK OF ICE.

WHEN AND WHY GLACIERS FORM.

The most spectacular features of the landscape in the Rocky Mountain National Park are due to ice. This is because the glaciation of this region was the last important event in its geologic history. The Great Ice Age dates back beyond the origin of human history, but in terms of geologic time it was very recent. The glaciation of the mountains was the last geologic event of the region, and the glacial epoch has in reality not yet closed for the higher parts of the park, where small glaciers still exist.

The popular notion that glaciers and fields of perpetual snow are due to excessively low temperature is not wholly correct. However, in order that the masses of snow and ice may endure, the average yearly temperature of the region must be low enough that the snowfall of winter does not all melt in summer. The one condition necessary for a snow field is an excess of accumulation over waste. Those of the mountains are due chiefly to drifting. In a region where there is heavy snowfall during the winter the snow fields endure throughout the summer at much lower altitudes than where the snowfall is light, for the obvious reason that the heat of summer, although it may be intense, can not melt all of the snow. On Mount Rainier, in the State of Washington, where the annual snowfall exceeds 20 feet, the glacial ice extends down within 3,960 feet of sea level, but in the Rocky Mountain National Park, where the annual snowfall is less than 10 feet, the glaciers extend little lower than 12,000 feet above sea level.

LIVING GLACIERS.

When the annual accumulation of snow is greater for any reason than the annual melting, snow fields are formed. The surface snow soon changes from the flaky form to a granular form, and these granules consolidate into ice. When this granular ice accumulates to a sufficient depth it begins to move and becomes a glacier. The difference between a glacier and other masses of ice seems to depend on motion. Profs. Chamberlin and Salisbury[1] state that—

> Brittle and resistant as ice seems, it exhibits under proper conditions some of the outward characteristics of a plastic substance. Thus it may be made to change its form and may even be molded into almost any desired shape, if carefully subjected to sufficient pressure steadily applied through long intervals of time. These changes may be brought about without visible fracture and have been thought to point to a viscous

[1] Chamberlin, T. C., and Salisbury, R. D., Geology, vol. 1, pp. 236, 237, 1904.

condition of the ice. There is much reason, however, * * * to question this interpretation of the ultimate nature of the movement. Whatever this may be, the mass result of the movement in a field of ice is comparable, in a superficial way at least, to that which would be brought about if the ice were capable of moving like a viscous liquid, the motion taking place with extreme slowness. This motion of the ice in an ice field is glacier motion and ice thus moving is glacier ice.

When the moving ice is confined to a valley or gorge it is known as a valley glacier. These are often called alpine glaciers, because they were first studied in detail in the Alps. Probably the nearest approach to a typical valley or alpine glacier in the Rocky Mountain National Park is found in Andrews Glacier. (Pl. XXXI, p. 68.) In some places the snow accumulates in a sheltered nook on a cliff and forms a small and often steeply inclined mass of ice called a cliff glacier. (Pl. XXIX, p. 67.) Such a mass of ice seems to be insecure and is sometimes called a hanging glacier.

Although movement is the essential character of a glacier, there seems to be no limiting rate of movement. Hence, as a mass of ice once large and active gradually diminishes it is difficult, if not impossible, to determine when it ceases to be a glacier. The question is especially pertinent in the Rocky Mountain National Park, where several bodies of ice are now at the critical stage between glacier and snow field. A few of these bodies have perceptible movement and are genuine glaciers. Others move intermittently and are therefore glaciers at certain times and not glaciers at other times,[1] but the greater number are not known to have measurable motion—at least their rate of motion, if they have any, has not been determined and is so slight that it is not made apparent by any recognized external signs. The bodies of ice in this park now recognized as true glaciers are Hallett Glacier, Sprague Glacier, Tyndall Glacier, Andrews Glacier, and Taylor Glacier. A mile south of the park are two splendid masses known as the St. Vrain Glaciers, and about 10 miles farther south lies Arapahoe Glacier, the finest body of glacial ice in the southern Rocky Mountains.

It was Hallett Glacier that gave rise several years ago to a controversy as to what constitutes a glacier. The definite question arose, "Is Hallett Glacier a glacier?" In 1884 Mr. W. L. Hallett, of Colorado Springs, for whom this body of ice was named, discovered a crevasse in it. Crevasses are common in glaciers and indicate motion of the ice. Hallett's discovery was used as proof[2] that a

[1] In a letter to the writer dated July 25, 1916, Enos A. Mills states: "I have made three measurements on the small ice field that lies on the eastern wall of Longs Peak above Chasm Lake. In 1909 I made a 60-day test. The movement made was about 0.07 inch per day. In 1908 a 30-day test showed a movement of about 0.04 inch per day. A 10-day test in 1907 showed no perceptible movement.

"This ice field was measured also by Chapin in 1888, I think, and he reported no perceptible movement.

"A 15-day test on Sprague Glacier in 1906 showed a movement of 0.08 inch per day. In 1896 Hallett Glacier showed a movement of 1.01 inches per day, and in 1907 its movement was 0.06 inch per day. All these measurements were made in the autumn."

[2] Stone, G. H., A live glacier on Hagues Peak, Colo.: Science, vol. 10, pp. 153, 154, 1887.

MAP OF THE ROCKY MOUNTAIN NATIONAL PARK
AS IT MIGHT HAVE APPEARED DURING THE LAST STAGE
OF GLACIATION IN THE GREAT ICE AGE
Outlines of the glaciers approximate

Scale

0 1 2 3 4 5 6 7 8 9 10 Miles

true glacier had been discovered in Colorado. This raised the question of the likenesses and differences between snow fields and glaciers. The question was discussed by S. F. Emmons,[1] a well-known geologist, who pointed out that the present masses of ice in the Rocky Mountains are mere shadows of the former glaciers and argued that Hallett Glacier and similar masses of ice are not true glaciers. Nevertheless it has continued to be called a glacier, and, according to the definition previously given, several of the less well-known bodies of ice naturally fall with it into the class of true glaciers.

ANCIENT GLACIERS.

Whether or not the above conclusion is accepted as final there is no doubt of the existence of active glaciers in this territory in times past. Evidences of these are found in many places. Conspicuous among them are the lateral, terminal, and ground moraines, the smoothly rounded rock surfaces, polished and striated bowlders, steep-walled gorges, U-shaped valleys, and pocket lakes.

In the moraines are bowlders, cobbles, pebbles, sand, and clay intermingled. This physical heterogeneity is one of the most distinctive characteristics of morainal material and therefore one of the best evidences of the former existence of glaciers. All the distinctive marks of the ancient glaciers are found in great perfection, so that the park has been called a primer of glacial geology. The details of the several glaciated areas are enumerated in the descriptions that follow under the heading "The park as seen from the trails" (p. 45).

There appear to be two stages of glaciation represented in this park—an older one of which little is now known and a younger one called the Wisconsin stage, because it seems to correspond in time with the last stage of continental glaciation, which is typically developed in Wisconsin and was named for that State. Little need be said at this time of the older stage, for the proofs of its existence are not entirely conclusive. Apparently such broad open valleys as Estes Park and Tahosa Valley were shaped by glacial ice. They have the broad floors, the precipitous walls (Pl. XV, *A*, p. 48), and the perched lakes which characterize glacial valleys, but they lie outside of the area affected by the glaciers of the Wisconsin stage.

During the younger or Wisconsin stage of glaciation the ice accumulated in the valleys previously formed by the streams—and perhaps shaped to some extent by the older glaciers—and pushed its way from the high mountains down these valleys to altitudes of about 8,000 feet. The areas occupied by the ice are plainly marked and could be mapped accurately with little difficulty. But this mapping would require a large amount of detailed work and

[1] Emmons, S. F., On glaciers in the Rocky Mountains: Colorado Sci. Soc., Proc. vol. 2, pp. 211, 227, 1888.

has not yet been done. The accompanying illustration (Pl. VIII) outlines the glaciated areas with sufficient accuracy for present purposes. The five named glaciers are outlined more accurately than those in the western and northern parts of the park. The areas occupied by the latter are not easily traversed at present for want of good trails. It is beyond question, however, that the high-altitude valleys and gorges were all occupied by glacial ice, although the outlines as shown in the figure are only approximate.

Fall River Glacier.—The body of ice which occupied the upper part of the Fall River drainage area had a maximum length of nearly 10 miles and a width of more than 7 miles. Its principal lobe originated in the high mountains to the west and filled the main valley. Its principal tributary originated on Hagues Peak and filled the valleys between this peak and Mount Chapin. The Fall River lobe seems to have been much more powerful than the other lobes of ice and so modified its course that the valley of Roaring River was left "hanging" about 500 feet above Fall River. The ice of the united lobes was pushed through Horseshoe Park, where it built lateral moraines along its northern and southern margins about 900 feet above the present floor of the valley. Each of these conspicuous ridges of loose bowlders is separated from the solid mountain rock on either side of the park by a narrow trough.

Horseshoe Park is the melting basin of Fall River Glacier. Here the supply of ice which moved down the steep gorges just equaled the waste due to melting. For this reason all the fragments of rock borne by the glacier were dropped here as the ice melted from under them. The fragments which fell from the sides piled up in lateral moraines. Some of those in the central parts of the glacier were carried downstream to the end of the ice and deposited as the terminal moraine. Others lodged at the bottom of the glacier to form the ground moraine and were overridden by the ice, thus forming the relatively level floor of Horseshoe Park.

Before the Great Ice Age Horseshoe Park was doubtless a part of an ordinary V-shaped valley like that between Deer Mountain and McGregor Mountain east of the terminal moraine, but the narrow lower part of the "V" was filled with fragmental rock. This narrow part of the valley east of Horseshoe Park would appear now as wide as that park if it were filled to the same extent. The quantity of morainal material in the floor and walls of Horseshoe Park indicates that the ice occupied it for a long time. Also the smoothness of the floor and the absence of large piles of bowlders indicate that the retreat of the glacier was relatively rapid when the ice finally melted.

Thompson Glacier.—Two large glaciers formed on the headwaters of Thompson River. The largest one, heading in Forest Canyon and its tributary gorges, was about 15 miles long. It had several tributary lobes from the Continental Divide, among them one in Hayden Canyon, one in Spruce Canyon, at the head of which now lies Sprague Glacier (Pl. XXV, p. 60), and one in Odessa Gorge. The ice from the united lobes crept down the valley of the Thompson, overriding such minor ridges as that north of Cub Lake, and halted in Moraine Park. This park is similar in nature and origin to Horseshoe Park and is the melting basin of Thompson Glacier.

To judge from results, Thompson Glacier was a vigorous one. Forest Canyon and the tributary gorges just mentioned contain numerous and forceful reminders of its power. Many cirques and deep gorges were scooped out of the solid rock by it, and rounded bowlders were carried down to Moraine Park, where the valley floor was built up by ground moraine and the lateral moraines raised to a height of nearly 1,000 feet. It would be difficult to find a better or more conspicuous example of a lateral moraine than the even-crested ridge south of Moraine Park.

Bartholf Glacier.—The glacier which descended through Bartholf Park was a relatively short one, never exceeding 8 miles in length. However, it originated on the highest mountain in the park and its gradient, or average slope of bed, was steep, hence its gouging action was vigorous. The principal lobe of ice occupied Glacier Gorge. Another scarcely less vigorous lobe occupied Loch Vale and headed in the cirques now occupied by Taylor Glacier and Andrews Glacier. Less extensive but scarcely less vigorous lobes occupied the gorges south of Flattop Mountain, in one of which Tyndall Glacier reposes.

These lobes of moving ice joined in a grand mêlée in Bartholf Park. The relatively small tongue of ice from the Flattop region tended to move eastward but was crowded toward the north by the more powerful mass from Glacier Gorge and Loch Vale. Hence most of the ice-borne material was carried north of the park and piled up in the great moraine, on the top of which is Bierstadt Lake. This moraine occupies most of the space between Milk Creek and Glacier Creek and is more than a mile wide. Its thickness is not definitely known, but it rises 900 feet or more above the floor of Bartholf Park, and this floor is itself built up to some unknown extent by ground moraine.

Mills Glacier.—Mills Glacier seems like a small one when compared with others (see Pl. VIII). It was not more than 4 miles long and a mile wide, but the area occupied by it is one of the most accessible and easily observed of those occupied by the ancient glaciers in the park. The entire site of this glacier can be seen from a single position. From Twin Sisters, east of Longs Peak, The Chasm, or cirque in which this glacier originated, and the glacial trough and moraines are spread out before the observer as on a map (Pl. XXXV, *A*, p. 71).

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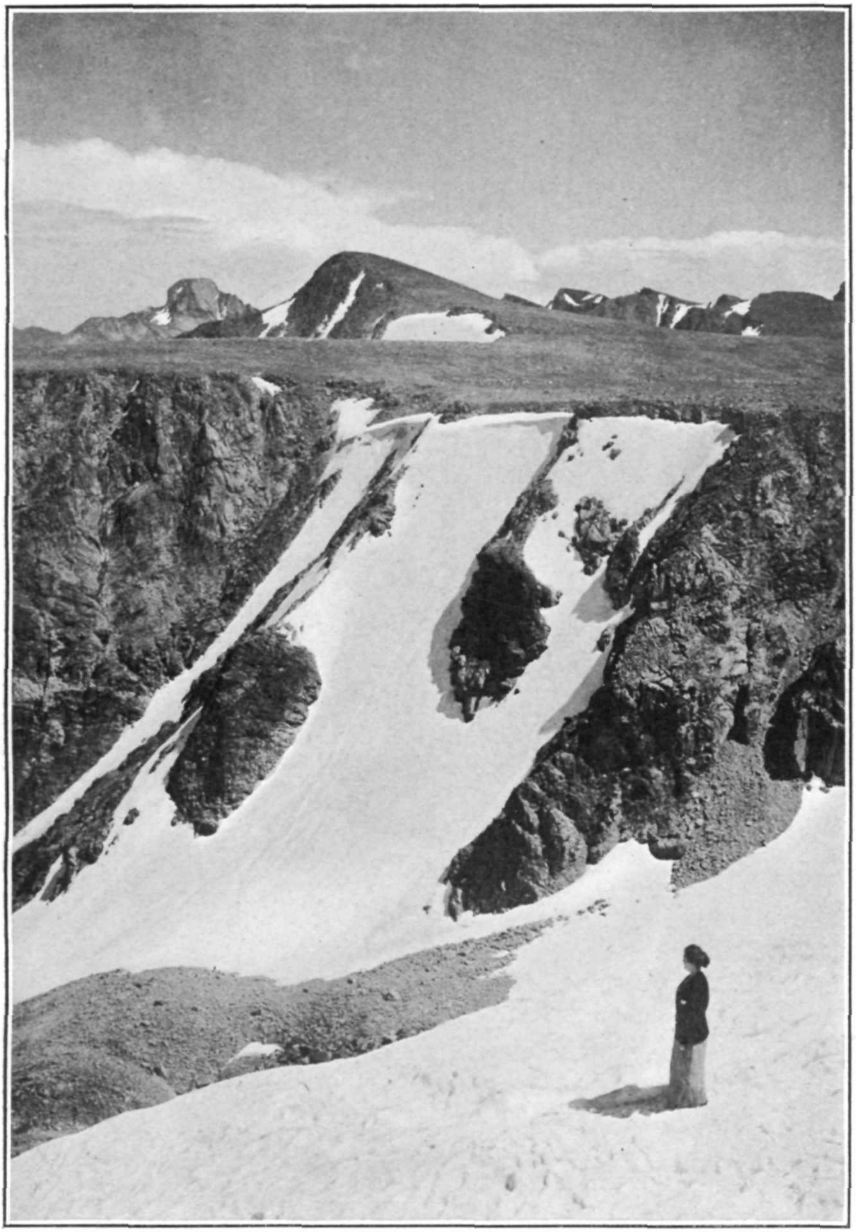
For some reason not now known, this glacier differed from the others described in not building at its lower end a melting basin or moraine-inclosed park. In the other four the parklike melting basins lie between the most conspicuous portions of the lateral moraines. In the case of Mills Glacier the most prominent portions of the laterals inclose only a narrow trough. There is some doubt as to the relation of the moraines of Mills Glacier to those of the possibly older glacier which is supposed to have filled Tahosa Valley. In this valley are basins now filled with boggy material and accumulations of glacial débris, which might be either old till or outwash material from Mills Glacier. Also outside of the conspicuous ridge called Mills Moraine is at least one less prominent morainal ridge, which denotes that this glacier covered a somewhat larger area during the early part of its existence than it did later. As the bowlders of this outer ridge are not notably more weathered than those of the higher inner ridge, the outer moraine seems to belong to the Wisconsin stage of glaciation rather than to the earlier stage.

Wild Basin Glacier.—The body of ice which formed at the head of the St. Vrain drainage area was the most symmetrical of the five named glaciers of the Wisconsin stage of glaciation. It filled Wild Basin to a width of about 6 miles, heading in the numerous gorges of the high range from Longs Peak to Ogalalla Peak. It extended nearly 9 miles down the valley of the North St. Vrain, forming a long melting basin between Copeland Moraine on the north and an equally prominent lateral on the south (Pl. XLIII, *B*, p. 81). Copeland Lake lies within this basin, on a shelf of morainal material a few feet above the general level of the valley floor, and the stage road between Ward and Estes Park crosses the basin near the eastern end. The terminal moraine lies east of the road near the junction of Horse Creek and the St. Vrain.

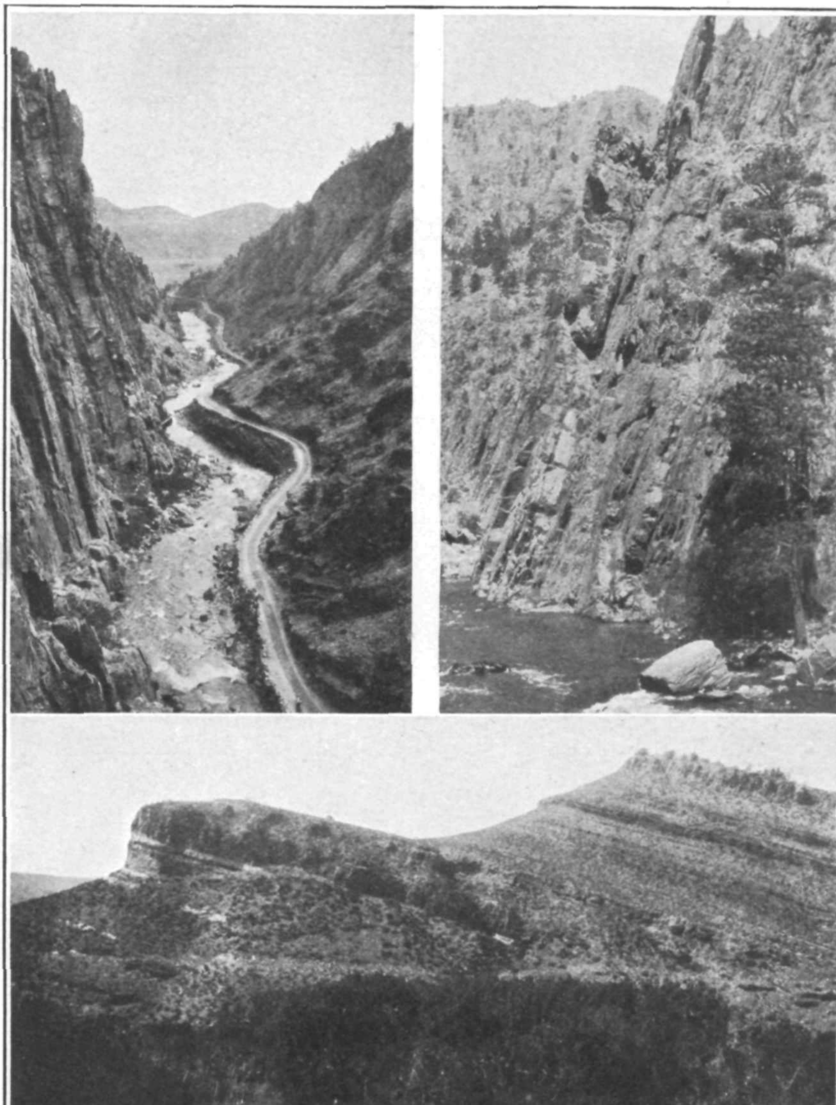
Glaciers of North Fork and its tributaries.—Little is known of the geology west of the Continental Divide. The evidences of former glaciers were seen in many places and the general outlines of the ancient ice are indicated by the topography, but the boundaries shown in Plate VIII (p. 30), are only approximate. The essential facts relating to the old glaciers of this region have long been known from the description of Archibald R. Marvine in the report of the United States Geological and Geographical Survey of the Territories for the year 1873, from which the following account is chiefly adapted:

The floor of Grand Valley consists of terminal and ground moraine as far south as the southern extremity of the Rocky Mountain National Park. Throughout most of its length the floor consists of ground moraine or material left at the bottom of the glacier and leveled off by the ice riding over it. Thus was formed the "Meadows"



THE FLATTOP PENEPLAIN.

View of a part of Flattop Mountain, showing Hallett Peak in the middle ground and the square head of Longs Peak in the distance to the left. The gently rolling surface covering several square miles at altitudes near 1,200 feet is a remnant of a surface of erosion which once extended continuously over the site of the Rocky Mountain National Park when the mountains were much lower than they are now. During the elevation of these mountains this surface was raised and in most places was destroyed by later erosion. It suffered especially from the glaciers, which gnawed great holes in the sides of the mountains, but it is still recognizable in many places. Photograph by Frank W. Byerly.



NARROW PLACES IN THE NARROWS OF THOMPSON CANYON.

On the road between Loveland and Estes Park there are many places where there is scarcely room for the road between the river and the precipitous walls. The rocks of these walls were originally formed of sand laid down in horizontal layers. The sand consolidated and the layers were upturned to their present steeply inclined position when the mountains were elevated. Upper left, Looking down the canyon toward the foothills and plains; upper right, Upturned layers of pre-Cambrian quartzite; lower, Layers of red rocks in the foothills upturned against the mountains. Photographs by Willis T. Lee, United States Geological Survey.

or flat floor over which the river now winds, in serpentine course, among the swamps, grassy meadows, and dense thickets of brush. From the southern extremity of the moraine northward for several miles the meadows are interrupted by ridges and irregularly shaped hills made up of rock débris deposited by the ancient glaciers. They are roughly semicircular in form and north of Grand Lake cross the valley somewhat regularly. These constitute the terminal moraines of the glacier which occupied the valley of the North Fork of Grand River. In its halting retreat the glacier built a succession of terminal moraines, reaching altitudes of 300 or 400 feet above the level of the meadows. Each semicircular ridge across the valley represents a halt at the front of the retreating glacier. Their surface is uneven, there being in some places abrupt depressions down to 60 feet in depth, having no outlet. Some of these are occupied by undrained lakes. West of Grand Lake is a semicircular ridge situated between the North Fork and the drainage from the lake. This is a medial moraine formed where the glacier of North Fork Valley joined the glacier from the gorges which converge in Grand Lake. The latter seems to have extended down the Great Valley several miles, but it is not possible, without more detailed field study, to say whether the southernmost ridges are moraines of the North Fork Glacier or the Grand Lake glaciers, or a combination of both. There are, however, three fairly well defined ridges which seem to represent stages in the retreat of the glacier that passed through Grand Lake. The western end of the lake is inclosed by a low morainal ridge. It is narrow and steep sided, ranging in height from a few feet to 100 feet or more, and offers choice sites for summer cottages. It represents a relatively short halt in the retreat of the glacier.

The next older terminal moraine crosses the valley about 2 miles south of the outlet of the lake. The North Fork, which flows west of the medial moraine previously described, turns sharply to the north, cutting through the low but well-defined ridge of this moraine, and flows in an easterly direction north of the ridge for more than a mile to its junction with the Grand Lake drainage, where the combined stream breaks again through the moraine. Between this gap and the lake the ridge is a lateral moraine, attaining an altitude of 800 feet or more above the level of the lake.

A still older and also more prominent terminal moraine lies nearly a mile farther south, the two separated from each other by a meadow. The river breaks through this ridge and enters a narrow canyon cut in the granitic rock. The river which had obviously occupied the main valley previous to the Great Ice Age apparently was crowded out of its former course by the accumulation of ice-borne material. When the glacier ice melted the river found the lowest course at the side of the moraine and, in place of reexcavating its old valley, cut a new one through the solid rock.

Good exposures of the rocks in the moraines are not numerous. These rocks consist of schist and granite, which decompose readily on exposure. The morainal masses are covered with scanty soil, and

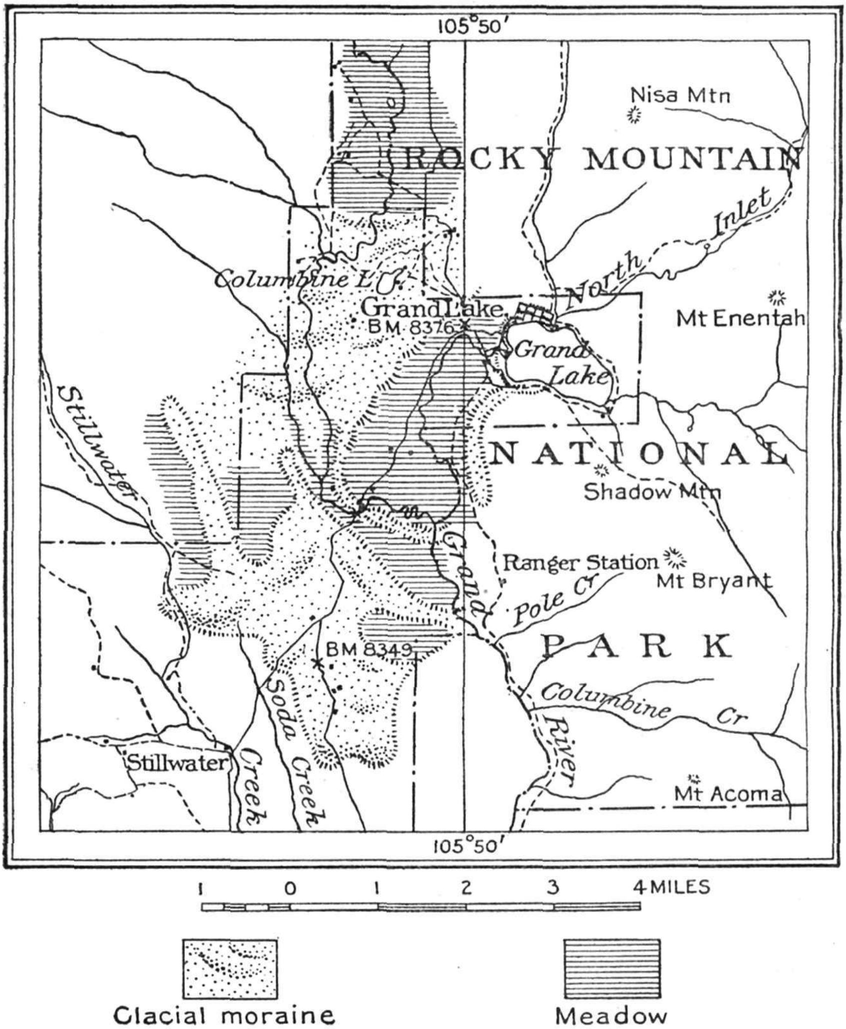


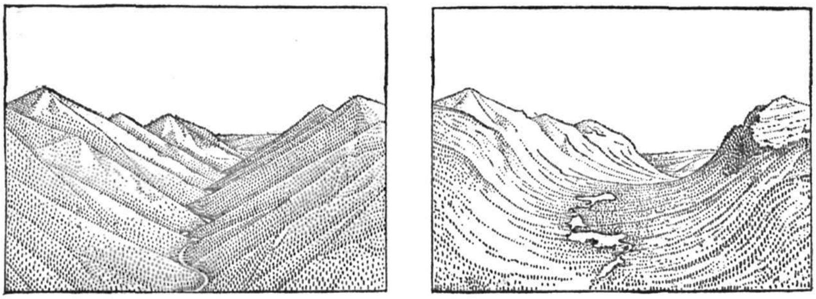
FIG. 5.—Sketch map showing the glacial moraines in the valley of North Fork of Grand River near Grand Lake, Colo.

on them is a thick growth of pines. In many places the lodgepole pines grow so close together that passage across the moraines is almost impossible. Traversing these thickets is particularly annoying when they have been partly destroyed by wind or fire, the fallen trees making the thickets almost impenetrable.

Glaciers in the northern part of the park.—It is known that the valleys in the northern part of the Rocky Mountain National Park, such as those of the Cache la Poudre and its tributaries, are glaciated, but I have seen them only from a distance, and the outlines of the glacial ice shown in Plate VIII (p. 30) have been drawn chiefly from topographic evidence. The boundaries may be materially changed when these areas are examined in detail.

HOW THE GLACIERS WORKED.

The kind of work performed by the ice in shaping the mountains was much the same in each of the glaciers, and if we can see in imagination how a bowlder was formed, what work it did, and how it was carried to its present resting place, we will come close to an understanding of glacial erosion. As we stand at the head of one of the gorges and gaze down its rock-walled trough we may easily picture the great river of ice that formerly cascaded over its cliffs, gnawing at the sides of the mountains, plucking out their rock ribs, grinding and polishing the rocks, and sweeping away the débris.



A. *B.*

FIG. 6.—*A*, Sketch of stream-cut valley; *B*, Sketch of same valley after modification by glaciation.

Along the cliffs above the ice, and as far below its surface as water will freeze and thaw, fragments of rock large and small are loosened. Those from the overhanging cliffs fall on the ice and are carried on it down the valley. Those from below the surface of the ice are plucked from the walls and held within the ice, where they serve as the cutting tools which wear down the floor of the gorge. A thickness of 2,000 feet is a conservative estimate for the ice which filled many of the cirques and gorges of this park. A mass of ice of this thickness exerts a pressure of 56 tons on each square foot of its bed. The deeper the ice the stronger is its hold on the rocks and the greater is its ability to tear fragments of it from the walls and from the floor. The fragments of rock near the bottom and sides of the moving mass are held as in the grip of a vise. This rock-shod ice under pressure from above acts like a giant rasp, plucking away loosened fragments, scouring, grinding, and polishing the rocks over which it moves.

Such masses of ice do not adjust themselves readily to the irregularities of the valleys which they occupy. In consequence of this, more than ordinary force is exerted on the projecting mountain spurs and opposing ledges and these are worn away relatively fast. Hence a glacial trough has fewer irregularities than a stream-worn valley. Also, since the work of the ice increases with pressure, the bottom of the trough undergoes great modification. A glacial gorge has a characteristic U-shaped profile and is distinguishable by this feature from a stream-cut valley, which is characterized by a V-shaped profile (see fig. 6).

In an alpine glacier the ice always moves down the valley. It never retreats. If the ice at the lower end melts faster than it is renewed from above the glacier may retreat, but the ice of the glacier moves always forward. Hence we may properly speak of a retreating glacier, but not of retreating ice. For this reason whether the glacier is advancing or retreating it is always bearing a load of rock débris forward. That borne to the end of the ice is dropped as the ice melts from under it and forms the terminal moraine; some lodges at the bottom behind the terminal, allowing the ice to ride over it, and is called ground moraine; and some accumulates at the sides as lateral moraine.

APPROACHES TO THE PARK.

LOVELAND TO ESTES PARK.

Loveland is the railroad station on the Colorado & Southern Railway near the mouth of Thompson Canyon, where the tourist destined for the Rocky Mountain National Park leaves the railroad and begins the stage journey. On leaving the railroad he travels for several miles between the orchards and through the meadows of the irrigated plain. Just east of the foothills the road traverses a short rock cut, in the sides of which may be found the petrified shells of extinct species of marine mollusks. These clamlike creatures flourished here during the Cretaceous period, when this region was under the sea.

The foothills consist of a series of ridges separated by troughlike depressions lying in a general north and south direction along the mountain front. They were formed by erosion of the upturned strata. The sedimentary rocks of this region were formed in a nearly horizontal position, some of stream-laid deposits, others of sediments deposited in sea water. When the mountains were elevated these horizontal layers were bent upward, so that near the line of flexure they are steeply inclined toward the plains. Much of the uplifted part has been worn away by rain, frost, and stream. The soft layers were worn down more rapidly than the hard ones and valleys were formed where the softer strata outcrop. The harder layers were worn down more slowly, hence they outcrop in ridges.

Thompson River has cut its way eastward through these ridges, thus forming an easy passage utilized by the road. The first prominent hogback or sharp ridge consists of Dakota sandstone.[1] It is prominent because the sand is cemented together firmly to form a quartzite which strongly resists erosion. The Morrison formation described (p. 16) as containing fossil bones of huge dinosaurs outcrops in the brush-covered slope west of the Dakota hogback. Then in order westward are the several layers of red rocks of Carboniferous age (see table, p. 20). The upper part of these red beds, known as the Lykins formation, contains a bed of gypsum.

In traveling up the canyon we pass a mill where cement plaster, a product resembling plaster of Paris, is manufactured from this gypsum. In the middle part of the red beds is a thick layer of hard cross-bedded light-red sandstone, known as the Lyons sandstone, which is described on page 41. A little farther to the west is a great series of still older red sedimentary rocks which lie on the crystallines of the mountains proper (Pl. X, p. 35). The geologist sees here in the contact of the red beds with the crystalline rocks the evidence of a long period of unrecorded time. The rocks at the base of the red beds are Carboniferous in age (see table, p. 20), while the crystallines on which they lie are older than Cambrian. This line of contact therefore represents four geologic periods and a length of time as great as that represented by all the sediments of the foothill region, or perhaps even greater.

Soon after reaching the crystalline rocks the canyon proper of Thompson River is entered. The first deep, narrow part of this canyon west of the foothills is known as The Narrows. It has been cut by the stream in a complex consisting of hard metamorphosed sedimentary rocks, into which were forced many dikes and irregular masses of igneous material which now appear as coarsely crystalline rocks of lighter color than the fine-grained sedimentaries. The strata are upturned steeply and in some places stand nearly vertical (see Pl. X, p. 35). Their attitude and physical characteristics give rise to the interesting features for which this canyon is justly famous.

In cutting its passage the river has naturally sought the line of least resistance. When it strikes a layer of unusually hard rock it turns abruptly to one side, passes around the obstruction, and doubles back upon itself, following in some places an intricately winding course. The canyon walls are here characterized by sharp projecting edges of rock, and the top by pinnacles (see Pl. X), of varying form and height. In many places the walls rise sheer from the stream for hundreds of feet and are entirely wanting in

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[1] This sandstone was named for Dakota City, Nebr. It is exposed in many places throughout the Rocky Mountain region and extends from New Mexico northward for 1,000 miles or more. It underlies the Great Plains and comes to the surface again in the Mississippi Valley many hundreds of miles east of the mountains. The pores of the rock are filled with water, which is reached by artesian wells in 11 States.

vegetable growth. In other places trees have gained a precarious foothold by sending their roots into rock crevices, and we wonder how they survive. The bottom of the canyon is little wider than the stream, and in many places the roadway has been blasted from the cliff or is held up on the streamward side by a retaining wall.

At the mouth of the canyon is a beautiful waterfall at the spillway of the reservoir of the Loveland waterworks. Farther upstream the granitic rock which was forced into the sedimentary rock during ages long past is more abundant, and because it weathers more readily than the quartzite, the walls of the canyon here change from sheer precipices to craggy, forested slopes, and finally the canyon widens into an open mountain valley. Near the forks of the Thompson the rock is a coarse crystalline granite, much of which has the form known as pegmatite and consists chiefly of large crystals of pink feldspar, light-colored quartz, and crystals of mica, popularly, though erroneously, called isinglass. Crystals of this mineral may be found as large as one's hand and several inches thick, which can be split into thousands of thin transparent sheets. In this part of the canyon are many picturesque rapids (Pl. XI, where the water leaps and plunges from rock to rock and lashes itself into foam as if in impotent rage at the innumerable obstacles to its progress.

Above the forks we enter the second narrow portion of Thompson Canyon, known as The Rapids and famous for unusual beauty. The canyon walls are steep and high, but the granite of which they are composed is variable in its resistance to erosion and weathers to an infinite variety of craggy forms that contrast strongly with the great barren faces which characterize The Narrows. Also the forest trees find more favorable conditions of growth here, and the pinnacled slopes (Pl. XI) are decorated in a variety of patterns in many shades of green on the somber background of the weathered granite.

The bowlders along the stream are smooth and polished and are worn into a variety of forms by the never-ending friction in the bed of the stream. Where the channel is straight, grooves are cut into the rock, but where there are eddies in the current, circular depressions or "potholes" may be formed. One of these may be seen from the road near Linger Longer Lodge (Pl. XI).

Probably the greatest admiration for this part of the canyon is aroused by the rapids. The canyon contains great numbers of granite bowlders worn smooth and round by the never-tiring current. Over and among them the water dashes and foams. Out of some dark brushy obscurity (Pl. XI) it leaps, flashes for an instant in sunlight as it breaks in spray against some rocky obstruction, gathers its shattered parts, and passes again into obscurity, only to repeat the ever-varying performance again and again on its eventful journey, until it emerges from the mountains and finds rest for a time in some of the numerous irrigation reservoirs on the plain. Like the tourist who leaves the humdrum existence of everyday life and enjoys a summer of unusual experience in the mountains, this water in its eternal round of change through vapor, rain, snow, and stream, has visited the park, has spent its vacation on the Snowy Range, and is now on its way back to less spectacular but more useful vocations. For this water will find its way through the intricate maze of irrigation ditches to the orchards and to the fields of alfalfa and sugar beets on the plains. There it will linger for a time and make the desert beautiful in blossom and rich in fruit.

LYONS TO ESTES PARK.

Lyons is the terminal of a branch of the Chicago, Burlington & Quincy Railroad, where the traveler destined for Estes Park by way of the Lyons route takes stage.

Lyons is located in the foothills, in the midst of the sharp-crested ridges or "hogbacks," composed of upturned and eroded sedimentary rocks. The easternmost prominent "hogback" consists of the hard sandstone called Dakota. East of this ridge the rocks are chiefly shale which accumulated as mud in the ancient sea. Because this shale is soft and easily eroded it has been worn down to a nearly level plain, which contrasts strongly with the uneven surface in the foothills, where hard and soft layers of rock alternate.

The troughlike depression just west of the Dakota "hogback" is due to erosion in the soft rocks of the Morrison formation, named for the town of Morrison, situated about 40 miles south of Lyons. This formation contains the fossil bones of some of the most remarkable extinct animals that ever lived (see p. 17). West of this trough the ridges consist of red sandstone and shale. In their midst is a series of thick cross-bedded flaggy layers, known as the Lyons sandstone, named for the town of Lyons. This rock has been quarried extensively for buildings and has furnished many flagstones for the streets of Denver and other cities of Colorado. In the sandstone are preserved the footprints of some of the animals that roamed over this country long ages ago. The strata were formed during the life of the earliest known land animals; hence in the streets paved with these stones we literally follow in the footsteps of the first beings that walked on land.

The parklike opening in which Lyons is situated was formed by St. Vrain River cutting a passage through the red rocks. After leaving the town we follow up the river between cliffs of the red strata. To the right may be seen quarries from which flagstones are obtained. At Steamboat Rock (Pl. XII, *B*, p. 45), which stands like a dominating headland overlooking the valley, we turn to the right through a trough cut by the river along the junction of the red beds and the underlying granite. The river cut along this junction because the rocks here are softer than those on either side. The granite near the contact with the overlying sedimentary rocks is coarsely crystalline and breaks down into coarse gravelly débris. Also the lower layers of the red rocks are soft and are easily worn away.

After following this trough for about 2 miles we turn westward and plunge into the narrow canyon between walls of gray and pink granite. Some of the pink varieties are delicately colored and may some day be valuable as ornamental stone. Attention is divided between the rushing waters of the river on the one hand and the precipitous walls and wooded slopes on the other (Pl. XII, *A*, p. 45). On leaving the canyon we take a winding course through forested hills, which assume huge proportions as we approach Estes Park. Mount Pisgah (8,500 feet) and Mount Olympus (8,808 feet) appear at the right and Kruger Rock (9,342 feet) at the left. As we emerge from the hills which lie between these higher summits a splendid view is obtained of the group of commanding summits that culminate in Hagues Peak (13,562 feet).

WARD TO ESTES PARK.

One of the approaches to the Rocky Mountain National Park is by way of Ward, a small mining town situated at the terminus of the railroad commonly known as the Switzerland Trail. Ward lies 9,269 feet above the sea and is near the top of the once nearly level surface called the Rocky Mountain peneplain (p. 16). Over this elevated surface, now trenched by the streams, the road winds northward to the canyon of the Middle St. Vrain. This canyon is cut to a depth of more than 500 feet below the general level of the ancient plain. The route leads eastward down this canyon, then northeastward up a branch canyon to Allens Park and the North Fork of the St. Vrain. Here we descend the lateral moraine of Wild Basin Glacier (see p. 34), cross the floor of the melting basin of this glacier, and climb the low ridge at the end of Copeland moraine—the great elongated hill of bowlders and smaller fragments of rock deposited at the northern edge of the old glacier. Here we are fairly within the region of the Rocky Mountain National Park, and the route farther to the north is described elsewhere (pp. 71 et seq.).

One of the interesting views obtained on this trip is that of Longs Peak and the mountains surrounding it. Here is seen one of those landscape curiosities which usually arouse interest. The crest of the ridge west of Longs Peak outlined against the sky resembles the profile of a human face. At the sky line is seen forehead, nose, and chin in form suggestive of the upturned face of an Indian. The eye is represented by a bank of perpetual snow. Because of this likeness the mountain is called Chiefs Head.

From this direction as well as from the north Longs Peak and Mount Meeker appear as a conspicuous double peak. For this reason the "Arapahoe Indians called them Two Guides (nesóttayah), because they are the landmarks of the whole region." [1]

GRAND LAKE ROUTE.

Grand Lake is the western gateway to the Rocky Mountain National Park. It is situated in the valley of North Fork of Grand River and is the largest lake in the vicinity of the park. The valley of North Fork lies along the western margin of the park. From the heights to the east of this great valley may be obtained magnificent views of the towering peaks of the rugged Medicine Bow Mountains to the west of it (Pl. XXII, *A*, p. 54), which some prefer to call the Never-Summer Range, following the nomenclature of the Arapahoe Indians, who called them nichéebeeche-nokhu (Never-no summer).

The floor of the valley is nearly flat, is beautifully wooded in many places (Pl. III, *B*, p. 14), and ranges in width from about 2 miles near Grand Lake to half a mile or less farther north. From the nearly level floor of the valley the surface rises abruptly on both sides in steep, rocky slopes which merge into the great cliffs and cirques in the sides of the mountains. East of the valley the mountain slopes are heavily forested in most places below timber line, but the Medicine Bow Mountains are less generally timbered and are more attractive to those interested in the land forms produced by erosion at these high altitudes.

As seen from the south up the great valley the slopes appear regular, but in them are numerous great gorges extending from the main valley to the crest of the mountains. These so break up the seeming regularity that when the slope is viewed from the side it appears to consist of an intricate maze of rugged peaks, serrate ridges, sharp spurs, and deep canyons. The gorges in the Medicine Bow Mountains are relatively short and steep, for the mountain crest is only 2 to 4 miles from the center of the valley and rises about 4,000 feet above its floor. Because of this steepness the rocks have been carved into a great variety of picturesque forms, and in the absence of continuous forests these forms may be seen to good advantage. They are especially conspicuous near the head of North Fork, where the top of the Medicine Bow Range consists of a short ragged crest which reaches a maximum altitude of nearly 13,000 feet.

[1] This and following notes on Indian nomenclature are taken from a manuscript by Oliver W. Toll (see p. 11).

PLATE XI.

SCENES IN THE RAPIDS OF THOMPSON CANYON ON THE ROAD BETWEEN LOVELAND AND ESTES PARK.

Upper, A typical scene in the depths of the canyon, where the Thompson polishes the bowlders of granite and quartzite and grinds out the cobblestones.

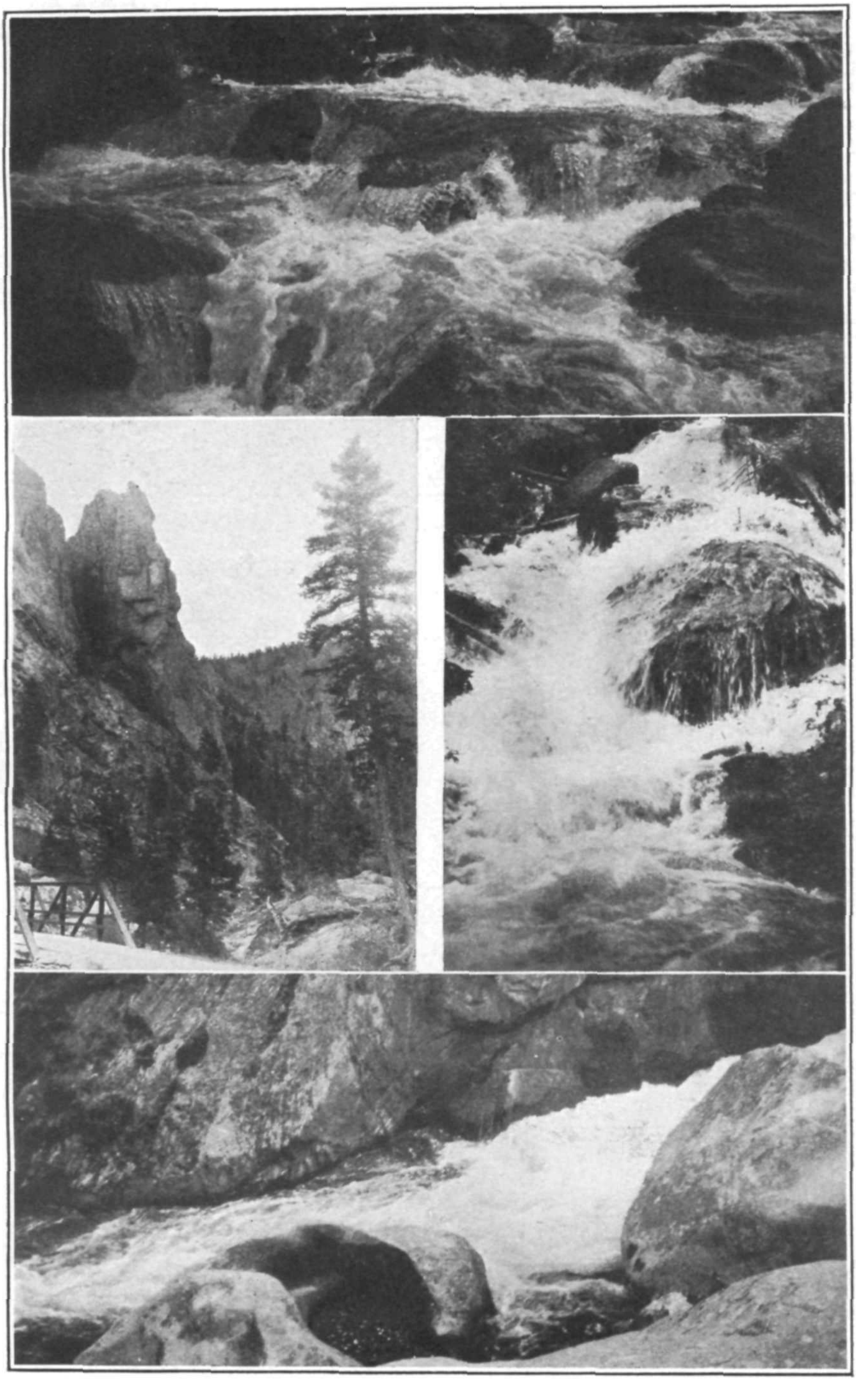
Middle left, One of the numerous pinnacles in the wall of Thompson Canyon.

Middle right, Water versus rock. Where the river plunges and dashes itself into foam on its way to the plains.

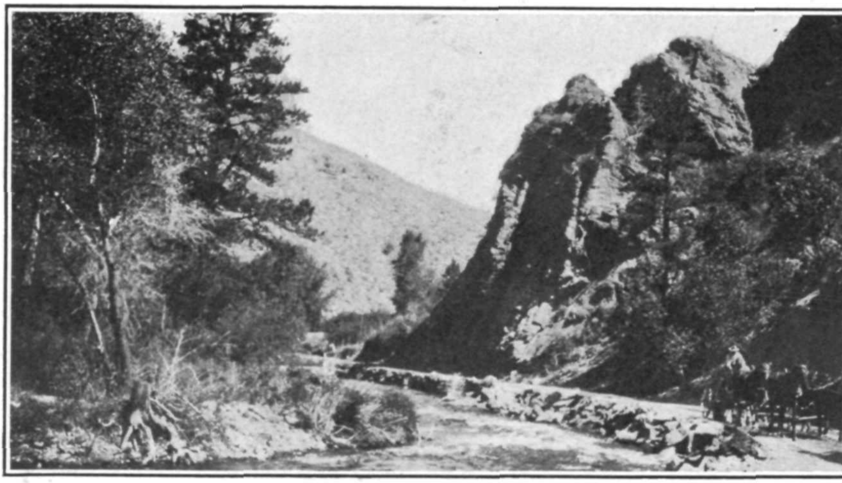
Lower, A "pothole" near Linger Longer Lodge, worn in a block of granite by sand and pebbles which are kept in motion by the eddying water.

Photographs by Willis T. Lee, United States Geological Survey.

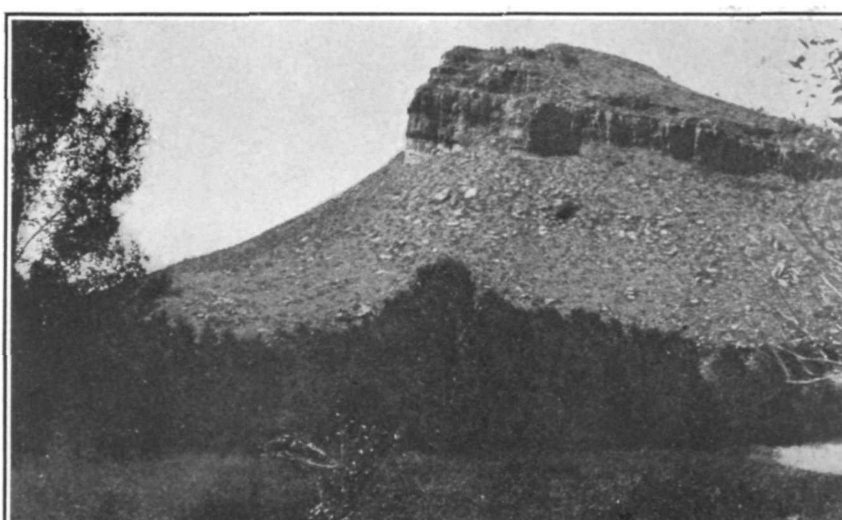
PLATE XI



THE RAPIDS, THOMPSON CANYON.



A. THROUGH WOODED LANE BETWEEN RAPID AND CRAG.



B. STEAMBOAT ROCK.

A promontory of red sandstone west of Lyons overlooking the St. Vrain.

VIEWS IN THE CANYON OF THE ST. VRAIN ON THE ROAD BETWEEN LYONS AND ESTES PARK.

Photographs by Willis T. Lee, United States Geological Survey.

The gorges east of North Fork are longer and are eroded much deeper than those west of the valley. This is due to the greater distance of the valley from the high mountains, the crest of the range lying 3 to 10 miles east of the great valley and reaching altitudes of more than 14,000 feet. Originally these gorges were ordinary canyons or valleys formed by stream erosion. But during the Great Ice Age they were filled with ice which crept from the heights down the canyons to the great valley. They modified the canyons, which were V-shaped in profile, to the broad-floored valleys of U-shaped profile characteristic of glacial erosion. Also they scoured the bottoms and sides of the valleys, removing the partly decomposed rock and the loose débris. They broke off and carried away the projecting pinnacles and spurs of rock so that what may have been crooked, irregularly shaped valleys now appear as relatively straight or gently curved gorges with steep walls. Like the better known glacial gorges of the eastern slope, which will be described in greater detail, these contain numerous ice-smoothed surfaces of rock, glacial lakes, and beautiful waterfalls (Pl. XIII, *A*).

THE PARK AS SEEN FROM THE TRAILS.

Progress is being made toward opening the Rocky Mountain National Park by means of trails, but in so rugged a country it will be a long time before all points are made easily accessible. On the following pages are described only such parts as were seen from trails in use during the summer of 1916.

The village of Estes Park is the center from which radiate many of the trails to the Rocky Mountain National Park. It takes its name from the basin-like opening among the hills which in turn was named for Joel Estes, the first white man to settle here. Prior to his arrival the Arapahoes visited the park frequently and knew it as "The Circle (ta kah ay non)."

From this "circle" as a center I shall "personally conduct" the reader over the several trails and point out to him some of the glories of the mountains. We shall start with the Black Canyon Trail and make our way gradually southward to Wild Basin, which is situated near the southern boundary of the park.

BLACK CANYON TRAIL.

From Estes Park one may go on horseback or on foot up Black Canyon to Lawn Lake, where there is a lodge at which bed and board may be secured. From this point he may go on foot to Hagues Peak, Hallett Glacier, and many other points of interest. On his return to Estes Park he may ride down the glacial gorge of Roaring River through Horseshoe Park and Fall River Valley, thus encircling a small but rather interesting group of mountains.

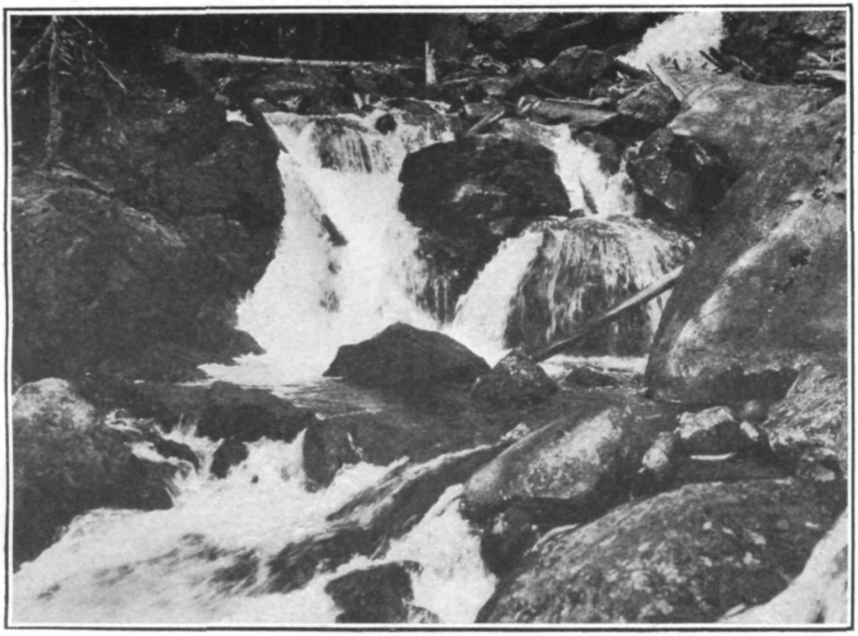
The Black Canyon Trail passes for several miles through a somewhat open and easily traversed valley. But it grows steeper and more difficult farther up the canyon. On leaving the village we pass close to the Stanley Hotel, which was built at a cost of half a million dollars in 1907, at a time when tourist travel was light and before success was assured by the establishment here of a national playground. From this place there is a superb view of the mountains (Pl. XIV, *A*), and many an attractive nook may be found among the pines and the granitic rocks which the forces of erosion have shaped in curiously interesting forms (Pl. XIV, *B*).

Still farther up the canyon we leave Castle Mountain (8,675 feet) on the left and pass The Needles, or "Little Lumps on Ridge (tha thay-ai ay tha)," as the Indians called these mountains, which reach a maximum altitude of 10,075 feet. The Needles take their name from the sharp pinnacles near the crest. Viewed from below these appear so sharp as to make the name seem singularly appropriate. The broad floor of the valley gives place abruptly to the precipitous side of The Needles (Pl. XV, *A*, p. 48) in a manner which suggests that this valley was shaped by a glacier. It is not situated in the area occupied by the ice during the last stage of glaciation but may belong to the older stage described on page 31. Some of the needle-like pinnacles are so shaped as to resemble well-known forms when viewed from certain directions. One of the best known is called Twin Owls (Pl. XV, *B*).

About 2½ miles from Estes Park the trail forks, the left-hand prong leading to a waterfall at the intake of the Estes Park water main. The right-hand prong leads up the mountain side toward Lawn Lake. Here we find ourselves on a typical mountain trail in the primeval forest, which winds in and out among the trees, sometimes with scarcely enough room to pass between them. It traverses rocky slopes and passes in some places uncomfortably close to the brinks of dizzy precipices.

Through the thick growth of trees we occasionally catch a glimpse of Bighorn Mountain (11,473 feet) and of McGregor Mountain (10,482 feet), which perpetuates the name of R. O. McGregor, who settled in Black Canyon in 1874. The beautifully rounded summit of the former is caused by concentric shells of the granite peeling off, a process known as exfoliation. Probably the best view of this mountain is obtained from a little parklike opening where beavers have cut away the underbrush and small trees and built a dam.

Just north of Mount Tileston (11,244 feet) the trail reaches a maximum altitude of 11,000 feet. There are few trees to obstruct the view and there are numerous snow banks; but we are shut in between walls of rock until the crest of the wind-swept ridge is reached, where there are no trees to interfere with the superb view (Pl. XVI, *A*). From this ridge there bursts upon us one of those matchless high



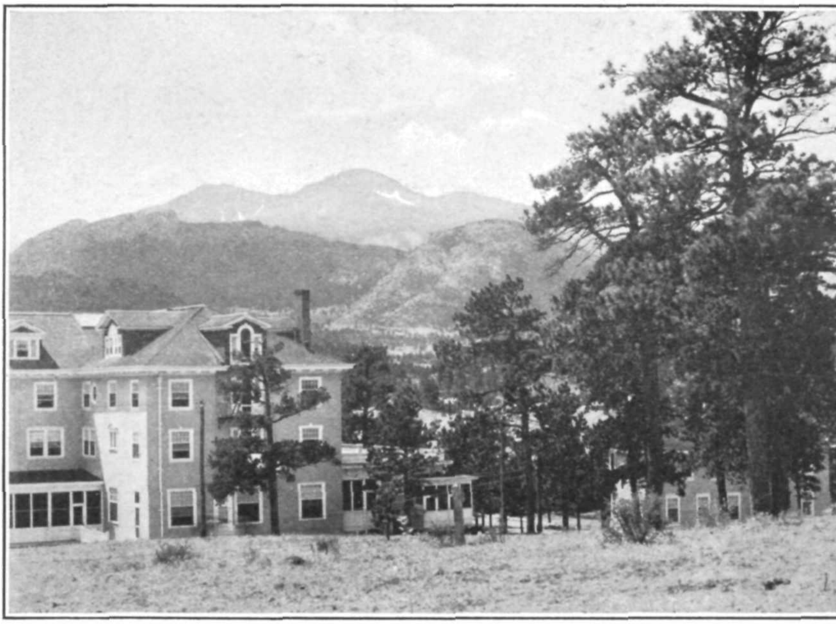
A. CASCADE FALLS, ON NORTH INLET, ABOUT 4 MILES ABOVE GRAND LAKE.

B. THE LODGE ON NORTH FORK OF GRAND RIVER, WEST OF MILNER PASS.

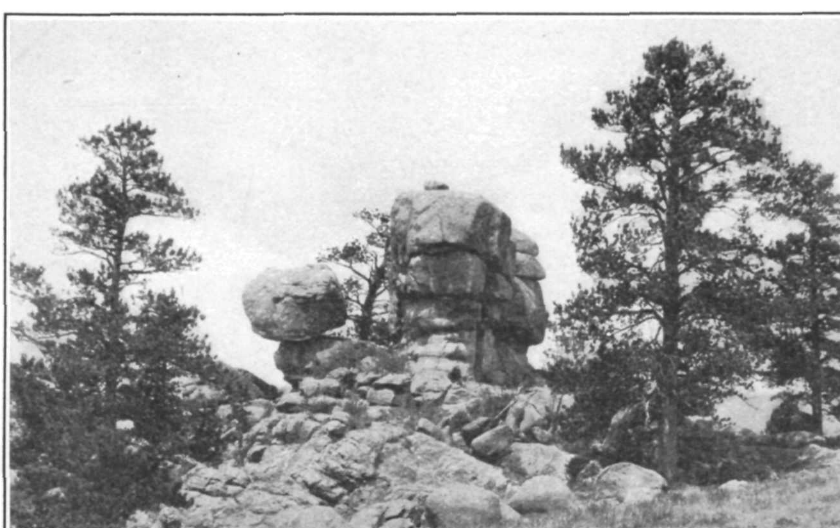
Generally known as "Squeaky Bob's place."

SCENES IN THE VALLEY OF NORTH FORK OF GRAND RIVER.

Photographs by Willis T. Lee, United States Geological Survey.



A. ESTES PARK AND LONGS PEAK FROM STANLEY HOTEL.



B. A REMNANT OF EROSION IN THE GRANITE OF ESTES PARK.

Showing character of weathering.

VIEWS NEAR ESTES PARK.

Photographs by Willis T. Lee, United States Geological Survey.

mountain scenes which it is quite impossible to describe. We gaze down 400 feet into the bowlder-strewn gorge of a glacier which once occupied the valley of Roaring River. Directly in front lies Lawn Lake, in the center of a great cavity that was gouged out of the mountain side by the ice which gathered for the Roaring River limb of Fall River Glacier (p. 32). Still higher may be seen, though imperfectly from this position, the subsidiary glacial cirque which holds Crystal Lake. To the left stands Mount Fairchild (13,502 feet); to the right Mummy Mountain (13,413 feet); and directly in front the dominating point of the region, Hagues Peak (13,562 feet).

LAWN LAKE.

Lawn Lake, which has an area of 65 acres, lies at the bottom of the main cirque at the head of Roaring River. It is one of the many glacial lakes of the park. The size and beauty of this one have been increased by the construction of a dam. In this way the water, which is abundant when the snow is melting early in summer, is held in storage until it is needed on the plains for irrigation later in the summer. The lake lies just below timber line, at an altitude of 10,950 feet; hence tourists are here sheltered by trees while they have every advantage of the unobstructed views usually obtained from points above timber line. In a horizontal distance of little more than a mile from the lake the precipitous walls at the head of the cirque rise more than 2,600 feet above the surface of the water to Hagues Peak and nearly as high on either side.

HAGUES PEAK AND HALLETT GLACIER.

The trip to Hagues Peak and Hallett Glacier is a difficult one and must be made on foot, for the route is too steep and rough for a horse. The start from Lawn Lake should be made early in the morning. We follow a trail for a short distance, then take a bearing to an objective point on the crest of the mountain and work toward it as best we may up the steep bowlder-strewn slope; for here no trail that can be followed has been laid out. Although this trip is as difficult as any other in the national park, we are not unmindful of the glorious panoramas that stretch out before us as far as the eye can reach. Almost at our feet lies Crystal Lake in its rock-walled basin high in the side of Mount Fairchild, and we understand better than before seeing it why such lakes are called "pocket" lakes.

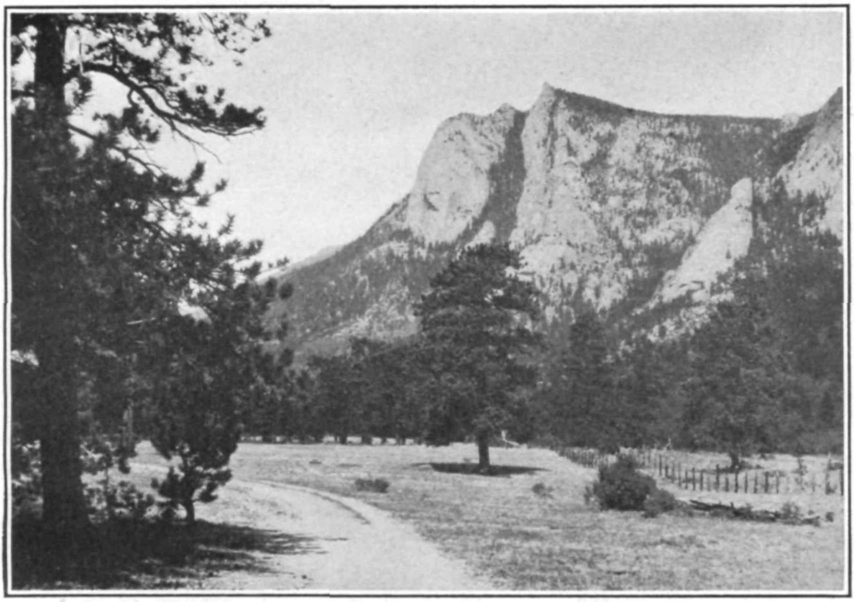
A side trip to the saddle between Hagues Peak and Mount Fairchild is worth all the effort required to obtain the unusual views from this point. Here may be seen the bighorns or wild mountain sheep and flocks of ptarmigan. Slightly to the south of Comanche Peak, partly within and partly north of the Rocky Mountain National Park, may be had an impressive view of a glacial cirque (Pl. XVII, *A*, p. 50). As the photograph was taken from a distance of about 5 miles, the cirque is shown in its true relation to its surroundings. This hollow, a mile long and half a mile wide, was gouged out of the mountain side by the ice of an ancient glacier to a depth of about 1,000 feet.

At the top of Hagues Peak are small remnants of the gently rolling plain (the peneplain of the geologist) which once occupied this region. A much larger remnant of this peneplain lies north of the peak. This surface seems nearly horizontal where its edge is seen above Hallett Glacier in the accompanying illustration (Pl. XVI, *B*, p. 49), but much of the old plain has been destroyed by recent erosion.[1] In some places, as between the cirque occupied by Hallett Glacier and the one immediately north of it, the old surface is broken down. The wall separating these two cirques is only a few feet thick at the top and is sharply serrate. Through the notches in this wall may be obtained views into the glacial gorges of the Cache la Poudre drainage area, which are well worth the effort they cost and which some maintain are the most charming to be found in the park (Pl. XVII, *B*, p. 50).

In order to reach Hallett Glacier we must cross the mountain ridge and descend into the cirque which lies at the head of the North Fork of Thompson River. The climb to the crest of the ridge is exhausting, and a few moments may be spent resting and viewing the entrancing scenes. To the east lies Mount Dunraven, named for the Earl of Dunraven, who came to Estes Park in 1872 and later acquired property there with the intention of establishing a game preserve. Still farther south is Mount Dickinson, named in honor of Anna E. Dickinson, who is said to be the first woman to reach the top of Longs Peak. Toward the west is the sharp ridge of Mummy Mountain, whose face, nearly 2,500 feet high, is so precipitous that it seems to overhang Lawn Lake. Beyond this is the galaxy of peaks and gorges which we are to visit as we traverse the trails farther to the south.

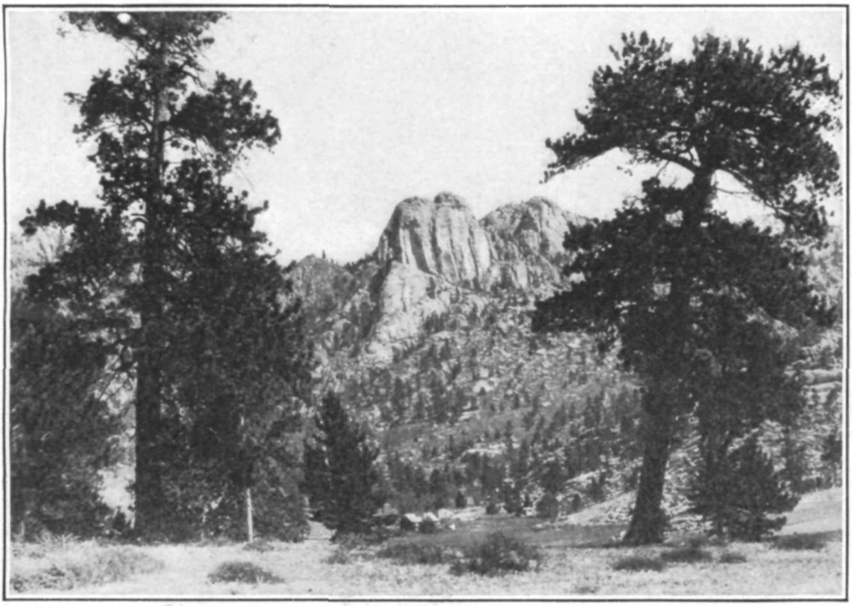
From this ridge there is a view of Hallett Glacier which is not surpassed from any other point (Pl. XVI, *B*). The glacier is a great crescent-shaped mass of snow and ice partly surrounding a lake about 300 feet in diameter. Its surface rises steeply from the water's edge to the mountain walls. As seen from below the glacier appears to slope steeply down from the south, west, and north, like tiers of seats in an amphitheater. As the ice all moves toward the lake, it moves in a northerly direction from the south and in the opposite direction from the north, while in the center it moves eastward. As the length of a glacier is reckoned by the distance covered by the moving ice from source to melting point, Hallett Glacier is much wider than it is long. This anomaly is perhaps matched for curious

[1] When the geologist speaks of recent erosion he means erosion that has been accomplished within the last million years or so.



A. THE SOUTH FACE OF THE NEEDLES.

Precipitous cliffs rising about 2,000 feet above the nearly level floor of Black Canyon.



B. THE TWIN OWLS, AS SEEN FROM A POINT NEAR STANLEY HOTEL.

These remnants of erosion indicate clearly why the Indians called The Needles "Lumpy Ridge."

LANDSCAPES IN BLACK CANYON.

Photographs by Willis T. Lee, United States Geological Survey.

A. LAWN LAKE AND THE GLACIAL CIRQUE AT THE HEAD OF ROARING RIVER.

The lake lies near timber line, and the mountains rise more than 4,500 feet above it.

B. HALLETT GLACIER, ABOUT THREE-FOURTHS OF A MILE WIDE, AT THE HEAD OF NORTH FORK OF THOMPSON RIVER.

Showing the lake at the foot of the ice caused by the ponding of water back of the moraine which appears in the foreground; remnants of the high-altitude plain (Flattop peneplain) formed by ancient erosion; the white snow of the previous winter, which had not melted from the surface of the glacier by August 25, when the photograph was taken; a part of the old dark-colored, dirty crevassed ice near the center exposed by the melting of the fresh snow; and the approach of the first snowstorm of the winter, which mantled the mountain in white.

Photographs by Willis T. Lee, United States Geological Survey.

interest by the question raised some years ago as to whether this body of ice should be called a glacier, a subject already discussed (see p. 30).

Great interest has been shown in the crevasses of Hallett Glacier. They differ somewhat in their mode of origin from the crevasses of some other glaciers and seem to be caused, partly at least, by the relief of pressure from below due to melting of the ice in the water of the lake. Some of the crevasses are concentric and conform essentially to the outline of the lake, as if large portions of the glacier were seeking to break off and float away with the surface ice which parts from the more massive body as small icebergs (Pl. XVIII).

But the crevasses of the higher slopes seem to be of different origin. Where the surface snow has melted away, the old ice is found deeply fractured. In exceptionally favorable seasons some crevasses open in late summer so wide that they may be entered and examined (Pl. XVIII, upper). A crevasse several hundred feet long was explored in the fall of 1915, to a depth of about 50 feet. But for 15 years prior to that time, according to report, it had not opened wide enough to be accessible.

ROARING RIVER.

On leaving Lawn Lake we pass southward for nearly a mile across the wooded floor of the cirque to a small but unusually perfect terminal moraine. It is a crescent-shaped ridge extending across the valley and is composed of rounded bowlders carried by the ancient glacier out of the Lawn Lake cirque and deposited at the end of the melting ice. This moraine is relatively young and marks one of the last stands made by the vanishing glacier, whose retreat may be likened to the withdrawal of a defeated army. In this case the enemies were the warmth of the moderating climate, which forced retreat, and the decrease in snowfall, which cut off supplies. This glacier once filled the valley of Roaring River (see Pl. VIII, p. 30), but was forced back toward the embattled strongholds of the high mountains. A mile south of Lawn Lake it made a final stand, built up a breastwork of bowlders, and maintained its position for a brief period before final extinction.

Farther south the trail angles down the steep slope of the glacial valley. Its east wall is precipitous and the cliffs show marks of ice action up to a height of several hundred feet. The western slopes are now densely forested but probably were once entirely covered with glacial ice which gathered east of the high range that extends from Mount Chapin to Mount Fairchild (see Pl. XIX, *A*, p. 50). These mountains have been carved by rain, stream, and ice into a group of picturesque gorges, cirques, and pinnacled ridges, but except for places near Ypsilon Lake these points of interest are not easily accessible for want of trails. However, the great peaks of this range are so prominent that they are plainly recognizable from many parts of the park. Ypsilon Mountain is especially attractive and is easily distinguished from all others by the Y inscribed in perpetual snow in its eastern face. At the southern end of this group stands Mount Chapin, whose name perpetuates the memory of F. H. Chapin, the author of "Mountaineering in Colorado," who first visited this region in 1886.

HORSESHOE FALLS.

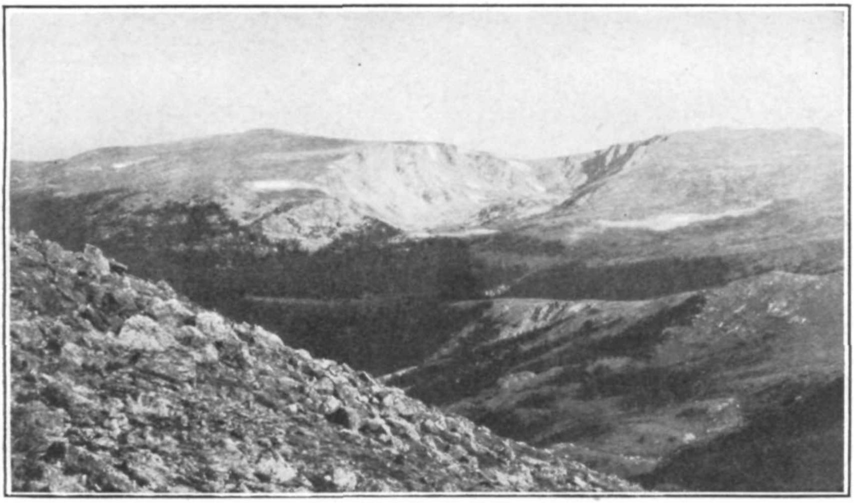
The main mass of Fall River Glacier (Pl. VIII, p. 30) occupied the valley of Fall River and eroded this valley much more extensively than the eastern lobe of this glacier eroded the valley of Roaring River. Hence Roaring River occupies what is called a "hanging valley"—that is, its floor lies at a higher level than that of the valley into which it empties. In its descent of 500 feet from this hanging valley Roaring River forms a succession of picturesque rapids and waterfalls, known collectively as Horseshoe Falls (Pl. XX).

There are great numbers of glacial bowlders along Roaring River, and as the water descends over these it is buffeted and torn and lashed into spray. The slopes on either side of the stream are densely wooded, and as we follow the winding trail through the woods and among the rocks the ever-changing scene holds many a pleasing surprise.

FALL RIVER ROAD.

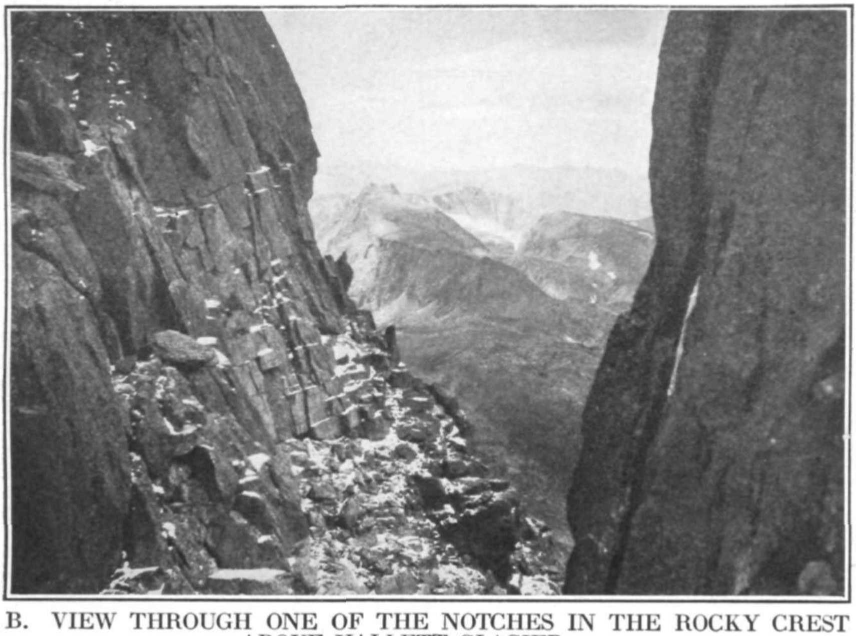
One of the favorite outings in the Rocky Mountain National Park is a trip up Fall River. An excellent automobile road across the Continental Divide had, in 1916, been completed nearly to the head of Fall River. The altitude of the mountains at the crossing point and for 3 miles beyond is nearly 11,800 feet. The course is westward near Poudre Lakes, through Milner Pass, and down the western slope to the North Fork of Grand River. On or near this route there are numerous plainly recorded evidences of ancient glaciers; many interesting evidences of volcanic activity in past ages, especially on Specimen Mountain; and unsurpassed views of the high mountains.

On leaving Estes Park for the Fall River drive we pass between Castle Mountain (8,675 feet) on the right and Oldman Mountain (8,306 feet) on the left. A short stop may be made at the fish hatchery, the yearly capacity of which is 1,000,000 rainbow, eastern brook, and black-spotted native trout. Farther upstream the course lies between two commanding summits of nearly equal height, McGregor Mountain (10,482 feet) on the north and Deer Mountain (10,028 feet) to the left, south of the river. Here we meet the first clear evidence of the ancient glacier which occupied Fall River valley. The hill on which we rise nearly 500 feet within a mile is the terminal moraine. The glacial material, consisting of striated bowlders, angular stones, and



A. A GLACIAL CIRQUE.

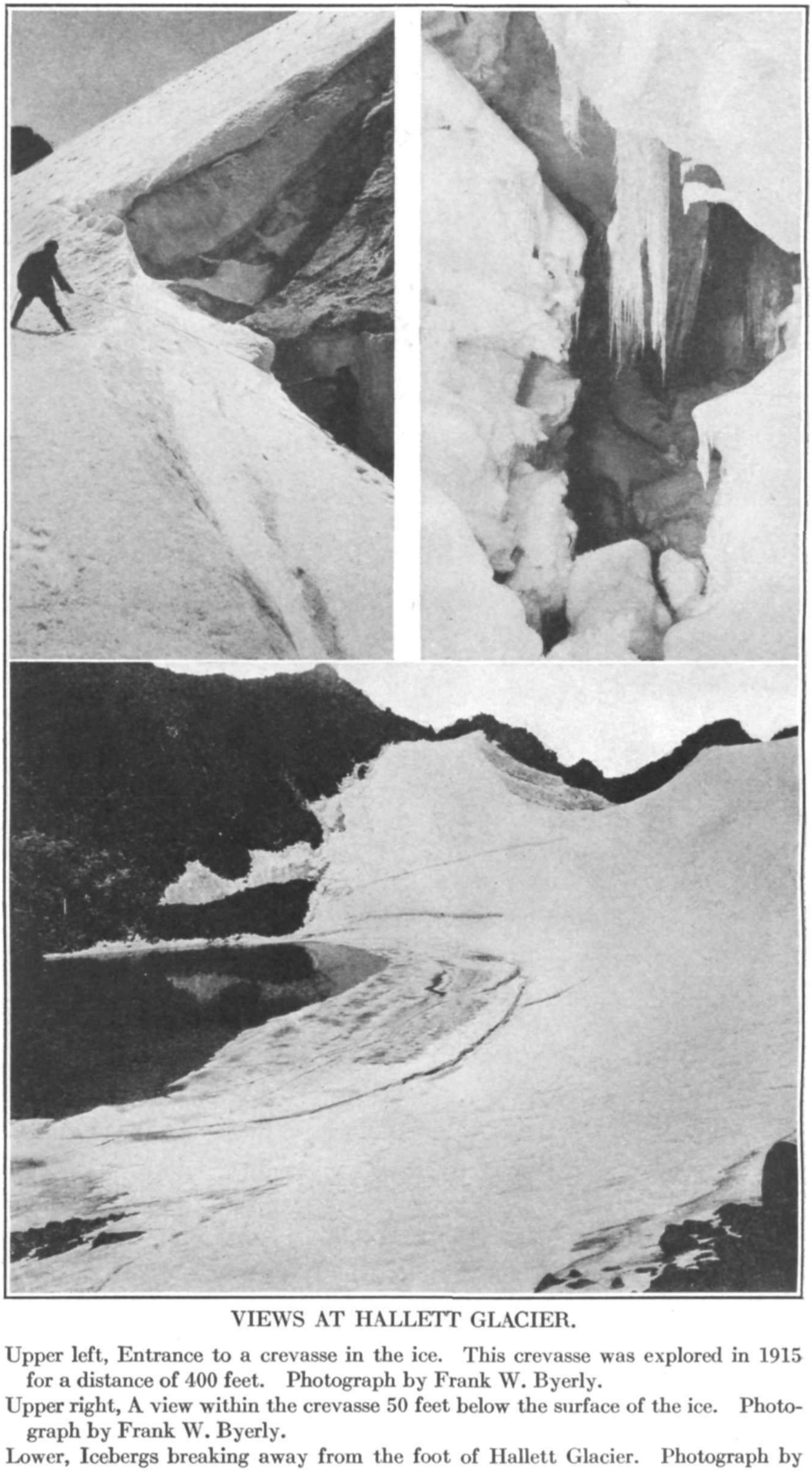
Situated chiefly above timber line southwest of Comanche Peak, as it appears from Hagues Peak at a distance of about 5 miles. It is a depression more than a mile long in the line of vision, half a mile wide, and 1,000 feet deep. One of the lobes of the glacier that occupied Cache la Poudre Valley during the later part of the Great Ice Age gouged into the mountain side and produced this unusually fine example of a cirque.



B. VIEW THROUGH ONE OF THE NOTCHES IN THE ROCKY CREST ABOVE HALLETT GLACIER.

Looking westward into the glacial cirques at the head of one of the tributaries of Cache la Poudre River.

Photographs by Willis T. Lee, United States Geological Survey.

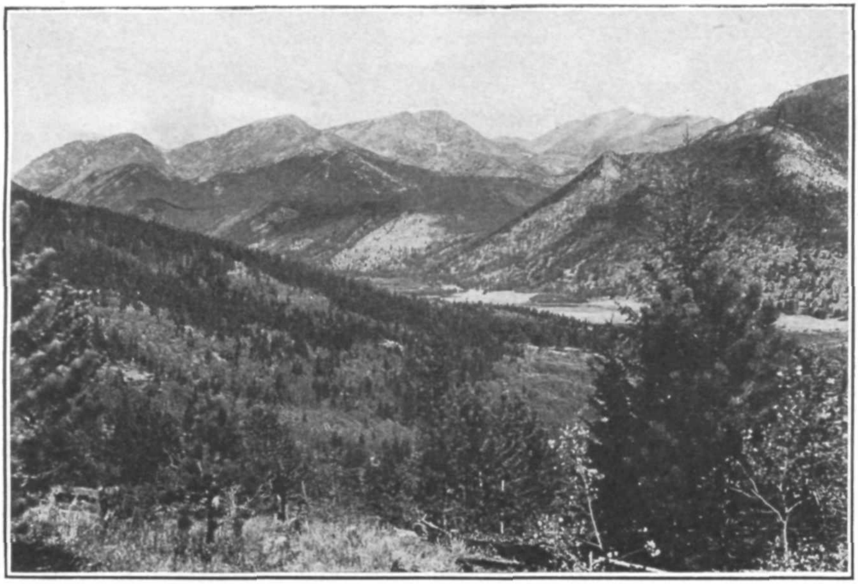


VIEWS AT HALLETT GLACIER.

Upper left, Entrance to a crevasse in the ice. This crevasse was explored in 1915 for a distance of 400 feet. Photograph by Frank W. Byerly.

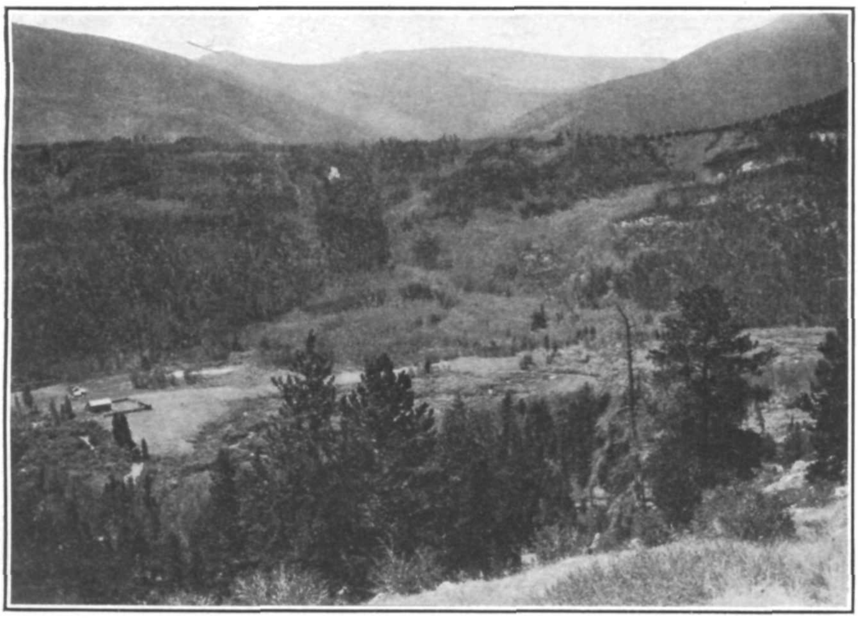
Upper right, A view within the crevasse 50 feet below the surface of the ice. Photograph by Frank W. Byerly.

Lower, Icebergs breaking away from the foot of Hallett Glacier. Photograph by Willis T. Lee, United States Geological Survey.



A. VIEW FROM HIGH DRIVE ACROSS HORSESHOE PARK TO THE MOUNTAIN RANGE NORTH OF FALL RIVER.

Including Mount Chapin (12,458 feet), Mount Chiquita (13,052 feet), Ypsilon Mountain (13,507 feet), and Mount Fairchild (13,502 feet).



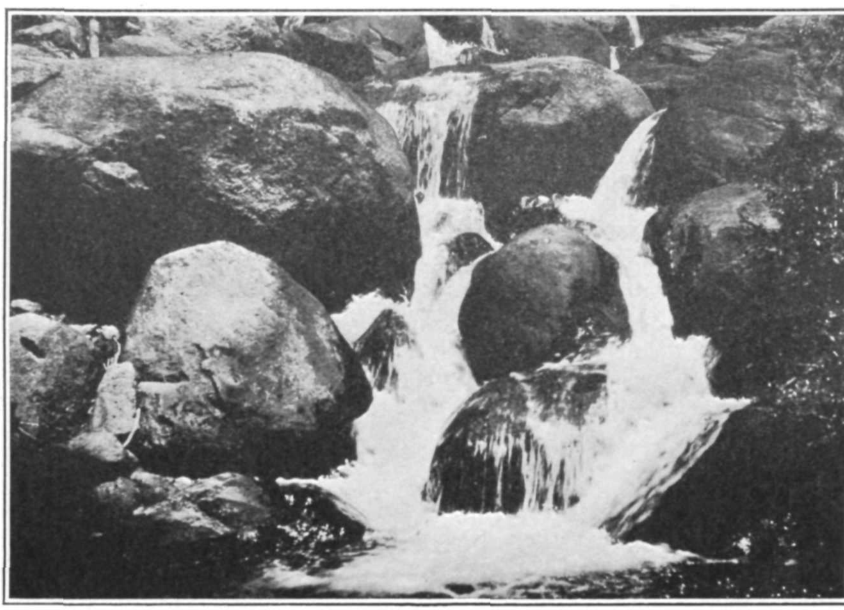
B. HORSESHOE PARK AND THE MORAINE SOUTH OF IT.

The even-crested morainal ridge in the middle ground was formed at the south edge of the Fall River Glacier, 900 feet above the floor of the melting basin. It was built across a tributary valley, as shown in the background, deflecting the stream southward (to the left) nearly 2 miles.

Photographs by Willis T. Lee, United States Geological Survey.

A. HORSESHOE FALLS, ROARING RIVER.

The stream plunges through the dark recesses of its wooded gorge over and among the glacial bowlders in a descent of 500 feet from its hanging valley to Fall River



B. RAPIDS NEAR HORSESHOE FALLS.

Showing great bowlders of granite deposited here by the ancient glaciers.
Photographs by Willis T. Lee, United States Geological Survey.

rock meal, may be seen in some of the cuts where grading has been done. To the right lies the lateral moraine, a narrow ridge which increases in altitude westward to about 9,500 feet, where it joins the solid mountain rock south of Horseshoe Falls. Here the top of the ridge is nearly 1,000 feet above the floor of the valley. To the right, north of this ridge, is an eastward-draining valley about 1½ miles long, which is the trough between the moraine and the unglaciated mountain slope north of it.

Horseshoe Park is a basin-like opening surrounded by high mountains. In the early days this park was the home of great numbers of wild animals. These were easily secured because of the shut-in nature of the park; hence the Arapahoes called it the "In-lodge." It is the melting basin of the old Fall River Glacier. The nearly level floor of the park is the surface of the ground moraine and consists of rock fragments carried down from the mountains by the moving ice. Fall River valley was filled in this way to a maximum depth of nearly 500 feet, as measured between the bottom of the moraine at its end and its top within the park. The floor of Horseshoe Park is not entirely flat; small rounded hills or hummocks rise slightly above the general level, where for some reason now unknown the melting ice dumped more than the average load of rock débris. Some of the depressions between the hummocks are now occupied by undrained lakes. One of these, called Sheep Lake, lies close to the road.

This lake has long been a favorite resort for the bighorns. These wild mountain sheep claim Bighorn Mountain (11,473 feet) for their home and come down to Sheep Lake nearly every day for water. A supply of salt placed near the lake has tempted them to frequent the spot. The old veterans no longer run wildly from the admiring tourist nor jump at the click of the camera; but when a strange sheep visits the flock and comes for the first time to the lake, amusing performances are likely to occur. He and the tourist view each other with mutual distrust. The bighorn usually considers the craggy mountain side the safest place from which to inspect suspicious strangers and springs hastily for some high point of vantage. When he finds that his companions do not share his concern, he is in a quandary whether to seek safety for himself or to wait for the others.

The conspicuous ridge south of Horseshoe Park is the lateral moraine built up along the south margin of the Fall River Glacier. It is an even-crested ridge (Pl. XIX, *B*) which rises about 900 feet above the floor of the valley and consists chiefly of bowlders dropped at the edge of the moving ice. A tributary of Fall River, which drains the eastern end of Trail Ridge, was dammed by this moraine and deflected. From the beaver dams eastward for nearly 2 miles this stream now flows in the trough between the moraine and the unglaciated mountain south of it.

PLATE XXI.

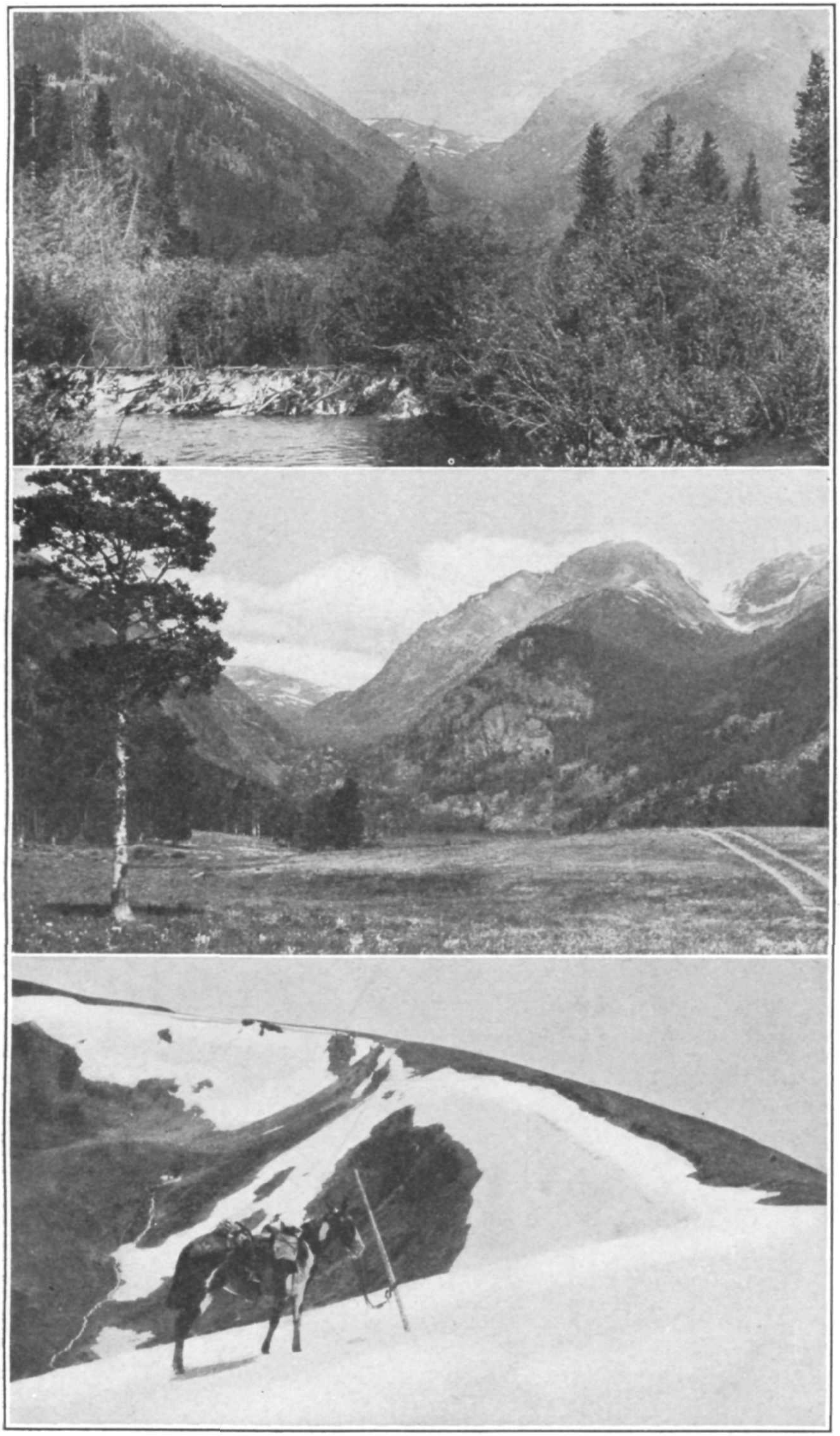
SCENES ON FALL RIVER.

Upper, A beaver dam on Fall River and the brushy floor of the upper part of Horseshoe Park, where the valley is made swampy by obstruction of the natural drainage.

Middle, Fall River valley as seen from Horseshoe Park, looking westward. Showing the nearly level floor and the characteristic U-shaped profile of the glacial gorge. A tributary glacial valley is shown at the right, with a mass of snow and ice at its head. Between the two valleys is Mount Chapin.

Lower, A midsummer scene (July 4) in the Rocky Mountain National Park. The rim of the glacial cirque at the head of Fall River, where the Fall River road will cross the Continental Divide. From the gently sloping plain at the top the winter snow is blown by the prevailing westerly winds and finds lodgment just below the rim of the cirque.

Photographs by Willis T. Lee, United States Geological Survey.



SCENES ON FALL RIVER.

Over the nearly level floor of Horseshoe Park the river winds in a serpentine course and is obstructed in many places by beaver dams (Pl. XXI), so that much of the valley floor is now swampy and covered with dense thickets of underbrush. Toward the head of the valley is an excellent view of a typical glacial gorge with the broad bottom and steep walls characteristic of a valley shaped by a mountain glacier (see fig. 6, p. 37). A stream-formed valley is likely to be somewhat crooked, to show a V-shaped profile, and to have irregular tributary gorges separated by ridges which project into the main valley. A typical glacial gorge such as Fall River valley above Horseshoe Park has a U-shaped profile with broad bottom (Pl. XXI), is relatively straight, and has few tributary gorges and few rock spurs projecting into it from the sides.

The regularity of form in Fall River valley is conspicuously broken near Chasm Falls, where a salient projects into the valley from the south. The surface of this salient was rounded and polished by the ice passing over it. The upstream side, which sustained the main force of the descending ice, was worn down to a gentle slope, while on the downstream side rocks were "plucked" from the face of the cliffs, leaving a ragged precipitous slope. It is here that Chasm Falls is situated in a narrow gorge originally formed by the ice, but later modified to some extent by the stream.

These smoothed surfaces may be seen in many places along the Fall River road. Where they have been protected from the weather by surface débris the polish has been preserved. Such surfaces were uncovered in many places during the construction of the road and may be recognized by the parallel scratches and grooves and by the rounded surfaces. In one place at the side of the road below the falls is a hole about 10 feet in diameter, where an eddy in the glacier ground out a circular depression in the solid rock.

Above Chasm Falls the snow banks begin to appear. They are numerous and large during the early part of summer but diminish rapidly where exposed to the sun. From the trail near Ranger Station we gaze into the broad cirque which constituted the catchment basin where the snow gathered during the glacial epoch to form the main lobe of Fall River Glacier. Many large banks of snow lie on the steep sides near the rim of the cirque, where it seems incredible that they should maintain their places on the precipitous walls (see Pl. XXI). A splendid example of the gouging action of ice may be seen in the pocket occupied by Iceberg Lake, which is inclosed on three sides by almost vertical walls of rock 500 to 800 feet high.

The last steep climb carries us to the rim of the cirque, at an altitude of nearly 11,800 feet. Here we are on the divide between the area drained by Thompson River and that draining into the Cache la Poudre. Directly in front across the valley of the Cache la Poudre lies Specimen Mountain (12,482 feet), a relic of the ancient volcanism which disturbed this region long ages ago. The road follows the crest of the divide for about 3 miles, and the great variety of scenery obtained from it well repays every effort it costs. In little more than a mile from the point where we leave the cirque at the head of Flla River we come to the head of Forest Canyon (Pl. XXII, *B*) and gaze down the long trough once occupied by Thompson Glacier, almost straight for nearly 10 miles. From this place also may be seen the great series of barren summits culminating in Longs Peak.

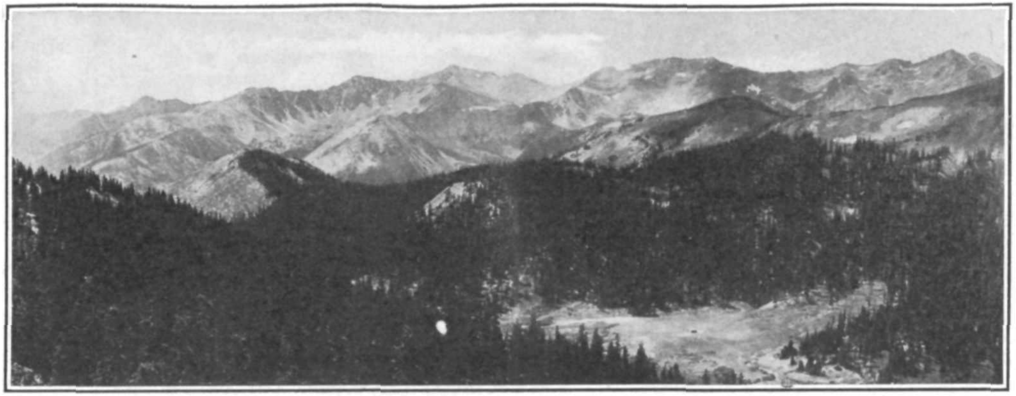
To the west, across the great valley of the North Fork of Grand River, rise the numerous needle-like pinnacles of the Medicine Bow Mountains or Never-Summer Range (Pl. XXII, *A*), many of which are nearly 13,000 feet high. These peaks are slightly lower than those in the part of the Continental Divide within the national park, but they are no less imposing. Their varied beauty and rugged grandeur surpass description. It is useless to try to picture them except by means of the camera; and no reproduction can do them justice. Mountains like these must be seen in all their wild surroundings to be appreciated.

TRAIL RIDGE.

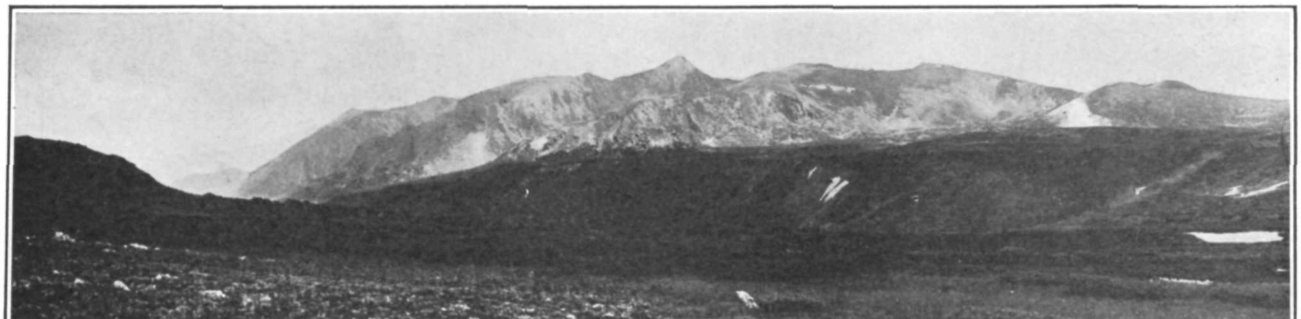
Although Trail Ridge is accessible from the east, the climb to it from this direction is difficult. It is more easily reached from the Fall River Road to the west. For nearly 8 miles Ute Trail, so named because it was used by the Ute Indians in years gone by, follows the ridge at altitudes greater than that of timber line. Eight miles of easy trail and unrestricted view is unique even for high-altitude landscapes. From many a point on this ridge there open before us panoramas extending through the complete circle and including every mountain in the Rocky Mountain National Park and hundreds of scarcely less prominent peaks outside its boundaries.

The top of this ridge is a part of the gently sloping surface called the Flattop peneplain, which occupied this region before the present mountains were carved out and before the great valleys, such as that of Fall River and Forest Canyon, were excavated. In the final shaping of the mountains the peneplain on Trail Ridge was almost destroyed in some places. For example, at Iceberg Lake there remains little more than enough of it to accommodate the trail. The ice of Fall River Glacier encroached upon it from the north and gouged out the rock-walled pocket in the bottom of which lies the lake, nearly 800 feet below. The ice of Thompson Glacier encroached upon it from the south in shaping the great gorge of Forest Canyon.

Some of the chief delights of a walk along the old Ute Trail are the unusual views of the peaks on the Continental Divide and the gorges which have been cut into their sides. This divide lies nearly parallel



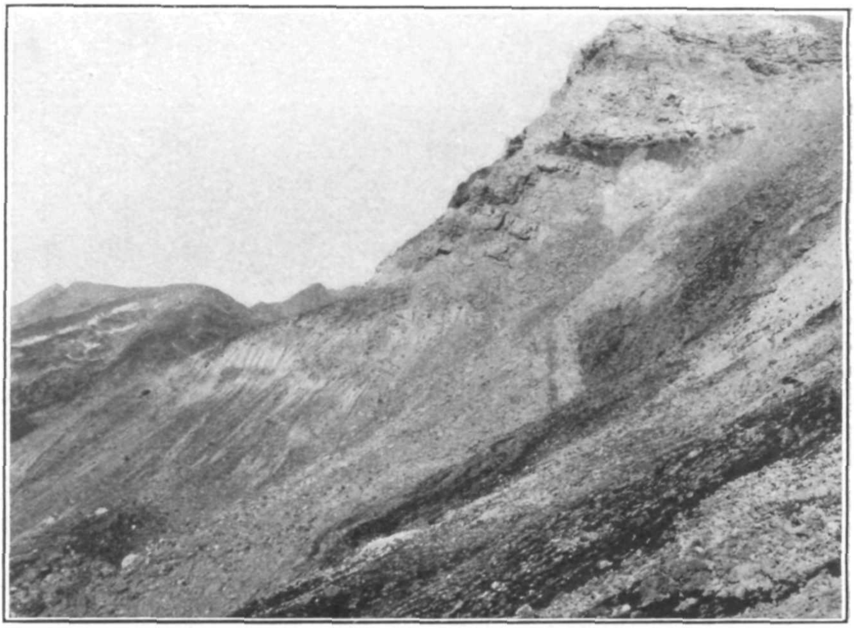
A. THE MEDICINE BOW OR NEVER-SUMMER RANGE AS SEEN FROM THE PROPOSED FALL RIVER ROAD.



B. A SCENE FROM THE FALL RIVER ROAD AT THE CREST OF THE FRONT RANGE.
Showing the head of Forest Canyon in the foreground and parts of the gently rolling surface of the high-altitude plain.

SCENES FROM THE CONTINENTAL DIVIDE.

Photographs by Willis T. Lee, United States Geological Survey.



A. WALL OF THE STEEP GULCH IN THE SIDE OF SPECIMEN MOUNTAIN.

Erroneously called "The Crater." Showing inclined layers of obsidian (volcanic glass), tuff, breccia, volcanic ash, and conglomerate.

B. DETAIL IN THE WALL OF SPECIMEN MOUNTAIN.

Showing the eroded edge of a layer of breccia and conglomerate. The angular blocks are andesite and the rounded ones are bowlders of granite and schist.

SPECIMEN MOUNTAIN.

Photographs by Willis T. Lee, United States Geological Survey.

to Trail Ridge at a distance of about 4 miles. In the clear atmosphere of these altitudes objects at this distance are outlined in remarkable perfection. From the trail the view is unobstructed across Forest Canyon to such noble masses of rock as Terra Tomah Peak (12,686 feet) and the high flat-topped ridge of the Continental Divide, and into the steep-walled glacial gorges with their picturesque waterfalls and pocket lakes. Some of these, like George Lakes, appear so close together that with the connecting stream they resemble a string of jewels.

SPECIMEN MOUNTAIN.

Another point of special interest reached by a side trip on our way across the divide is Specimen Mountain. From the ridge at the head of Forest Canyon just described we descend a steep slope of 500 feet or more to Poudre Lakes (Pl. XXII, *A*), where we cross the Continental Divide. Here is another of the curious anomalies of this region, namely, a continental divide at the bottom of a valley.

At the lakes we leave the main trail and follow a path which leads westward to Specimen Mountain (12,482 feet). This mountain differs notably from the other peaks of this region both in form and in the kind of rocks composing it. From the trail it appears a great rounded mass which seems out of place in this region of jagged pinnacled mountains. And in a peculiar sense it is out of place, for it differs not only in outline and composition but also in its mode of origin from all the other mountains of the Rocky Mountain National Park. Instead of the massive granite and schist which compose most of the mountains of this park, Specimen Mountain consists chiefly of rocks of eruptive origin, most of which are fragmental, arranged in thick irregular layers. The layers are steeply inclined and consist of beds of light-colored volcanic ash, flows of black obsidian or volcanic glass, and layers of conglomerate or masses of rock fragments. The blocks of rock in these beds range from grains of sand to bowlders 10 feet or more in diameter. Some of them are angular and were evidently derived by erosion from masses of igneous rock [1] which

[1] Because the rocks of this mountain differ in kind and character from all others in the park a short description of them by Esper S. Larsen is included as follows:

1. Altered andesitic rock. Contains abundant plagioclase and some altered dark mineral, probably augite, in a fine-textured groundmass made up of minute plagioclase laths and probably interstitial quartz and orthoclase. Apatite and magnetite are present, and carbonate is abundant, replacing both feldspar and dark mineral.

2. Rhyolite tuff, indurated and altered. It contains a few fragments of plagioclase, orthoclase, quartz, and biotite in a matrix originally made up of fragments of glass, largely the walls of bubbles, now altered and partly devitrified. Some undetermined secondary minerals fill some of the cavities.

3. Hornblende andesite (or latite). Contains rather abundant crystals of labradorite and brown hornblende, somewhat broken and resorbed, with a little augite in a groundmass made up of a felted mat of minute feldspar laths, probably largely orthoclase or a very sodic plagioclase. Cavities are filled with chlorite, chalcedony, and quartz.

4. Hornblende andesite. Contains abundant phenocrysts of andesine, brown hornblende, and biotite in a very finely crystalline groundmass made up largely of minute plagioclase laths. Apatite is abundant, and zircon and magnetite are present. Secondary calcite and a reddish-brown, very finely crystalline fibrous material with an index of refraction considerably below that of balsam are abundant.

had cooled and consolidated elsewhere. Others are well rounded and consist of granite and schist, such as are found in the neighboring mountains. The fragmental rock consists of several varieties of rhyolite and andesite, some of which are mineralized. Many of the green and blue shades of color are due to the presence of minerals containing iron. The fine-grained layers consist of volcanic tuff and ash, some well consolidated, others soft. Some of the fine material absorbs water until it has the consistency of soft wax or tar and is one of the causes for the formation of the gulch or so-called "crater." This sharp reentrant into the side of the mountain has walls so precipitous that some observers have imagined that it is the vent through which the igneous material of the mountain was poured out. It is not a volcanic crater in any sense, but a sharp gulch, eroded where the rocks are soft.

Because of the many unusual features connected with Specimen Mountain, we may stop a moment to consider its history. Some time within the Tertiary period, long ages before the agents of erosion had carved out the present mountains—before such valleys as that of Cache la Poudre and the North Fork of Grand River had been excavated—the material now constituting Specimen Mountain was poured out as molten rock on the surface near where this mountain now stands. It is possible that the location of the old volcanoes may be determined by further search, but it is not now known whether they were near the present mountain or at a considerable distance from it. It is probable that all surface indications of them were obliterated ages ago.

The ancient volcanoes were in eruption intermittently for a long time—probably for hundreds of thousands of years. Some of the early flows of lava cooled and hardened into rock through which solutions of mineral matter found their way. Crystal line matter was depositd, some in hollows—forming the so-called geodes of Specimen Mountain [1]—and some as a general coloring, like the green and blue stains due to iron silicate. Later these rocks were broken up in the process of erosion and transported, probably by streams, to their present position in the beds of Specimen Mountain. With these blocks of lava were embedded many rounded or waterworn bowlders of granite and schist, transported by the streams of that remote time from areas not covered by the lava. These beds of fragmental rock were in turn covered with flows of volcanic glass, which now appear as sheets of black obsidian. The mountain is made up of numerous beds or superimposed layers which differ from one another in character, thickness, and composition (Pl. XXIII).

[1] Some of the specimens from this mountain contain jasper and small pieces of opal. Agate, onyx, and other forms of chalcedony also are found. Some of the onyx has the parallel banding desired for cameos.

These beds were formed in nearly horizontal layers, but they are now steeply inclined, owing to rock movements which have occurred since they were laid down. The movements may have been in progress at the same time that the valleys were being eroded, but as the beds were formed nearly horizontal on relatively low land and are now steeply tilted and form the top of a high mountain, it follows that they were formed before the mountains attained their present altitude and before the great valleys were excavated. It follows further that although the rocks of Specimen Mountain are of igneous origin, this mountain can not correctly be called a volcano.

MILNER PASS.

At Poudre Lakes it is noticeable that the granite and schist contain dikes of the same kinds of rock as those found on Specimen Mountain. Some of these are light-colored; others are dark pink. They consist of the material forced from some reservoir of molten rock beneath the surface, which found its way upward through cracks in the older rock.

From the trail west of this pass we obtain beautiful views of the southern end of the Medicine Bow Mountains, or Never-Summer Range. The Continental Divide,[1] which is crossed at Poudre Lakes, ascends Specimen Mountain, crosses the saddle of La Poudre Pass, swings westward over Mount Neota and through Lula Pass, around the head of the North Fork of Grand River. Here it turns southward and follows the crest of the Medicine Bow Mountains (Pl. XXII, *A*) to Cascade Mountain, where it swings west beyond the boundary of the area mapped (Pl. I). The stormy character of this range, conveyed by the Indian name translated as Never-no-summer, is indicated by the modern names of the peaks, such as Mount Cirrus (12,804 feet), Mount Cumulus (12,724 feet), and Mount Nimbus (12, 730 feet).

For many tourists the Fall River route ends at "Squeaky Bob's," a lodge famous as a pleasant stopping place in North Fork Valley west of Milner Pass. It is owned by Robert Wheeler, who is called Squeaky Bob because of a falsetto voice. The nickname is accepted with good humor, and many a tourist who has enjoyed the hospitality of the lodge, which the owner chooses to call "Hotel de Hardscrabble" (Pl. XIII, *B*, p. 46), may be surprised to learn that he has a more formal name.

[1] The Continental Divide does not always follow the highest ridges. Longs Peak, the highest peak in the park, is 2 miles east of this divide. In La Poudre Pass it is more than 4,000 feet lower than the top of Longs Peak. In some places the divide crosses areas so nearly level that it is not easy to determine where the line should be drawn. In both Milner and La Poudre passes lakes lie so nearly on the divide that it is not easy to determine whether they are on the Atlantic or the Pacific slope. The Continental Divide is the line along which the waters separate, those on one side finding their way naturally toward the Atlantic Ocean and those on the other side toward the Pacific.

Several Indian traditions are perpetuated in the names of this part of the Rocky Mountain National Park. Milner Pass was called "Deer Pass" (bihhee-thoson) and the needle-like peaks to the north of Mount Richthofen, sometimes called Saw-Tooth Mountain, the Arapahoes called the "Eagle's Nest" (necihhi-nohhoo). At the head of the valley is Lula Pass, which the Arapahoes named "Thunder Pass" (bonnapah-neethason), for they said there was always a black cloud over it. South of this lies the beautifully sculptured "Never-Summer Range," near the southern end of which is Mount Baker, which the Indians called "Where the Sparrow Hawk's Young Hang" (haiya sona toyothay), because there were sparrow hawks' nests there. Also according to Mr. Toll, who is the authority for these statements, the North Fork of the Grand was called Coyote Creek (ka wu nee che), and the big open plain of the valley below Squeaky Bob's place was called "Plenty Jerked Elk Meat" (tee wohhoó tho).

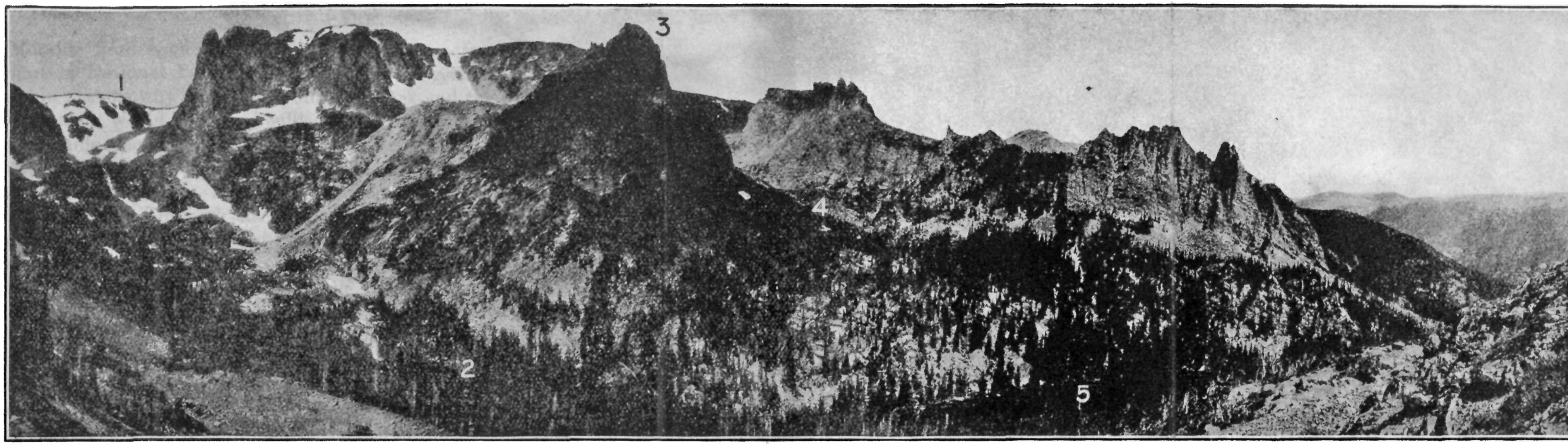
HIGH DRIVE.

Returning now to Estes Park we will next take the trip by automobile over the High Drive. This is one of the easiest excursions in the vicinity of Estes Park, although it embràces many features of unusual interest. We may go up Fall River and return by a southern route around Deer Mountain, or we may start up Thompson River and pass around this mountain in the opposite direction. On the latter route we leave Prospect Mountain (8,896 feet) on our left and mount the southern slope of Deer Mountain (Pl. VII, *A*, p. 28) over a naturally macadamized road made of the crystals of quartz and pink feldspar from disintegrated granite. From the top of the ridge north of Deer Mountain there are superb views of the group of mountains surrounding Hagues Peak to the north, and of the high range from Longs Peak to Flattop to the southwest.

To the south, stretching out as on a map, lie (1) the broad rolling surface of an unglaciated valley; (2) the northern lateral moraine of Thompson Glacier, separating the broad valley from Moraine Park; (3) the flat-bottomed melting basin of this glacier, known as Moraine Park; (4) the great even-crested ridge or southern lateral moraine of Thompson Glacier, more than 2 miles long and rising 800 feet or more above the floor of the park. Beyond these are the great snow-flecked mountains which dominate the view and dwarf the less magnificent features of the foreground. These are best brought out by the panoramic view given as Plate VII, *A*, p. 28.

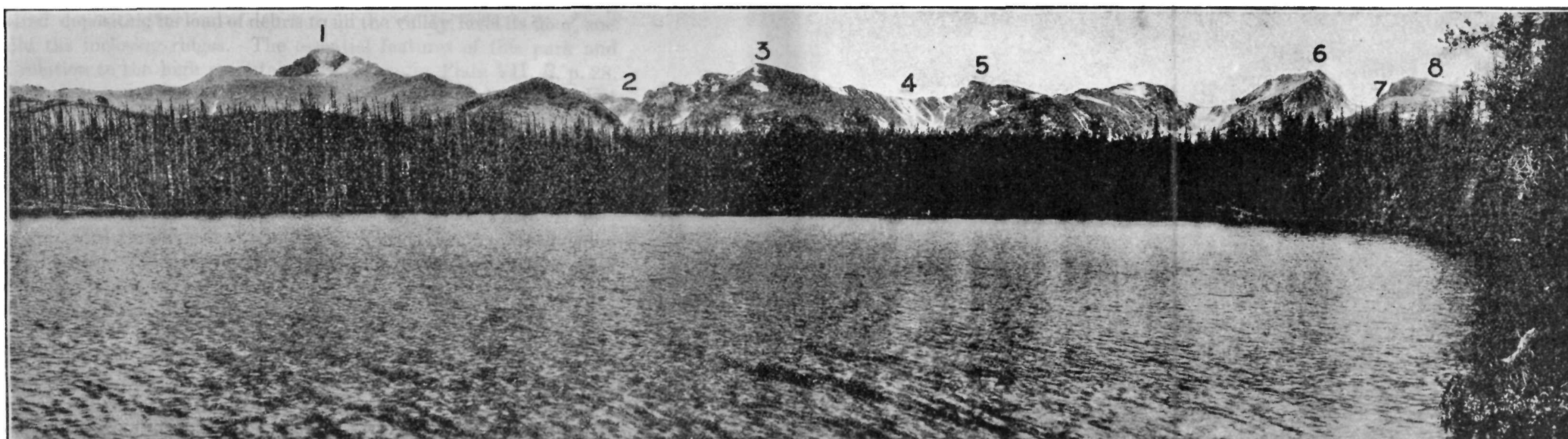
The view toward the north is scarcely less impressive. Below lies Horseshoe Park, the level-floored melting basin of Fall River Glacier, and beyond it Ypsilon and its neighboring mountains rise in dominating magnificence (see Pl. XIX, *A*, p. 50).

On the return trip we traverse the part of the Fall River route described on page 50.



A. ODESSA GORGE AS SEEN FROM THE MOUNTAIN SOUTH OF ODESSA LAKE.

1, Flattop Mountain; 2, Odessa Gorge; 3, The "Matterhorn"; 4, gorge of Tourmaline Lake; 5, Odessa Lake.



B. CREST OF THE SNOWY RANGE FROM LONGS PEAK TO FLATTOP MOUNTAIN, AS SEEN FROM BIERSTADT LAKE.

1, Longs Peak; 2, Glacier Gorge; 3, Thatchtop; 4, Loch Vale; 5, Taylor Peak; 6, Hallett Peak; 7, Tyndall Glacier; 8, Flattop Mountain.

VIEWS IN THE ROCKY MOUNTAIN NATIONAL PARK.

Photographs by Frank W. Byerly.

MORAINE PARK.

Moraine Park is one of the favorite tourist resorts of the Rocky Mountain National Park. There are excellent geologic and physiographic reasons why this is so. Moraine Park and the history of its development would be a good subject for a dissertation upon physiographic influence on tourist travel. Many natural features of unusual interest, which are easily accessible from this park, result from the natural processes that are grouped under the general heading of physiography. The park itself was formed during the Great Ice Age by the glacier which crept down Forest Canyon bearing loads of bowlders, some of which it dropped at the sides to form the lateral moraines and some in the middle of the valley as ground moraine to build up the broad floor of the park.

On the route from Estes Park to Moraine Park we ascend Thompson River, leaving Gianttrack Mountain on the left. Near the mouth of Aspen Brook, just before reaching Moraine Park post office, we mount the terminal moraine of Thompson Glacier (see Pl. VIII, p. 30). This moraine shows to good advantage in the bed of the stream, where the swift current has carried away the finer material, leaving only the large bowlders. The town of Moraine Park is located on the top of this moraine. The even-floored valley called Moraine Park is the opening into which the ice from Forest Canyon pushed, spread out, and finally melted, depositing its load of débris to fill the valley, level its floor, and build the inclosing ridges. The essential features of this park and its relation to the high mountains are shown in Plate VII, *B*, p. 28.

The rocks over which the ice moved are striated and polished, but those outside the moraine are rough and irregular and the outer portions crumble easily. The difference in character may be readily distinguished from the road east of Moraine Park post office, where the road lies between the moraine, seen south of the stream, and the unglaciated rock of the mountain side to the north.

A trail at the south side of Moraine Park leads up a tributary valley to Cub Lake. This valley is a short glacial gorge heading in a cirquelike depression in the side of the mountain. It receives very little drainage, and in these lakes, as in so many which contain nearly stagnant water, are great numbers of water lilies.

Near the west end of the park a trail branches off for Trail Ridge, which was used by the Ute Indians as a route across the Continental Divide. This is locally known as the Windy Gulch Trail. The Indians seem to have had the habit of choosing routes on which they could not easily be surprised by enemies. A steep, difficult climb out of Windy Gulch leads to the top of this ridge, which was described on page 54.

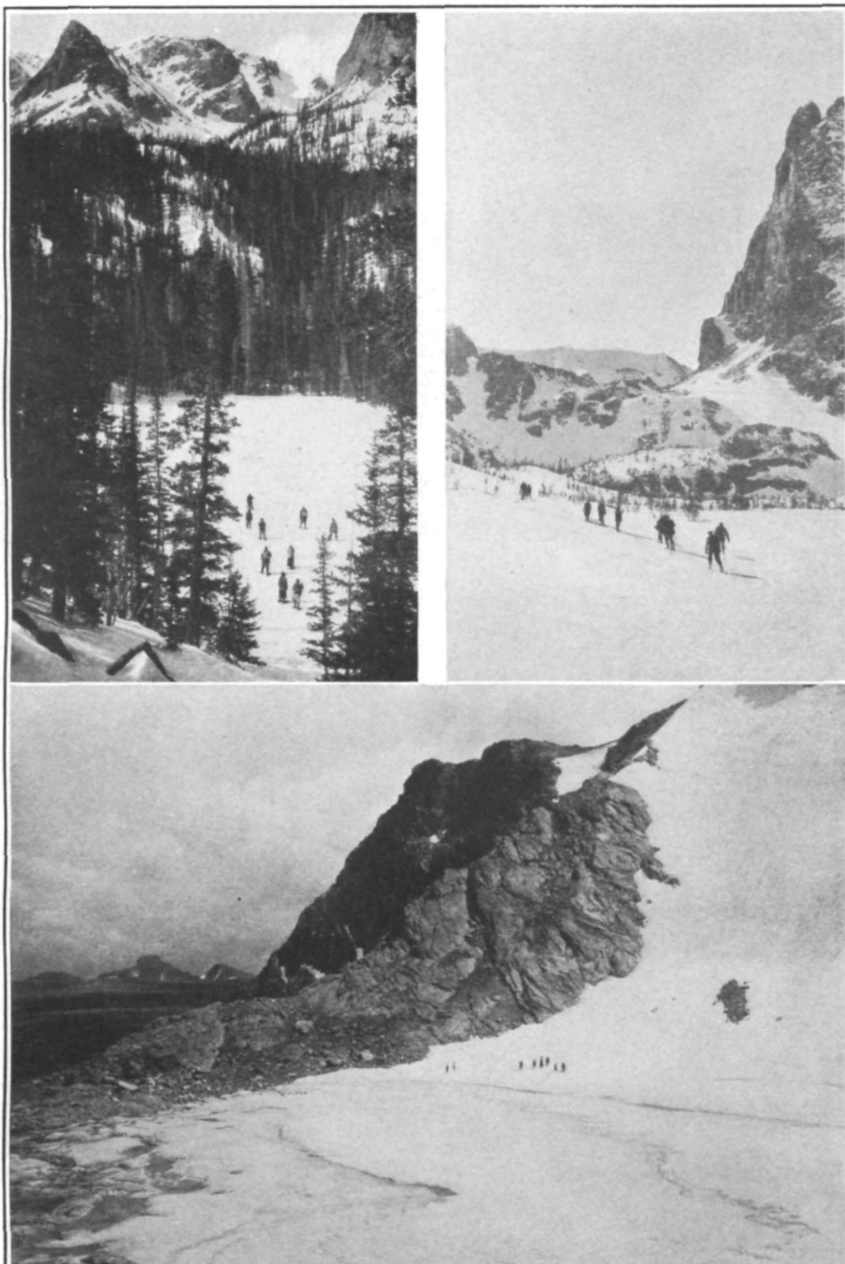
FERN LAKE AND ODESSA GORGE.

The road along the north side of Moraine Park is continued westward as the trail leading to Fern Lake. West of the park the valley narrows and assumes the U-shaped profile typical of a glacial gorge. Here the rocks are rounded and polished by the ice. Great bowlders of granite, some of them 40 feet or more in diameter, are strewn along the trail where they were dropped when the ice of the ancient glacier melted. Some of the bowlders may be seen perched high on the sides of the canyon. They appear to be so nicely balanced that they might be pushed from their pedestals with little effort. However, these balanced rocks have rested in their seemingly insecure position century after century, just as they were left by the ice which brought them from their native cliffs near the crest of the range.

The principal part of Forest Canyon is not now easily accessible from any direction, for trails have not yet been built into it. Near the point where Fern Creek joins the main stream the gorge is narrow, steep, and irregular in form. Where the trail crosses the stream the water races and plunges through a narrow gorge called The Pool. Its tumultuous action here is suggestive of the vastly greater and more profound disturbances in the ancestral glacier. What crevassing and grinding and crushing there must have been as the ice from Forest Canyon was joined by that from Spruce Canyon and from Odessa Gorge, and the combined mass forced its way through these precipitous, irregular narrows!

The trail follows Fern Creek, zigzagging up the steep side of the main valley to the hanging valley of Fern Creek, in the lower part of which Fern Lake is situated. Below this lake the stream leaps and dashes from bowlder and shelf in a series of rapids and cascades, descending 500 feet within a horizontal distance of about half a mile. The most accessible of the scenic features in this half mile are Marguerite Falls and Fern Falls. At the latter the water has nearly a sheer drop and forms a typical waterfall. These falls and rapids are rendered particularly attractive by their wild surroundings of mossy crags and evergreen trees.

Fern Lake (Pl. XXV) occupies a typical glacial basin. It is surrounded on all sides by steep forested mountain slopes, on which ice-smoothed surfaces of rock may be seen in many places. Odessa Lake occupies a similar depression about 500 feet higher. The view up Odessa Gorge (Pl. XXIV, *A*) is particularly attractive. Flattop Mountain (12,304 feet) appears at the left of the gorge, and Notch Mountain, as it is called locally, to the right. Above Odessa Lake we work our way over the steeply inclined floor of the gorge, meeting with scenes of rare beauty at every turn. From the great bank of snow near the top the water gathers in a minute lake from which it pours over the rim of the cirque at Grace Falls. In its passage down the gorge numerous little lakes and cascades are formed. In some places the water disappears from sight under loose aggregates of bowlders. In other places it is hidden beneath great banks of snow



WINTER SPORTS IN THE HIGH MOUNTAINS.

Upper left, Fern Lake frozen over and covered with snow. Odessa Gorge and Flattop Mountain in the distance. Photograph by Frank W. Byerly.

Upper right, Snowshoeing on the Continental Divide. Notchtop on the right. Photograph by John K. Sherman.

Lower, A part of Sprague Glacier. In the distance at the left is the square head of Longs Peak, which seems to rise abruptly from the high-altitude plain that lies between Sprague Glacier and Longs Peak. Photograph by Frank W. Byerly.

A. A FOREST OF PINE TREES.

A group of trees forming a mass of interlocking branches so dense and unyielding that one can walk on them but not through them. The tangle of branches is shown by the dead tree in the foreground, which, though little more than 2 feet high, has a trunk about 1 foot in diameter.

B. A LIMBER PINE.

This tree grew in a spot sheltered by rocks from the strong westerly winds. It is about 5 feet high and has a trunk about 3 feet in diameter. These trees are said to grow at the rate of 1 inch in a century, hence this tree is more than 3,000 years old.

TIMBER-LINE TREES IN ODESSA GORGE.

Photographs by Willis T. Lee, United States Geological Survey.

which fill the gorge from wall to wall and from which it emerges as if from the mouth of a cave.

To the right, or north of the gorge, stands Notch Mountain, a projecting angle of Flattop Mountain, with sides rising almost vertically to the gently undulating surface at the top. Farther to the right is a little tributary cirque across the mouth of which is a mass of rock fragments piled up by the ice which once filled this cirque. This mass was built out so near the edge of the cliff that some of it has slipped off as a landslide (see Pl. XXIV, *A*). A little farther to the right a similar cirque, but one more perfectly formed, is occupied by Tourmaline Lake. This is one of the objective points for sightseers and is usually reached from Fern Lodge.

A superb view of wild, inaccessible mountain slopes may be obtained toward the northwest from Fern Lake. The point south of Spruce Canyon stands out as a wonderfully conspicuous sharp-pointed crag, and Stones Peak (12,928 feet) seems to push its precipitous snow-flecked cliffs into the very clouds.

Although the Rocky Mountain National Park is used principally as a summer playground, there are some who maintain that it is no less attractive in winter. Fern Lake and other parts have been visited in winter by those who delight in snowshoeing and skiing when the lakes are frozen and the bowlders buried and the evergreens draped in their mantles of white.

The remarkable timber-line trees conspicuous in the Longs Peak region, where they are particularly well developed, are by no means confined to that region. Many interesting specimens of them are found in Odessa Gorge. They are curiously stunted and gnarled. They exist under most adverse conditions and grow very slowly. It has been said by those who have studied these trees that on the average it takes a century to grow a branch 1 inch in diameter. The tree in the accompanying illustration (Pl. XXVI, *B*) has a trunk nearly 3 feet in diameter, although it is only about 2 feet high. At the above rate of growth this tree is more than 3,000 years old. During that time it succeeded in sending branches to a height of about 5 feet. The branches of these trees are tough, wiry, and unyielding. They form a tangled, interlacing mass so strong that one can walk over them but can not push through them (Pl. XXVI, *A*). The closely woven branches catch the drifting snows of winter and make of them a protecting cloak.

SPRAGUE GLACIER.

By a side trip from Fern Lake we may reach Sprague Glacier, a large mass of ice supposed to be a remnant of one of the great glaciers of long ago. According to information received from Enos A. Mills (p. 30) a test extending over 15 days was made on Sprague Glacier in 1906, when it was found that the ice was moving at the rate of eight-hundredths of an inch a day. This rate of movement would carry the ice 2 feet 5 inches in a year, a rate of movement which seems to place this body of ice appropriately in the class of true glaciers.

The high-altitude peneplain or gently undulating surface at the top of the range called the Flattop peneplain, because of its typical development on Flattop Mountain, is well shown here, and its relation to the more recent erosion is beautifully illustrated. In the illustration (Pl. IX, p. 34) the relatively smooth surface shown at the top is a remnant of the once continuous surface formed by erosion, probably at a much lower altitude. Later the mountains were uplifted (see p. 21) and the gorges were cut in the elevated mass by rain and ice. In some places the old surface was entirely destroyed, but here the relation of the old and the new surfaces is shown conspicuously where the snow which drifted from the old plain on Flattop has lodged in the lee of the mountain on the walls of the newly formed gorge at the head of Spruce Canyon (see Pl. IX, p. 34).

FLATTOP TRAIL.

Under this general heading may be described several of the scenic features in easy reach from the trail between Estes Park and Grand Lake, such as Bierstadt Lake, Tyndall and Andrews glaciers, and Hallett Peak. The Flattop Trail is the southernmost of the two routes across the range, the northern one being by way of Fall River Canyon. In order to reach Flattop from Estes Park we leave Thompson Canyon east of Moraine Park and ascend Milk Creek. For about a mile this creek flows in a trough between the morainal ridge south of this park and the northern slope of the moraine of Bartholf Glacier. This creek marks the line of nearest approach of the two ancient glaciers and probably at the time of their maximum extension they actually joined.

West of the trough we enter a small triangular parklike opening shut in on all sides by steep slopes. To the north rises the moraine of Thompson Glacier, to the southeast the moraine of Bartholf Glacier, and to the west the unglaciated slope of the mountain which separated these glaciers. In this triangular opening, as in almost every other place in these mountains where opportunity is given, beavers have established themselves. Occasionally a dam is broken and a beaver lodge destroyed, as here (Pl. XXVII), where the mud which once covered the framework of the dwelling crumbled when the pond in which it was built was drained.

West of this opening, as we follow up Milk Creek, we enter another trough, the northern wall of which is formed by the unglaciated rock and the southern wall mainly by glacial débris. For a considerable distance west of Ranger Station Milk Creek marks the junction of the moraine with the solid rock. South of Ranger Station the trail zigzags up the face of the moraine, where it forks, one prong leading to Bierstadt Lake, another to Bear Lake, and a third to Flattop Mountain. By a short side trip Bierstadt Lake is reached.

BIERSTADT LAKE.

Bierstadt Lake lies on the very top of the great glacial moraine which was built up at the side and end of Bartholf Glacier. Because of this perched condition the Indians called it Hanging Lake. The moraine is densely forested in the vicinity of the lake, but the trees have been killed by fire in neighboring parts. A magnificent view of the high mountains may be obtained from the shore of this lake (Pl. XXIV, *B*).

The lake is named for the artist Albert Bierstadt, a landscape painter of international fame, who came to Estes Park in 1874 as a guest of the Earl of Dunraven. The beauty of the scenery in the vicinity of the park attracted the artist, and the sketches for one of his famous paintings were made here.

FLATTOP MOUNTAIN.

West of Bierstadt Lake the trail winds at first through a dense forest and later crosses an area where the trees were killed by fire in 1900.[1] Many of the trunks are standing, others have fallen, making almost impenetrable thickets. Near the edge of this spectral reminder of a once noble forest we leave the moraine and enter an area of rough, unglaciated rock. Here the slope steepens and is covered with angular bowlders. Above timber line these bowlders are numerous, and the mountain slope is so steep that little soil remains on it. This want of fine material renders trail making difficult, and the path winds among the rocks wherever an opening can be found.

It would be difficult to follow a dimly marked or snow-covered trail through this monotonous wilderness of bowlders. In order to safeguard the traveler against accidents during storms, the part of this trail above timber line has been marked by conspicuous monuments (Pl. XXVIII) set at short intervals. By means of these a storm-confused traveler may find his way down the slope on either side of the divide to timber, where the trail is more easily followed.

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[1] The date of a forest fire may be determined by counting the annual rings of growth of trees which sprang up in the fire-swept zone. Enos A. Mills, who has made a special study of trees in the vicinity of Estes Park, gives the following information in a communication to the writer:

"Previous to 1781 Estes Park and other open places in the mountains, like Middle Park, west of the range, were covered with forests of Douglas pine. These were devastated by fire in this year. This fire, which swept the Grand Lake region, middle St. Vrain, Wild Basin, and neighboring regions, seems to have been general on both sides of the range.

"In 1864 the east side of the range was swept by fire. The destruction was especially heavy east of Longs Peak. The trunks of trees killed by this fire are still standing in many places on the side of Twin Sisters.

"In 1878 fire again swept Wild Basin.

"In 1886 fire swept for a second time over parts of the territory east of Longs Peak, especially over the lower part of Mills Moraine and the south slope of Twin Sisters.

"In 1900 a small area on Mills Moraine was burned over. In the same year a separate fire burned over Glacier Gorge, Loch Vale, and parts of Bartholf Moraine near Bierstadt Lake."

PLATE XXVII.

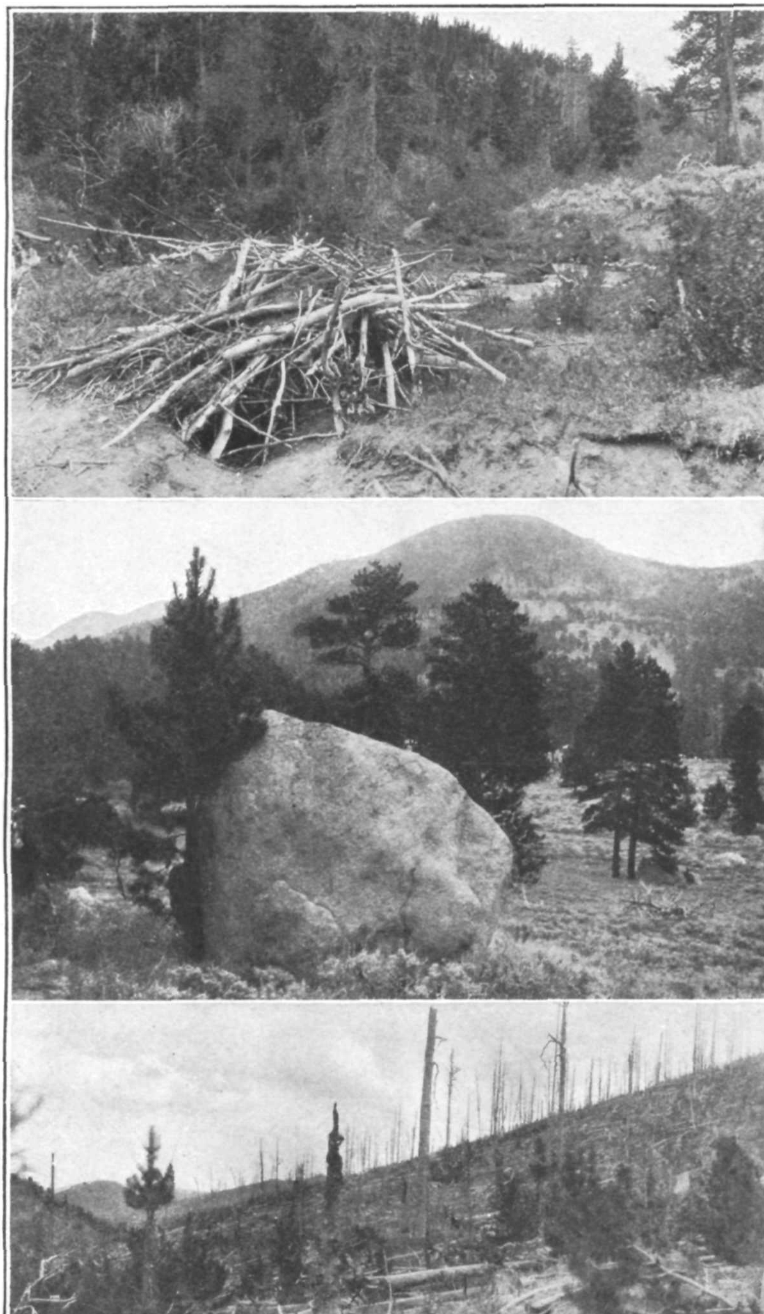
SCENES ON MILK CREEK.

Upper, A ruined beaver lodge on Milk Creek, deserted when the pond in which it was built was drained. The "front door" is seen at the bottom.

Middle, A typical scene in the area formerly occupied by the glaciers. This bowlder of granite was shaped by Thompson Glacier, carried by the ice many miles from its parent mountain, and deposited on this nearly level surface when the ice melted away.

Lower, The "ghost" of a forest where the timber was destroyed by fire.

Photographs by Willis T. Lee, United States Geological Survey.



SCENES ON MILK CREEK.

For a considerable distance up the east slope the trail is close to the edge of the precipitous cliff which forms the north wall of the gorge below Tyndall Glacier. At one point the trail is on the extreme edge, and we look downward 1,000 feet to Dream Lake (Pl. XXVIII) and outward into the remarkable gorge which was once occupied by the ancestor of Tyndall Glacier. At that time this glacier was a masterful body of ice instead of the feeble, dying, or perhaps wholly lifeless remnant of ice that it is at the present time.

Here the trail leaves the gorge and winds up the eastern slope of the ridge to the broad, gently sloping surface at the top, which, in comparison with the cliffs and precipitous slopes on either side of it, seems flat and is appropriately designated the flat top. The particular part of this slope called Flattop Mountain is only a small part of the gently undulating surface, remnants of which are found at the top of the highest mountains throughout the park along the Continental Divide. The water falling as rain west of this divide drains westward and enters the streams near the head of Grand River, finding its way at last to the Pacific Ocean. The rain falling east of this divide finds its way down the Big Thompson and out over the Great Plains to the Mississippi Valley and finally to the Atlantic. Hence the Continental Divide is the line of separation between the Atlantic and the Pacific drainage. It is here that the waters start on their long journey, hence their powers of erosion here are slight. For this reason the surface of Flattop has been preserved, while the old plain elsewhere has been entirely destroyed.

However, it is quite otherwise with the precipitation which comes in the form of snow. The prevailing westerly winds of winter sweep with such force over the unprotected surface of the high plain that large quantities of snow drift over the crest and accumulate in the deep cirques below the rim (Pl. XXIX). In this way the glaciers are formed. Were it not for this drifting of snow from the high plain and the protection afforded by the steep-walled cirques, it is doubtful if there would be any glacier in the Rocky Mountain National Park, although Hallett Glacier seems to be an exception.

It takes time to convert these accumulations of snow into glacial ice, and during this time the whole mass is slowly creeping down the slope. The upper part, called névé, is only partly transformed to ice and does not move as readily as the true glacial ice below. Hence the lower part of the mass settles away from the upper part, or névé, forming an open fissure, called the Bergschrund (see Pl. XXX).

The present glaciers furnish the key for unlocking some of the mysteries of the older and larger glaciers; the processes by which the present masses of ice are formed are probably identical with those which operated in the past. Doubtless, then as now, the winter

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winds were prevailingly from the west, and great quantities of snow drifted from the high plain and accumulated in such valleys as existed at that time. When these accumulations became voluminous enough, they began to move down the valleys, after the manner of glaciers, and by continued movement through long ages they scooped out the gorges and cirques. The snow which fell too far west of the divide to be swept over the crest accumulated at the head of the westward-sloping valleys and formed the glaciers of the western slope. But it is probable that the high plain at the top of the mountains remained relatively free from ice throughout the Great Ice Age, hence it escaped the intense gouging which the areas on either side experienced.

Throughout the park large bodies of snow and ice, which never entirely melt away, have accumulated near the heads of the gorges. This is particularly noticeable between Flattop and Longs Peak. Most of them seem to be motionless and are the dead remnants of glaciers that once were active, but a few have recognizable motion and may therefore be called true glaciers. Others are so small and their motion so slight that there is doubt about their glacial character (see p. 30).

GLACIERS AND GORGES SOUTH OF FLATTOP.

The crest of the range south of Flattop Mountain is most conveniently reached from the Flattop Trail. Hallett Peak, a rounded dome sheared at the side and rising somewhat abruptly from the Flattop peneplain (Pl. IX, p. 34), is one of the chief objects of interest in this region. It overlooks some of the wildest landscapes in the national park, and the Arapahoe Indians called it "Thunder Peak" (bonnahah-nottayah), from the thunder clouds which often hung over its summit.

The gorge south of this peak presents many unique features. Its snow fields, or glaciers, if they are such, have not yet been dignified with names. One of these especially deserves mention (Pl. XXIX, upper right), for it is a beautiful illustration of a hanging glacier, nestled in a hollow of the cliff and anchored by its ice roots to the solid rock.

At the head of the gorge south of Otis Peak lies Andrews Glacier. It is one of the largest masses of ice in the park and fills the upper part of its gorge, extending from the rim down to the lake which washes the lower end of the ice. Beneath the surface of this lake the hard blue or true glacier ice projects beyond the softer ice above it, which is more rapidly melted by the water. The surface of this glacier has a beautiful convex form (Pl. XXXI), probably because of radiation of the sun's heat from the rocks at the side. The middle of the ice, at a greater distance from the sun-heated cliff, is melted less rapidly than that at the sides.

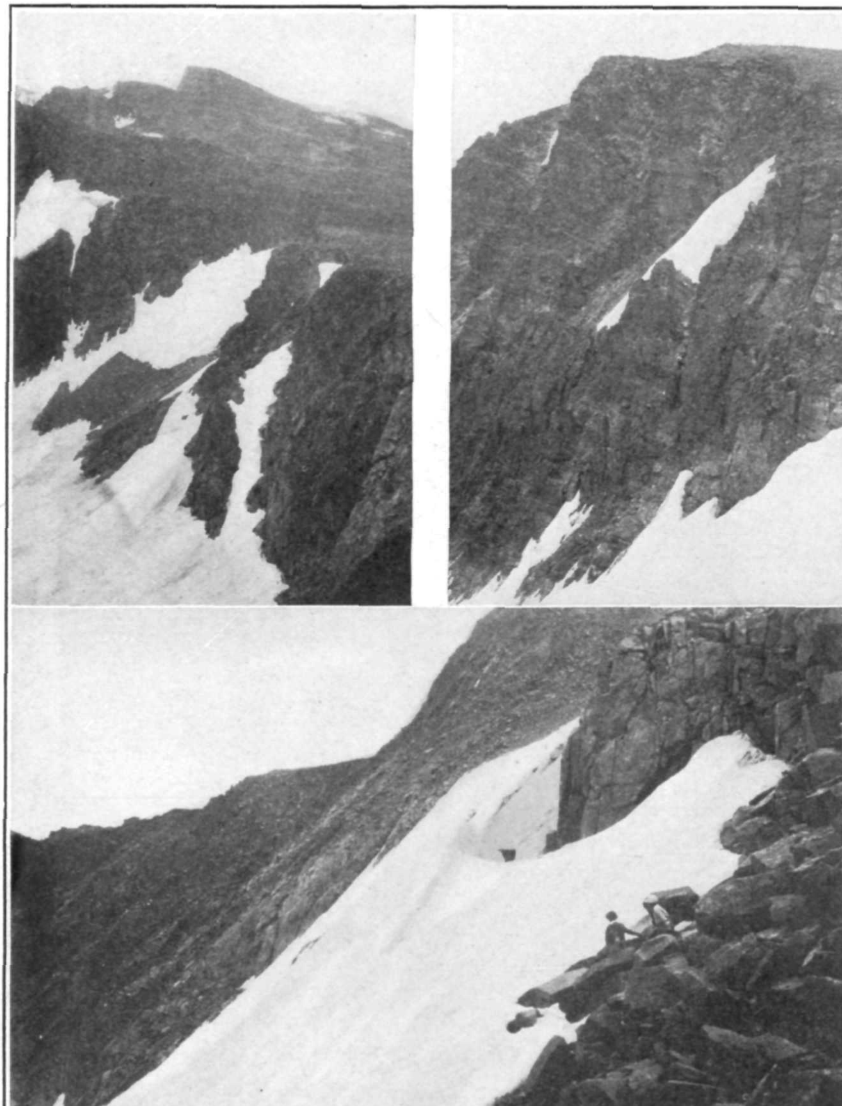
SCENES ON FLATTOP TRAIL.

Upper left, One of the monuments on the trail of Flattop Mountain.

Upper right, Longs Peak and Glacier Gorge as seen from the trail on Flattop Mountain. Longs Peak was named for Maj. S. H. Long and is the loftiest summit of the Front Range in northern Colorado.

Lower, One of the spectacular scenes in the Rocky Mountain National Park, due to glacial action—Hallett Peak, Tyndall Glacier, and the upper part of the gorge formerly occupied by glacial ice, as seen from the point where the Flattop trail approaches the rim of the gorge above Dream Lake. The remnant on the right is the side of Flattop Mountain. The gorge is the handiwork of the ancient glacier which gnawed into the heart of this originally rounded summit.

Photographs by Willis T. Lee, United States Geological Survey.



ON THE CONTINENTAL DIVIDE.

Upper left, How a glacier is fed. A part of Flattop Mountain and the rim of the precipice at the head of Tyndall Glacier. In winter the snow is swept by the wind from the gently sloping surface at the top and is deposited in the lee of the cliffs.

Upper right, A hanging glacier, a mass of snow and ice anchored to the solid rock in a sheltered nook of the precipice south of Hallett Peak. Masses of ice in such situations, if large enough, scoop out the tributary cirques and form the basins in which the pocket lakes are found.

Lower, The upper end of one arm of Tyndall Glacier. The semicircular hollow is formed by the melting of the ice, due to radiation of the sun's heat from the rocks.

Photographs by Willis T. Lee, United States Geological Survey.

Taylor Glacier, situated at the head of Loch Vale, is a long, steep body of ice clinging to the precipitous face of the cliff, anchored, doubtless, in crevices and reentrant angles in the rock. It is difficult of access from above and is more often approached from Loch Vale, although for want of suitable trails this is no easy matter.

In each of the several gorges is a succession of small lakes, most of which occupy basins cut in the solid rock. These lake basins were gouged out during the time of expansion of the ancient glaciers by bowlders held frozen into the ice. Each fragment thus dragged downward by the glacier helped to scour out the hollows and smooth the rocks over which they moved. However, a few of the lakes occupy depressions in morainal material or are formed behind dams built of glacial bowlders and rock meal.

One of the most beautiful of the gorges of this region is Loch Vale, which may be viewed either from above on the high ridge west of Andrews Glacier or from below. At its head is a typical glacial cirque, opening downward through a beautifully formed glacial gorge, the floor of which descends from shelf to shelf like a giant stairway. A small lake has formed on each shelf, as if the glacial giant strode down this stairway, leaving a hollow footprint at each step in which the water gathered to form a lake.

WEST OF THE CONTINENTAL DIVIDE.

From Flattop Mountain "The Big Trail," as the Arapahoes called it, is near the crest of the range for some distance. The mountain top is strewn with bowlders, among which may be found in summer great numbers of brilliantly colored flowers. The trail across this bowlder-strewn surface is difficult to follow, but the difficulty has been lessened by the erection of monuments at short intervals. (See Pl. XXVIII, *A*.)

On descending to the west we enter a cirque at the head of one of the tributaries of North Inlet and follow a zigzag trail down the precipitous slope to its floor. Thence westward the floor of the glacial valley is traversed to Grand Lake—the "Holy Lake" or "Spirit Lake" of the Arapahoe Indians. The main glacier which shaped this valley originated in the several large cirques between McHenrys Peak, Mount Alice, and Andrews Peak and received numerous tributaries (see Pl. VIII, p. 30). These tributary glaciers were relatively weak and did not deepen their gorges as rapidly as the main glacier. Thus were formed hanging valleys like that in which Lake Nanita and Lake Nokoni are situated. One of the main tributaries from the north descended from Snowdrift Peak and formed the small hanging valley in which lies Bench Lake. The water from this lake descends about 700 feet to the main stream in a series of cascades. But the surrounding forest is so dense in this region that many an attractive scene is missed by the traveler who has no time for long detours from the main trail.

In fact, the trail through the whole length of the valley of North Inlet is so shut in by the forest that only an occasional and inadequate glimpse can be obtained of the gorge, which seems remarkably attractive and picturesque to one who can climb to some commanding point. The glacier left numerous proofs of its presence along the bottom and sides of this gorge. The trail drops from shelf to shelf of ice-polished rocks, and from these shelves the stream descends in rapids and falls (see Pl. XIII, *A*, p. 76), some of which are exceedingly picturesque.

The Grand Lake region has been described (p. 73), hence we shall return to Estes Park and enter the next trail to the south.

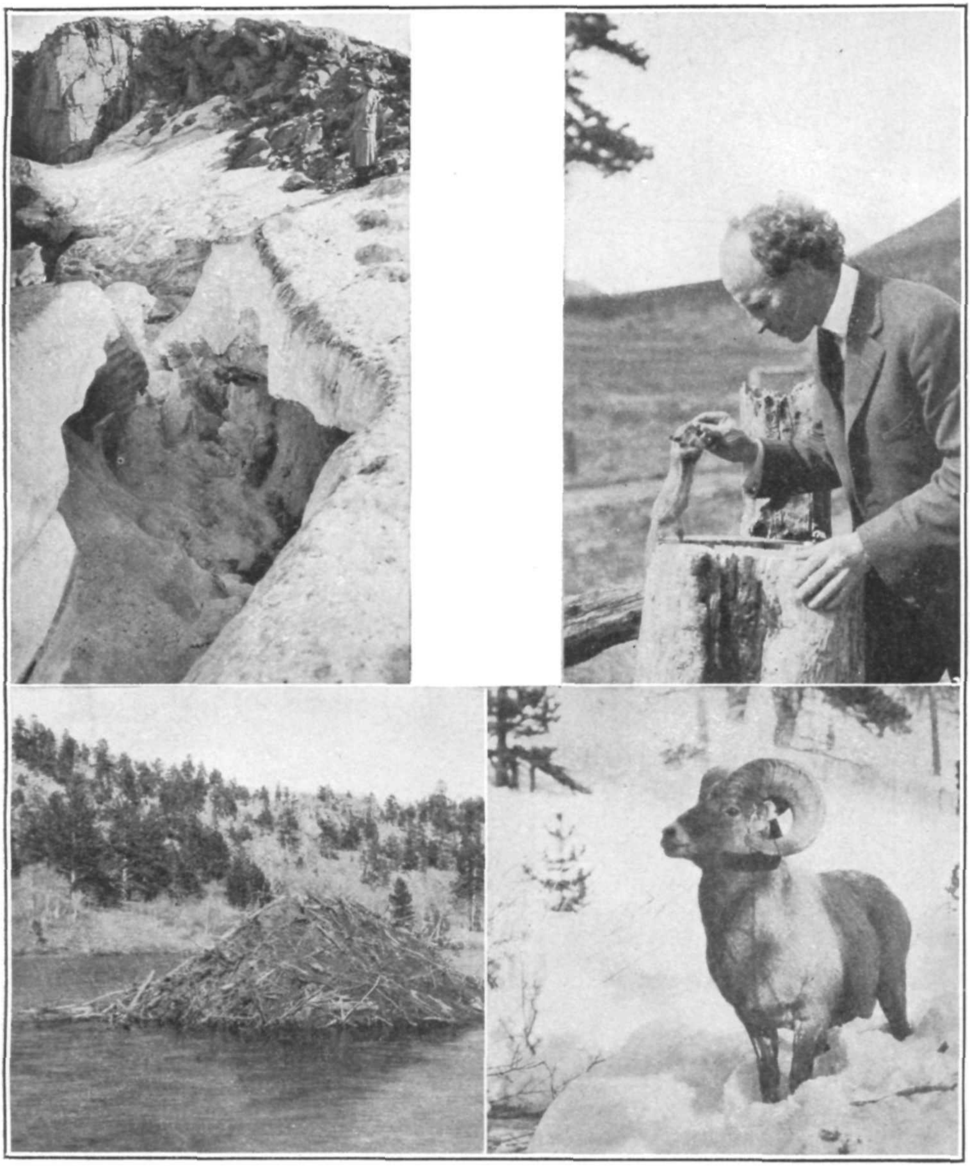
BARTHOLF PARK.

To reach Bartholf Park from Estes Park we follow up the Thompson River for nearly 4 miles, then cross it about a mile east of Moraine Park. Less than a mile from this crossing the route turns westward across the gently sloping surface of the parklike opening in which was established in 1910 the conference headquarters of the Young Men's Christian Association. Thence the road winds over a steep gravelly slope of disintegrated granite but before reaching the boundary line of the Rocky Mountain National Park passes on from this area of deeply weathered rock to the moraine of Bartholf Glacier.

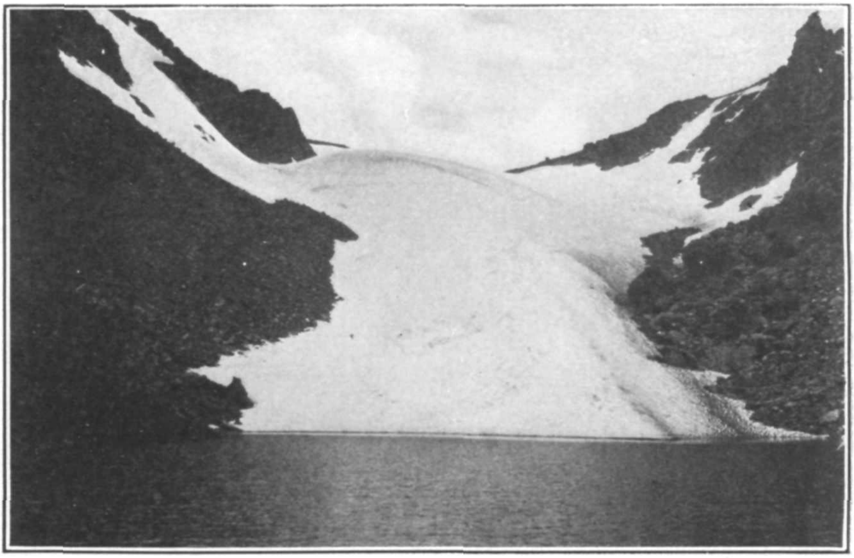
Bartholf Park was called "Timbered Flat" by the Arapahoe Indians, and the western end of this flat was called "Where the Apache was Killed," or literally, "Where the Apache was Shot Off the Rock"; (sáy nénne-cheb tet, Apache Shot Off Rock). It is a basin-like opening among the mountains, timbered in some places, although many of the trees have been killed by fire since the name "Timbered Flat" was applied to it. It is the melting basin of the ancient Bartholf Glacier, and its origin is the same as that of Moraine Park and Horseshoe Park.

The moraines of this glacier are more complicated than those situated farther north. They consist of piles of bowlders of varying size and shape, and the surface is rough. The side of the lateral moraine just south of Bierstadt Lake is regular in form and is an excellent example of a morainal slope. But the terminal moraine and the numerous recessional ridges in the park form a rough, hummocky surface, with imperfect crescentic ridges, rock piles, small undrained lakes or pools, and poorly drained basins. The surface, as viewed from a commanding elevation, is one which may properly be described as tumultuous. The glacier seems to have worked with unusual intensity and left a great variety of land forms. Probably

PLATE XXX

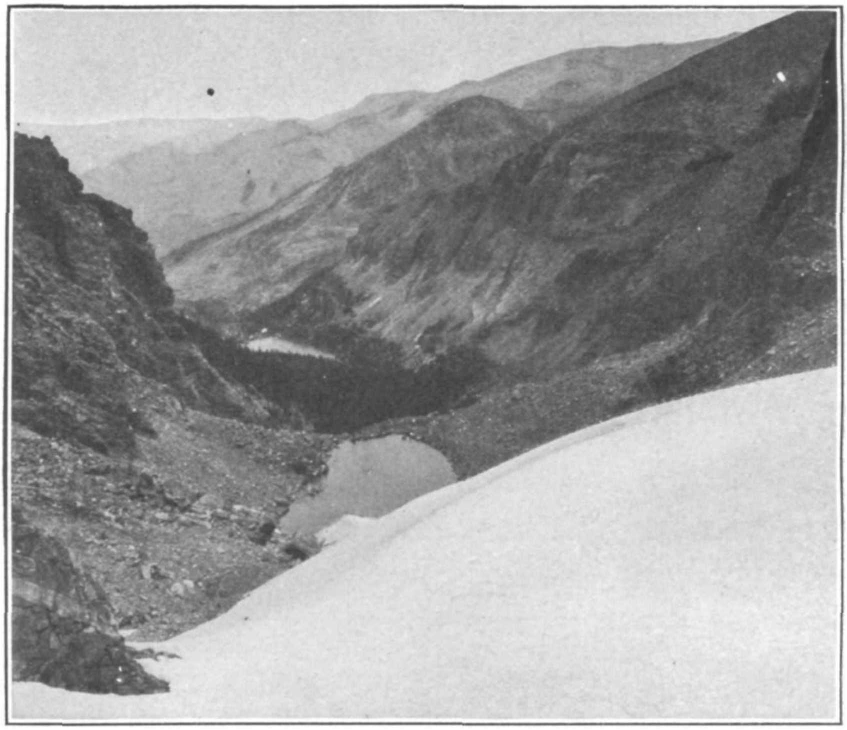


Upper left, A bergschrund on Tyndall Glacier, where the freely moving glacial ice below pulls away from the névé above. Photograph by George H. Harvey, jr.
Upper right, Enos A. Mills and one of his pets at Longs Peak Inn. Great numbers of these tamed chipmunks live at the inn and are sources of amusement to the guests.
Lower left, A beaver lodge. Beavers are numerous in the park, and their lodges in ponds may be seen in many places. Photograph by Enos A. Mills.
Lower right, A bighorn sheep. The mountain sheep are numerous in the northern part of the park. Photograph by Enos A. Mills.



A. THE GLACIER AS SEEN FROM THE LAKE AT THE FOOT OF THE ICE.

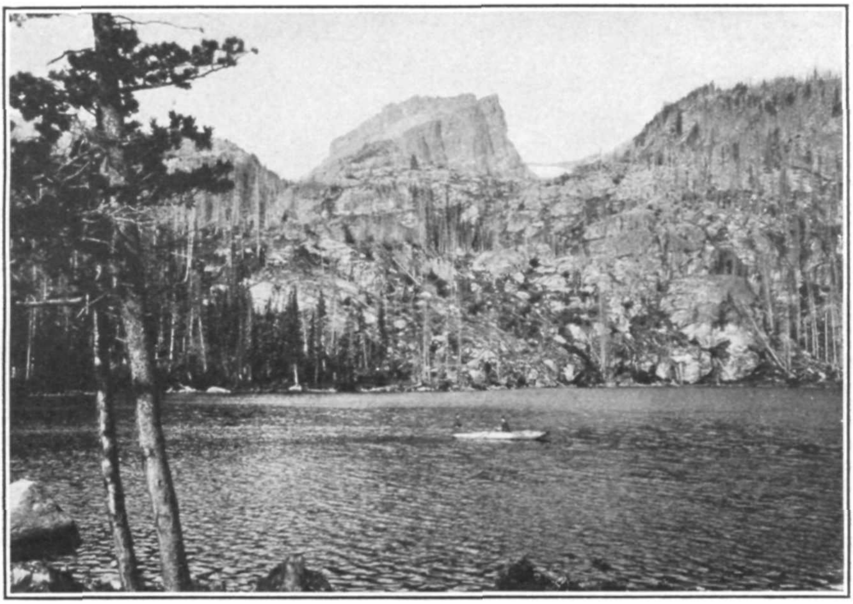
This is one of the finest beds of eternal snow and ice in the Rocky Mountain National Park.



B. THE EDGE OF THE GLACIER AS SEEN FROM ABOVE, LOOKING EASTWARD DOWN THE GORGE.

ANDREWS GLACIER.

Photographs by Willis T. Lee, United States Geological Survey.



A. BEAR LAKE AND HALLETT PEAK.

Looking up the gorge between Hallett Peak (12,725 feet) and Flattop Mountain to Tyndall Glacier. The lake has an area of 11 acres and lies at an altitude of 9,542 feet. The lake basin and the rock-walled gorge between the two mountains are the work of an ancient glacier which excavated this great hollow in the heart of the mountains.

B. LILYPAD LAKE, A DEPRESSION IN THE MORAINE NEAR BEAR LAKE.

Most of the trees near the lake were killed by a forest fire which swept this region in the year 1900. The spectral remnant on the farther shore is all that is left of a once glorious forest of spruce and pine trees.

Photographs by Willis T. Lee, United States Geological Survey.

LOCH VALE AS SEEN FROM THE LOCH.

To the left is the slope of Thatchtop Mountain and a part of Taylor Glacier. In the center is Taylor Peak and the mountain spur that extends from this peak northeastward between Loch Vale and Andrews Gorge. To the right is the slope of Otis Peak, with Andrews Glacier in the distance. Photograph by Willis T. Lee, United States Geological Survey.

in no other part of the Rocky Mountain National Park can so many points of interest be found in so small an area. For unusual landscapes and for wild, fascinating grandeur the region surrounding this park is unsurpassed.

From Bartholf Park forks of the trail lead in several directions. One to the right leads to Bierstadt Lake in a zigzag course over the moraine, which here rises steeply 700 feet or more above the floor of the park. Another leads southward over Storm Pass to Longs Peak Inn. Near the western end of the park the trail forks again, the right prong leading to Bear Lake and the left into Loch Vale and Glacier Gorge.

BEAR LAKE.

Bear Lake, with an area of 11 acres, is situated at an altitude of 9,542 feet. From the lodge on its shore excursions may be made to many parts of this most fascinating region. From this lodge we may look directly into the gorge between Hallett Peak and Flattop Mountain (Pl. XXXII, *A*). In this gorge lies Dream Lake, and on its steeply inclined floor are many recessional moraines or masses of bowlders dropped by the ice of the ancient glacier during the last stages of its retreat. At the head of the gorge lies Tyndall Glacier, the last remnant of the great body of ice which once filled it. At its lower end are large heaps of glacial material on which are situated such bodies of water as Bear Lake and its smaller neighbor, which some call Lilypad Lake (Pl. XXXII, *B*).

LOCH VALE.

The trail which was built into Loch Vale as far as The Loch (Pl. XXXIII) in 1916 winds in and out through a varied succession of cascades and bowlder-strewn gorges which lie between precipitous faces of rock. In many places the trees have been killed by fire and their dead trunks stand or lie among the remains of the dead glaciers. The weirdness of the landscape as it was left by the ice has been augmented by the destruction of the forest, and the specters created by the two opposing forces, heat and cold, here stand side by side. But there is some compensation even in destruction, for here many varieties of brilliant flowers bloom, especially the bright-red Indian paintbrush and the still more brilliant fireweed.

Beyond The Loch we make our way with some difficulty through the brush and over the bowlders and up the rocky slopes to Taylor Glacier. The climber who is experienced in the exploration of glaciers may enjoy scaling this steeply inclined body of ice, but the inexperienced will do well to remain below. To the right, west of The Loch, is the great rocky gorge at the head of which Andrews Glacier is situated.

PLATE XXXIV.

SCENES NEAR LONGS PEAK INN.

Upper left, Fire observer's station on the top of Twin Sisters. From the summit of this lofty mountain the view is unobstructed for many miles in all directions. The peak is used by the Forest Service for discovering and locating forest fires. The observatory is bolted to the rocks to keep it from blowing away. In it are instruments and maps by means of which a fire can be accurately located and the information telephoned to the rangers whose business it is to extinguish the blaze. The fire observer lives in a stone cabin built in a sheltered nook in the side of the mountain just below the observing station.

Photograph by E. P. Cole.

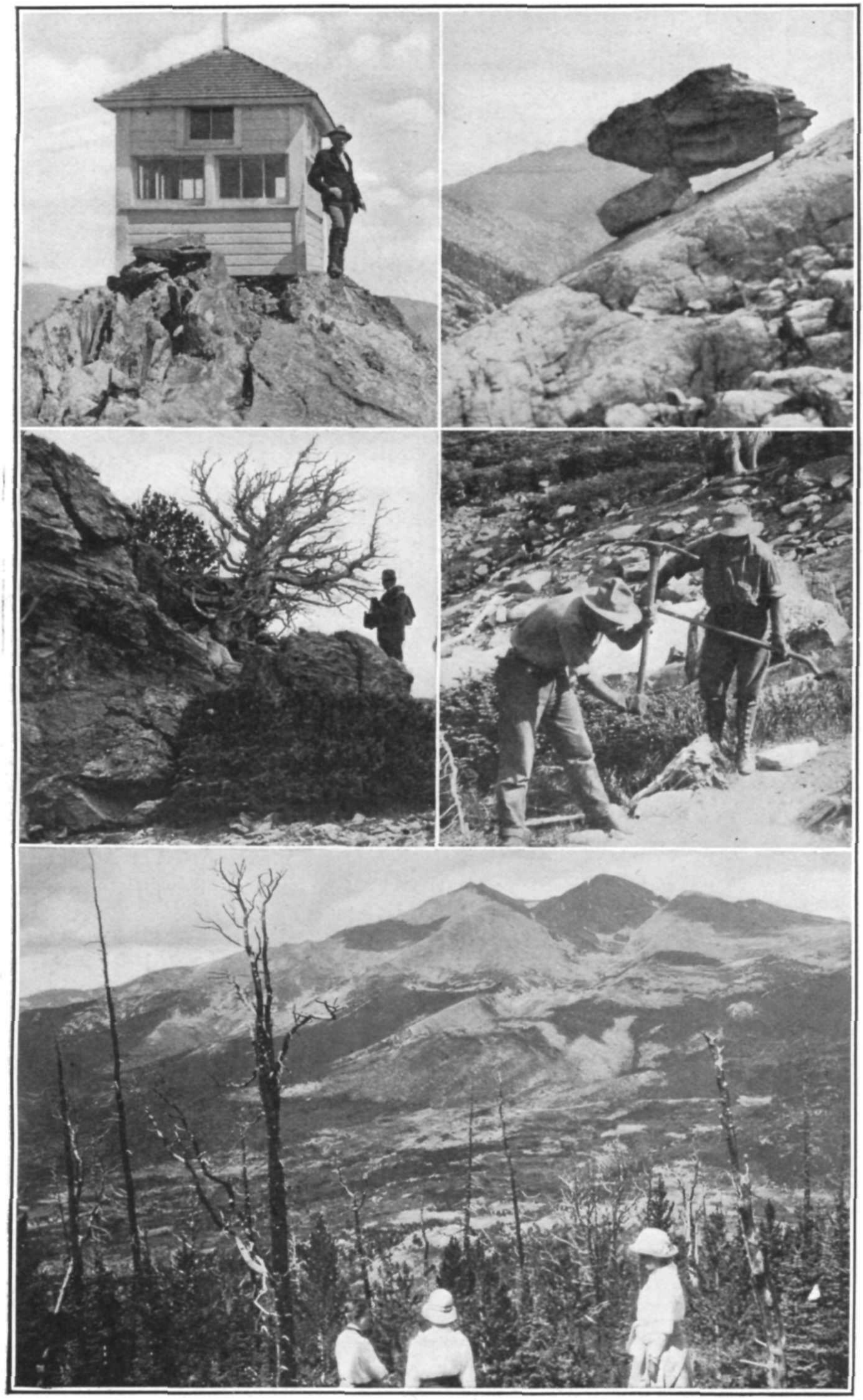
Upper right, A balanced rock left on an ice-smoothed surface when the glacial ice melted from The Chasm on Longs Peak.

Middle left, Timber-line trees on Twin Sisters. The dark-colored mass in the foreground is a living pine tree about 3 feet high. The dead tree, about 5 feet high, has a trunk nearly 2 feet in diameter and is probably about 2,000 years old.

Middle right, The trail makers at timber line on Longs Peak.

Lower, Longs Peak from Cabin Rock. In the foreground is the broad Tahosa Valley, in which Longs Peak Inn is situated. Showing also Longs Peak, Mount Meeker, Mount Lady Washington, The Chasm in the face of the mountains, and the heap of fragmental rock nearly 1,000 feet high carried by Mills Glacier out of The Chasm and deposited in the moraine.

Photographs by Willis T. Lee, United States Geological Survey.



SCENES NEAR LONGS PEAK INN.

A. MILLS MORAINE AND THE CHASM ON LONGS PEAK.

The moraine—the crescent-shaped ridge in the middle ground—is composed of rock fragments carried by the ancient glacier from The Chasm and deposited at the sides and end of the ice. The moraine is about 2 miles long and its two ridges are half a mile apart.

B. NEAR VIEW OF THE CHASM.

Looking up the gorge toward Longs Peak from the lake half a mile east of Chasm Lake. The floor and walls are composed of barren rock just as they were left when the ice of Mills Glacier melted.

Photographs by Willis T. Lee, United States Geological Survey.

Loch Vale should be considered together with its neighbor, Glacier Gorge, but unfortunately neither is now easily accessible. The two constitute one of the most fascinating regions in the Rocky Mountain National Park, or in fact in mountain country anywhere.

LAKE MILLS.

Glacier Gorge can be viewed from above to much better advantage than from below, and its description is deferred (see p. 79). However, the hardy climber will doubtless feel amply repaid for his trouble of a thorough exploration as he gazes at the many unusual scenes in this remarkable gorge. Mills Lake, having an area of 10 acres, occupies a basin scooped out of the solid rock by the glacial ice that once filled this gorge.

The waterfall just below Mills Lake is one of the most picturesque to be found in the Rocky Mountains (see frontispiece). Its volume of water is not remarkably large nor is the height of the fall great, but the form assumed by the water as it pours over the rocks and leaps into spray or dashes among the bowlders and under the fallen trees is a picture not soon to be forgotten. Especially attractive is the view from below, where the forest is dense and dark and the gorge is narrow. The water seems to gush from the very mountain side, suddenly springing into brilliancy as it breaks over the rocks.

ESTES PARK TO LONGS PEAK.

ROUTES.

Three routes are available between Estes Park and Longs Peak. One passes east of Prospect Mountain through the Dunraven property [1] and up Fish Creek. Another follows up Thompson River for about 2 miles, where it turns to the left and joins the first route. The third is by way of Aspen Brook.

On the second or main route we pass Marys Lake, a small body of water beautifully situated in the midst of a smooth rolling greensward and surrounded by granite crags which stand like monuments in a park. From points south of this lake superb views may be obtained of Estes Park and of the mountains surrounding it.

After a steep rise at the head of Fish Creek valley we reach Lily Lake, which is situated practically on the divide between Aspen Brook and the head of Fish Creek. Just north of this lake is Lily Mountain (9,793 feet), the top of which forms the picturesque serrate crest seen from points farther west. Thence southward we

[1] In his "Story of Estes Park" (p. 43, 1914), Enos A. Mills says:

"In the autumn and early winter of 1872 Earl Dunraven, with his guests, Sir William Cummings and Earl Fitzpatrick, shot big game in the park. Dunraven was so delighted with the abundance of game and the beauty and grandeur of the scenes that he determined to have Estes Park as a game preserve. * * * In 1874 Albert Bierstadt, the celebrated artist, came in as the guest of Dunraven and at once selected sites for Dunraven's cottage and the Estes Park Hotel. Bierstadt was delighted with Estes Park and made the second trip to it. Here he made many sketches and secured material for some of his famous pictures. His favorite place was on the shore of the lake which now bears his name."

pass into the broad open trough near the head of Cow Creek, called Tahosa Valley, a name appropriately expressing its situation, for it is said to mean "Dwellers in the mountain tops." The Arapahoes called the pass at the head of this valley "Where the Woman was Killed": Issay-bes—di—noh-kah wah—náytowah ah—náyt (Woman Log-It-Killed-Her). This name refers to the death of an Indian squaw who was killed there by a falling tree.

LONGS PEAK INN.

Longs Peak Inn holds the same relation to the southern part of the Rocky Mountain National Park that Estes Park village holds to the northern part; for it is the center from which trails radiate to points of interest. The site of this inn was first occupied by E. J. Lamb in 1875. Mr. Lamb lived here for many years and established himself as a guide to Longs Peak.

From the inn several panoramas open to view, which make this a favorite resort. The gentler slopes of the surrounding mountains are beautifully decorated with the dark-colored evergreens, prominent among which is the lodge pole pine, and with the lighter green of the aspens. Here and there are areas covered with trunks of trees which were killed by forest fire. Some of those on the mountain slope west of the inn were killed in the year 1864 (see p. 63).

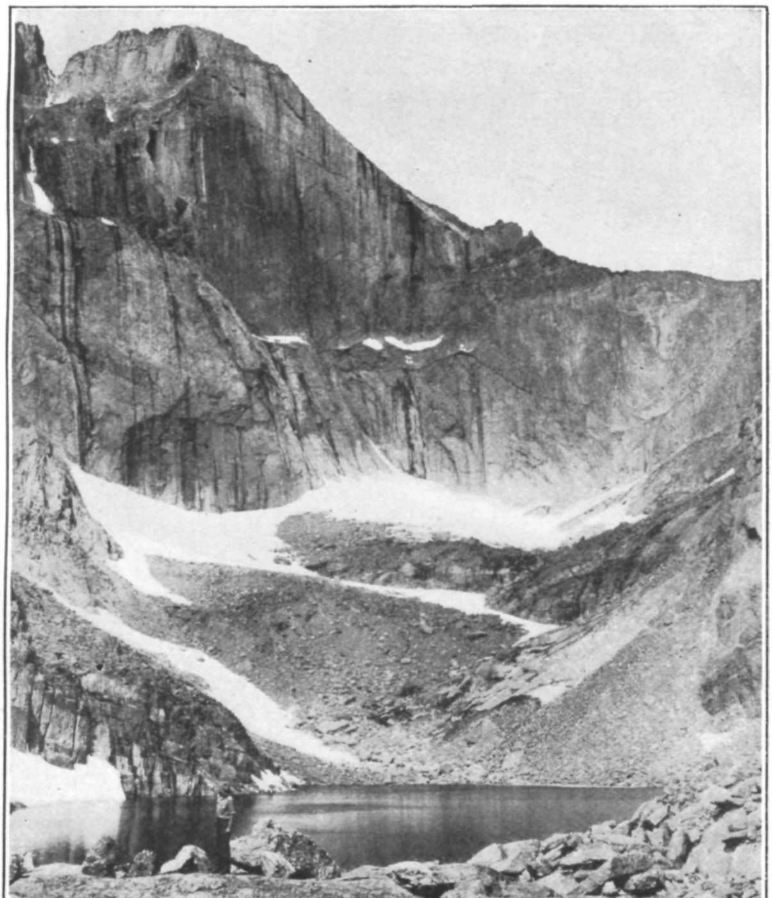
TWIN SISTERS.

To the east of Longs Peak Inn stands the precipitous craggy mountain called Twin Sisters (11,384 feet). Because of a well-built trail the climb up this mountain is relatively easy. From many points on the trail superb views may be obtained, but the dominating one is that which opens from the summit. Here the entire sweep of the compass is at our command. The trail zigzags up the steep slope, at first through the evergreen forest and finally through the lifeless trunks of trees killed by the forest fire of 1864. Near the top of the mountain are many of the curious gnarled, stunted, and wind-twisted trees usually found near timber line.

The top of this mountain is used by the Forest Service as an observing station. From the observatory on the summit (Pl. XXXIV), which commands a view of a large part of the national park and much of the neighboring national forest, a fire may be located accurately and its position reported by telephone. From this commanding point we may gaze eastward far out over the 25-mile belt of lower mountains to the plains beyond. East of the foothills, at distances of 30 to 35 miles, lie clearly outlined the irrigated lands and the numerous reservoirs where irrigation water is stored. Still farther to the east, as far as the eye can reach, stretches the apparently even surface of the Great Plains. To the north and

A. A DETAIL OF THE WALL OF THE CHASM.

Showing at the left the banding of the wall, caused by the varied composition of the rock. The light-colored bands are granite, and the dark-colored bands are schist. The vertical lines are surface stains due to running water.



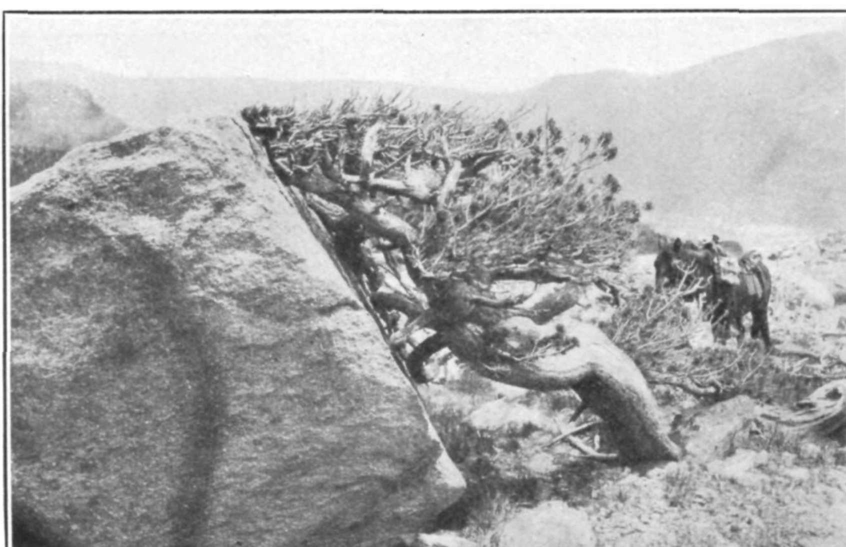
B. CHASM LAKE AND LONGS PEAK.

The lake covers 6 acres and lies at an altitude of 11,943 feet, 2,312 feet below the peak. At the foot of the precipice lies the small body of ice whose ancestor—Mills Glacier—shaped the cliffs and dug The Chasm.

Photographs by Willis T. Lee, United States Geological Survey.

A. TIMBER LINE ON LONGS PEAK.

Showing the great mass of snow and ice near Timber Line Cabin and the highest part of the slope on which trees grow. The relatively tall ones at the right are limber pines and Engelmann spruces. Still higher on the slope these species are stunted and only a few feet high. The "forests" of black birch and willow trees, about 6 inches high, form the dark-colored mats on the slope in the foreground.



B. A PINE TREE ABOUT 6 FEET HIGH AT TIMBER LINE SHELTERED BY A GLACIAL BOULDER.

The west wind bent the twigs eastward so constantly that the branches grew crooked. The twigs were sheared off by the snow blasts so that the tree did not succeed in growing beyond the shelter of the rock.

Photographs by Willis T. Lee, United States Geological Survey.

to the south lie mountainous areas which from this commanding elevation resemble the billowy surface of a storm-tossed sea; but the crowning glory is the view to the west across Tahosa Valley to Longs Peak (Pl. XXXIV, lower) and its neighboring mountains.

Northwest of the inn stands Estes Cone (11,017 feet), one of the isolated remnants of erosion which are so prominent in the vicinity of Estes Park. By way of the trail over Storm Pass west of this cone tourists from the inn may reach Bartholf Park and the picturesque region of Glacier Gorge and Loch Vale. Farther south is Battle Mountain and the Longs Peak trail.

But probably the most interesting of all the features to be seen from this commanding point are those in the eastern face of Longs Peak. From Twin Sisters we gaze directly into the great cirque known as The Chasm, shut in by the almost perpendicular faces of Longs Peak, Mount Meeker, and Mount Lady Washington. The western wall of this cirque constitutes the smooth, nearly vertical face of Longs Peak, which rises 2,400 feet above Chasm Lake, while the northern and southern faces are scarcely less precipitous but are more ragged and irregular.

The impression obtained on viewing this group from below, that there are three distinct mountains, is chiefly due to perspective. Mount Lady Washington (13,269 feet) is only about 300 feet higher than the lowest part of the ridge connecting it with the master peak. Mount Meeker (13,911 feet) is a little more distinct, its peak rising about 500 feet above the lowest part of the ridge that connects it with Longs Peak (14,255 feet). Meeker and Lady Washington are closer to the observer than Longs Peak and therefore when viewed from below appear nearly as high.

These three peaks form a single mountain mass. Before the Great Ice Age they were even more closely connected than they are now—probably so closely that they formed a single rounded summit. When the ice began to form during the glacial epoch it naturally accumulated around this highest mountain of the region. One glacier found its way down Hunters Creek toward the south and east into the valley of the North St. Vrain. Another moved toward the west and north through Glacier Gorge. Still another moved northward across Boulder Field and down into Bartholf Park. A fourth but relatively small one, known as Mills Glacier, formed on the eastern face of the mountain. It was this glacier that left records which appear so conspicuous from the top of Twin Sisters. In its early stage it spread out rather broadly and extended eastward beyond the road south of Longs Peak Inn.

Later this glacier, in a less extended form, built up the conspicuous ridges called Mills Moraine. The rocks plucked from the side of the mountain during the excavation of The Chasm were carried out by the ice and deposited in two parallel ridges or lateral moraines, the one north and the other south of Roaring Fork. This creek now occupies the trough down which the ice moved. The photograph (Pl. XXXV, *A*) of the cirque and moraine taken from Twin Sisters gives a better conception of the relation of this glacier to the peak than can be given in words.

LONGS PEAK TRAIL.

Longs Peak is the culminating point of the park and has long been one of the best-known summits in the Rocky Mountains. A number of historical notes concerning it have been collected by Enos A. Mills in his work entitled "The story of Estes Park," and from this account have been extracted the following notes:

In November, 1806, Longs Peak was seen from the plains by Lieut. Pike, who called it Great Peak.

On July 3, 1819, members of Col. S. H. Long's exploring party, while camped at the mouth of the Cache la Poudre, named Great Peak in honor of their leader. Since that time it has been known as Longs Peak. However, Long was never on this mountain.

In August, 1864, the first attempt seems to have been made to climb Longs Peak. W. N. Byers, with three companions, scaled Mount Meeker and went some distance through the Keyhole on the present trail of Longs. The attempt was unsuccessful, and on the 20th of August, 1864, Mr. Byers wrote:

> We have been almost all around the peak and we are quite sure that no living creature, unless it had wings to fly, was ever upon its summit. We believe we run no risk in predicting that no man will ever be, although it is barely possible that the ascent can be made.

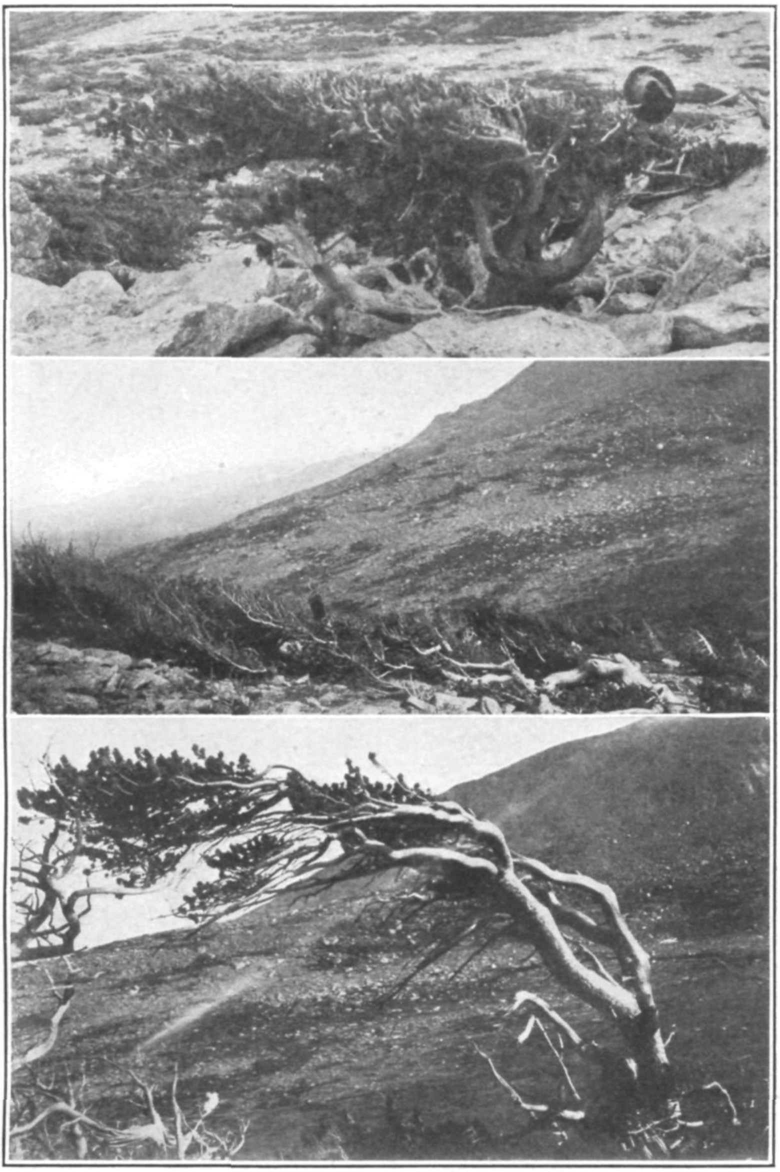
Four years later the intrepid Mr. Byers broke his own prediction by leading a party of climbers to the top.

> On August 23, 1868, the first ascent of Longs Peak was made. The persons who made it were Maj. J. W. Powell, W. H. Powell, L. W. Keplinger, Samuel Gorman, Ned E. Ferrell, John C. Sumner, and William N. Byers.

In making this ascent the climbers started from Grand Lake, crossed the Continental Divide into Wild Basin, and ascended the southern slope, passing near the Notch and over the Home Stretch (Pl. XLII, p. 80).

In August, 1871, Rev. E. J. Lamb, the first regular guide on Longs Peak, made his first ascent, and in coming down descended the "east precipice," a feat but once repeated—by Enos A. Mills in June, 1903.

In September, 1871, Dr. F. V. Hayden, of the Geological and Geographical Survey of the Territories, visited the park, and climbed Longs Peak. In his party was Anna E. Dickinson, who is supposed to be the first woman to make this ascent. Her name is perpetuated



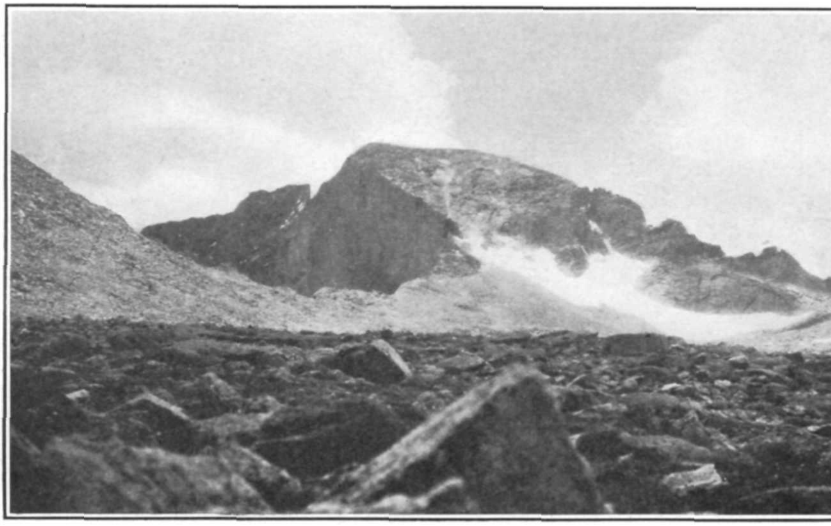
TIMBER-LINE TREES ON LONGS PEAK, INCLINED TOWARD THE EAST AWAY FROM THE PREVAILING WESTERLY WINDS.

Upper, Tree rooted in a protected spot among the rocks sheared off even with the top of a sheltering bowlder by the wind-blown crystals of ice.

Middle, "Where trees grow lying down." This is not a fallen tree, but one which began life in the lee of a protecting bowlder and grew along the ground, held close to earth during the greater part of each year by drifting snow. It is 20 feet long with branches 2 feet high.

Lower, A tree well known to climbers on Longs Peak as "The Winged Victory." The bark is worn by the snow blasts from the west side of the trunk and branches, and the living twigs stretch eastward as if trying to avoid the storm.

Photographs by Willis T. Lee, United States Geological Survey.



A. LONGS PEAK AND BOWLDER FIELD.

To the left is the slope of Mount Lady Washington and the upper part of the eastern face of Longs Peak, overlooking The Chasm. The snow field is a survival of the glacier that carried the bowlders from the peak and dropped them on Boulder Field. The trail to Longs Peak passes over these bowlders and through The Keyhole, at the extreme right.

B. NEAR VIEW OF THE KEYHOLE AND THE ROCKY ROAD TO IT FROM BOULDER FIELD.

SCENES ON LONGS PEAK.

Photographs by Willis T. Lee, United States Geological Survey.

in Mount Dickinson. This party gave the names Mount Meeker and Mount Lady Washington to the companions of Longs Peak.

In ascending Longs Peak we start from Longs Peak Inn and follow the trail westward through the forest of pine, spruce, and aspen. On the trail is an abandoned prospect, locally known as "the mine," near which the surface is covered with fragments of milky quartz derived from a large vein, into which an entry was once driven in search of gold.

Soon after passing this old mine we leave the rocky slope and ascend the outer rim of the lateral moraine of Mills Glacier. To the left, just south of Alpine Brook, rises the steep slope of the inner or younger moraine of this glacier. This is built of ice-borne material dropped along the northern margin of the great tongue of ice which once extended from The Chasm down the mountain side for about 4 miles. The maximum depth of this great mass of bowlders seems to be nearly 1,000 feet.

After traversing the outer moraine for a short distance we find ourselves again on the unglaciated rock outside of the moraine. Alpine Brook occupies the trough between the moraine and the solid mountain rock. Near timber line a log cabin has been constructed on the slope of Battle Mountain, a few rods from the outer edge of Mills Moraine, for the accommodation of visitors to the numerous points of interest near Longs Peak. The cabin is at an altitude of about 11,100 feet, and a few minutes' walk from it brings us to a large bank of perpetual snow and to an unusually fine group of the curious gnarled and dwarfed pine and spruce trees which grow at timber line. From this cabin we obtain an excellent view of the moraine to the south. The trees between it and the moraine are only a few feet high and do not interfere with the view. That part of the moraine lying above timber line is barren, and much of that below was laid bare in 1900 by a forest fire which swept this part of the mountain side.

POINTS OF INTEREST NEAR TIMBER LINE.

Several localities of unusual interest may be visited by short excursions from Timberline Cabin, among which may be mentioned Mills Moraine and the glacial trough lying between the two morainal ridges, The Chasm, and the grove of timber-line trees near Longs Peak trail.

Mills Moraine.—By a short and relatively easy walk directly south from the cabin we reach the crest of the moraine and from some vantage point on it we gaze into the great trough, hundreds of feet deep and nearly half a mile wide, which was once filled with ice. Its sides are precipitous and show bowlders of varying shape and size, piled in haphazard manner. In some places these are so nicely balanced that caution is necessary in climbing over them, for the pressure of the foot is sometimes sufficient to start a bowlder crashing down the steep slope. It is interesting to note that where the material beneath the original surface has recently been uncovered, the spaces between the bowlders are filled with smaller fragments and with rock meal ground fine by the moving ice. The bottom of the trough consists of heaps of bowlders irregularly placed and forming imperfectly constructed crescent ridges, convex downstream, which were formed during the halting recession of the glacier. On the upstream sides of some of these ridges water has gathered in small lakes along the course of Roaring Fork, a name quite appropriate for a stream which falls 2,500 feet in the course of less than 2½ miles and which finds its way through such a wilderness of bowlders as that left by Mills Glacier.

The Chasm.—The Chasm is a great rock-walled cirque in the eastern slope of Longs Peak, at the head of Mills Glacier. In order to reach it from Timberline Cabin we cross the northern lateral of the old glacier, descend the inner slope to the trough, and make our way up the gorge over the ice-smoothed rocks and the piles of glacial bowlders. On the way to the crest of the morainal ridge we pass through and over the dense mats of dwarf trees of willow and black birch, so abundant near timber line. On the side of the moraine are scattered the stunted forms of dwarf spruce and pine, most of them dead either from fire or from the exigencies of their strenuous existence on this extreme frontier of forest life.

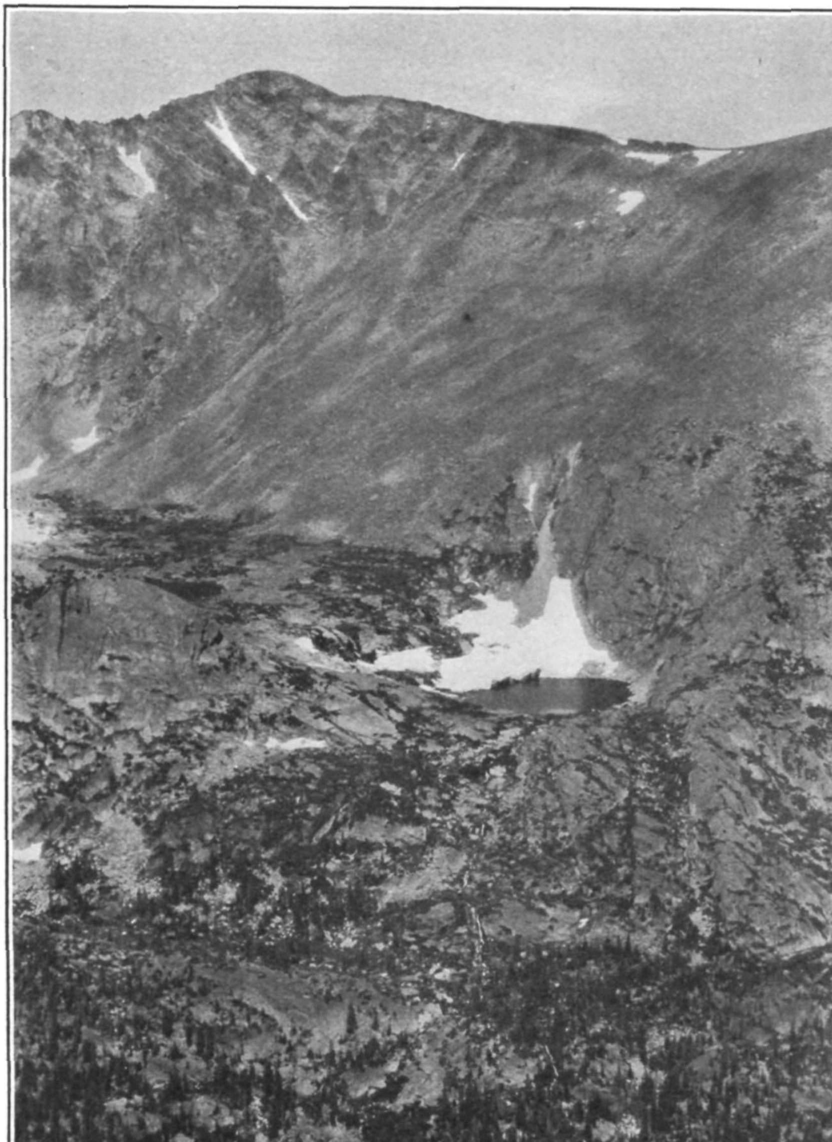
We enter The Chasm at the point where the heaped bowlders of the moraine join the solid mountain rock. Toward the left is a clear, unobstructed view down the great glacial trough formerly filled with ice to a depth probably of more than 1,000 feet. In front and toward the right is an equally unobstructed and still more remarkable view into the rock-walled cirque, the sides of which are vertical. Its floor rises rapidly toward the peak, shelf on shelf, like steps of a giant stairway. On some of these shelves are situated small lakes in hollows scooped out by the ice.

The water from the melting snow at the head of the cirque rests for a time in Chasm Lake, then flows through masses of bowlders and over cliffs, at some of which are picturesque waterfalls. The granite and schist at the surface of these shelves were rounded and polished by the ice. Few loose bowlders remain within The Chasm. Nearly all were carried out by the ice and deposited in the moraine, but a few were dropped within the cirque, some in insecure positions (Pl. XXXIV, p. 70), when the ice finally melted.

In the walls of this cirque may be found the key to the mystery of its origin. The rocks are composed of granite and schist. The face of Mount Meeker (Pl. XXXVI, *A*) shows that the older schists

THE HEAD OF GLACIER GORGE AS SEEN FROM THE KEYHOLE.

To the left is the snow-filled Trough, up which the climber must make his way to the summit of Longs Peak. Farther to the right is Chief's Head Mountain and the serrate ridge separating Glacier Gorge from Wild Basin. In the foreground to the right is the shelving surface worn on the face of the inclined slabs of granite. Photograph by Willis T. Lee, United States Geological Survey.



A POCKET LAKE IN THE WEST WALL OF GLACIER GORGE.

Nearly 1,000 feet above the floor of the gorge. As seen from Keyhole, on the Longs Peak trail, showing the remnant of the cliff glacier that scooped this pocket out of the solid rock. Photograph by Willis T. Lee, United States Geological Survey.

were fractured and that the younger granite was forced into them in more or less steeply inclined sheets. The younger sheets appear in the face of the cliffs as light-colored bands, some of them running to a thin edge, as if a huge wedge had been driven laterally into the mountain. The face of the main peak exhibits a somewhat different character, for the joint planes or cracks which divide the rocks into great slabs are here vertical or are very steeply inclined. This is conspicuously shown in The Notch (Pl. XLII) and may be seen also near The Keyhole, where the granite is split into huge steeply inclined slabs. The vertical eastern face of the peak is due largely to this vertical jointing of the rocks. The photograph of The Notch, showing the rock column parting from the parent cliff, illustrates one of the ways in which the ice plucked the rocks from the cliffs. If the ice filled the space behind such a column and was pressed downward by the weight of the ice above it, the column of rock would soon be wedged off. With this illustration before us, we may easily picture an ice wedge with 2,000 feet of ice pressing on it, driven into the cracks of the fractured rock, and splitting off the outer slabs.

Timber-line trees.—It is said that there is no place in the Rocky Mountains where the curious gnarled and stunted trees which develop near timber line can be seen to better advantage than on the side of Longs Peak. The larger trees are limber pines and Engelmann spruces. The smaller ones commonly found are willows and black birch. The timber-line trees occupy a relatively narrow belt at an altitude of about 11,500 feet. The same species of trees which at lower altitudes grow tall and straight are here dwarfed and develop strangely gnarled and twisted characters. They have a hard struggle for life where the cold is excessive and where snow covers the ground much of the time, in some places never melting away (Pl. XXXVII, *A*). The strong winter winds tear the snowflakes into minute crystals of ice and hurl them with such force that they act in much the same way as sand in a sand blast. These snow blasts not only cut the bark from the windward side of the tree, thus preventing the growth of branches on that side, but cut away parts of the wood (see Pl. XXXVIII). They shear off the tender twigs that grew in exposed places during the previous summer, so that the trees have the appearance of being trimmed like an ornamental hedge. (See Pl. XXXVIII, upper.)

In some places trees develop only where they are afforded special shelter (Pl. XXXVII, *B*), such as on the leeward side of a bowlder. The tendency of the snow blasts to cut away twigs and bark on the windward side causes the trees to develop leeward. Also the prevailing westerly wind bends them so that many have the appearance of stretching out in an easterly direction, as if trying to escape from constant annoyance (Pl. XXXVIII, lower). This tendency to grow in an easterly direction is carried to an extreme in some places. The accompanying illustration (Pl. XXXVIII, middle) shows one of many pine trees found near timber line lying flat on the ground. It is not a fallen tree but one which began life in the lee of a small bowlder. The wind bent the young shoots eastward and the snow held them flat on the ground through a large part of each year. Ambitious shoots which arose too high were sheared off by the snow-blasts. But in spite of all difficulties, this persevering pine succeeded in creeping 20 feet along the ground.

Timber-line trees grow slowly. It has been found by counting the annual rings that on the average a trunk or branch will increase in diameter about 1 inch in a century. In other words, it takes about 100 years for one of these trees to grow large enough to serve as the climbing staff which the tourist is fond of using. And yet some of these trees have trunks as much as 3 feet in diameter (Pl. XXVI, *B*, p. 61). Particularly interesting in this connection are the willow and birch "trees" which form the green mats on the mountain sides at timber line (Pl. XXXVII, *A*). The greater part of their bulk is underground, the exposed parts growing only a few inches above the surface. Some of these "trees" about 6 inches high have been determined as nearly 100 years old.

ASCENT OF LONGS PEAK.

Timberline Cabin is a convenient place from which to start for the top of Longs Peak, thus allowing the whole day for the ascent and affording plenty of time for enjoying the remarkable scenery. Soon after leaving the cabin we pass a group of the curious stunted trees just described. Close to the highest group is a large snow bank where the drifting snow gathers in a sheltered spot. This shelter is afforded by the terminal moraine of the small glacier which moved eastward from Boulder Field across the saddle between Mount Lady Washington and Battle Mountain and descended the slope as far as timber line. This slope above the snow field is covered with heaps of slightly worn glacial bowlders left there by the ice when this lobe of the glacier disappeared. Up the path of this glacier the trail winds to Boulder Field.

Boulder Field is a continuation of this débris-covered slope, but the greater part of the field is not so steep. As the name indicates, it is an area of scattered bowlders. The rocks are angular and only slightly worn, for they journeyed with the ice only the short distance between their present position and the peak from which they were derived. They vary greatly in shape and size. but such smaller fragments as may originally have been on the surface have been washed down into the spaces between larger bowlders, so that the surface is now occupied almost exclusively by the larger ones. The route (it can not be called a trail, for there is no path that can be followed) to the peak crosses these heaps of bowlders for fully a mile. Horses can not be ridden over them (Pl. XXXIX, *A*), and the feet of the tourists make little impression on the hard blocks of granite. It makes little difference what route we choose across this field. One is as good—or as bad—as another. We must step from rock to rock, always taking care that the bowlder we step on is firm. Many of them are so nicely balanced that the pressure of the foot will cause them to turn. Although we may not follow a trail, we have continually in view The Keyhole, the one opening through the rock ridge before us which we must pass in order to reach the peak (Pl. XXXIX, *B*).

The narrow and sharp-crested ridge in which The Keyhole is situated owes its existence to the structure of the rocks and to the action of glacial ice. The rock is broken into huge slabs which are vertical or steeply inclined. In days of old, when the upper portions of the mountain side were covered with ice, the water freezing between the slabs expanded as it always does on turning to ice and pried them apart. The ice forced between them by the weight of the overlying mass acted as a wedge to split them from the parent cliff, and the blocks thus loosened were carried away by the glacier. The earliest blocks to be loosened were carried to the end of the ancient glacier. The later ones were borne only part way down the slope before they were dropped by the melting ice. In this way Bowlder Field was formed.

As we pass through The Keyhole there opens before us one of the most impressive scenes in the Rocky Mountain National Park. From this point of vantage we gaze into Glacier Gorge, an enormous steep-walled basin, whose floor at Lake Mills lies 4,255 feet below the highest point of its rim. Toward the north across the gorge rise the great walls of barren rock in the more protected portions of which lie fields of perpetual snow. To the left is The Trough (Pl. XL), a narrow, steeply inclined ice-filled gulch. Up this trough the climber must make his way to the top of Longs Peak. To the right, nearly 2,000 feet below The Keyhole, is Blue Lake. Still farther below is Black Lake, situated in a rock basin, walled in on three sides by precipices and opening northward into the larger basin of Glacier Gorge proper. In the wall of the gorge opposite us, high on the side of Thatchtop Mountain, are several lakes occupying shelves or little pockets in the side of the mountain. Shelf Lake lies at the mouth of a small cirque tributary to Glacier Gorge, and the little unnamed lake to the north of it is a typical example of a pocket lake (Pl. XLI).

PLATE XLII.

VIEWS NEAR THE TOP OF LONGS PEAK.

Upper left, The Notch, on Longs Peak, showing the vertical lines of cleavage in the rock. Water freezing in the cracks would in time break the slabs of rock from the face of the cliff. Also, ice filling a crack would act as a wedge when forced downward by the weight of ice accumulating above it.

Photograph by Enos A. Mills.

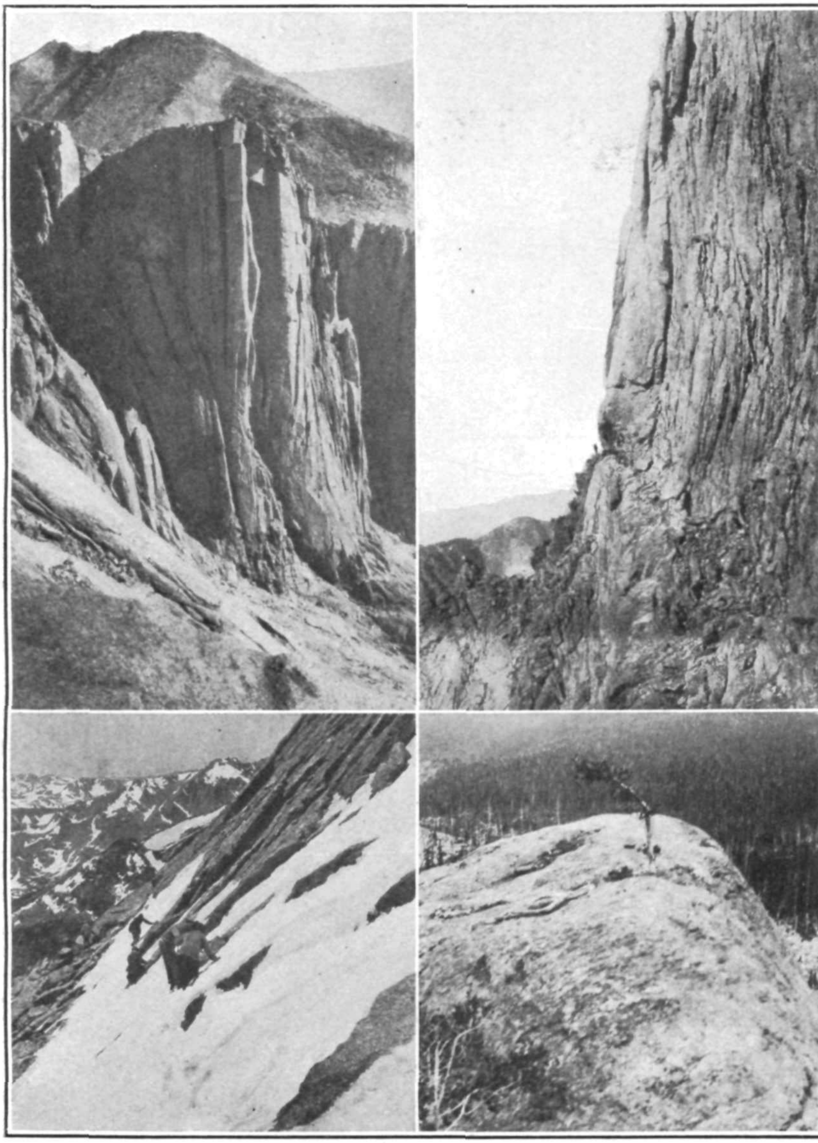
Upper right, The Narrows, on Longs Peak trail. The shelf in the side of the precipice must be traversed in order to reach the summit. This shelf was formed by faulting. A fault or great crack in the rocks extends diagonally downward to the right. The rocks above have slipped at this fault and have been displaced toward the right, leaving room for a pathway on the rocks below.

Photograph by Enos A. Mills.

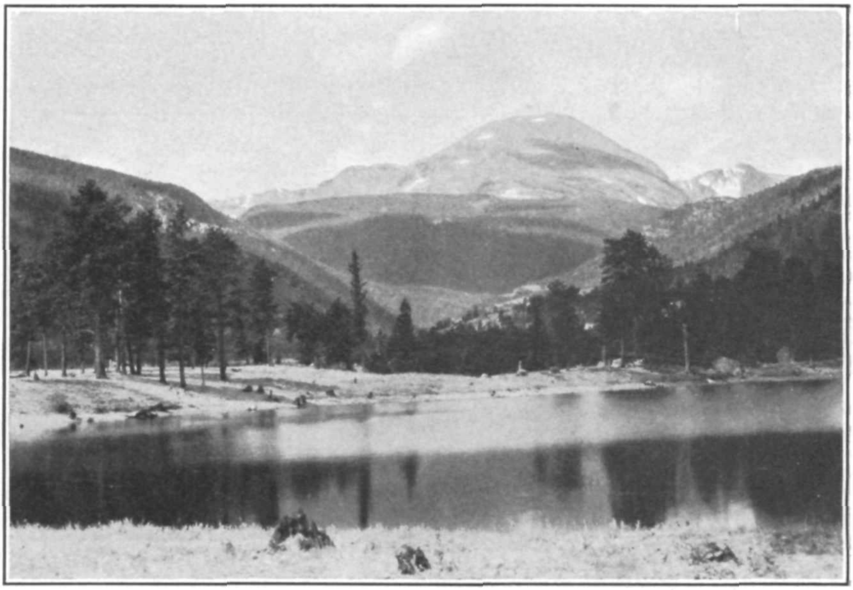
Lower left, Home Stretch, on Longs Peak—the last steep climb before reaching the top. The climber must make his way cautiously along this stretch of insecure footing with the shelving face of the mountain above and a precipice below.

Photograph by Frank W. Byerly.

Lower right, A rock rounded and smoothed by the ice of Wild Basin Glacier.
Photograph by Willis T. Lee, United States Geological Survey.



VIEWS NEAR THE TOP OF LONGS PEAK.



A. COPELAND LAKE, THE VALLEY OF THE NORTH ST. VRAIN, AND COPELAND MOUNTAIN (13,176 feet).

B. THE MELTING BASIN AND THE SOUTHERN LATERAL MORAINE OF WILD BASIN GLACIER.

As seen from the top of Copeland Moraine at Copeland Lake.

VIEWS IN THE VALLEY OF THE NORTH ST. VRAIN.

Photographs by Willis T. Lee, United States Geological Survey.

From Keyhole we make our way for a short distance across the steeply shelving rock on the west slope of the peak and enter the ice-filled Trough. Here the trail is steep, and climbing is attended with some danger, especially during seasons when steps must be cut in the ice. At other times the ascent is reasonably safe except from falling rocks loosened by some climber farther up the slope. But at best the climb is tiresome, for exertion at such high altitudes is exhausting. The Trough ends above at The Narrows, an opening through another sharp-crested ridge similar to that at The Keyhole. From The Narrows our path lies along a shelf in the face of a nearly vertical cliff (Pl. XLII). This shelf, which is the only practicable route to the peak, was formed by faulting of the rocks. The rocks were broken obliquely, and those above the break slipped downward and inward, leaving the rocks below the break projecting outward a few feet beyond those above it. Before us is The Notch (Pl. XLII), which is a conspicuous feature of the peak, as viewed from the east or from the south. Stretching before us toward the south lies Wild Basin, with its great variety of weird features and picturesque landscapes.

At the end of the shelf we reach Home Stretch (Pl. XLII), where we must choose our footing with some care on the steeply shelving surface, for a false step here might dash us over the precipice below. The climb up this slope is the final effort before reaching the top, where we find a nearly flat surface about 1,500 feet long and 1,000 feet wide. Here we are on the highest point in the Rocky Mountain National Park and one of the highest in the whole range of the Rocky Mountains.

NORTH ST. VRAIN RIVER.

St. Vrain Valley is conveniently reached from Copeland Lake Lodge, situated at the point where the road between Ward and Estes Park crosses the river. Like many of the other valleys of the region, this one was glaciated. The ice from Wild Basin extended downstream to a point about a mile east of the road crossing. About a quarter of a mile east of this crossing the river begins its descent over the terminal moraine of this ancient glacier, and for about three-fourths of a mile there is a succession of picturesque rapids where the water swirls among the bowlders or dashes itself into foam against them. The scenes of varied beauty along this part of the river's course amply repay us for the small effort it requires to reach them. The water power here was utilized at one time in mining, and the old flume and power plant still remain.

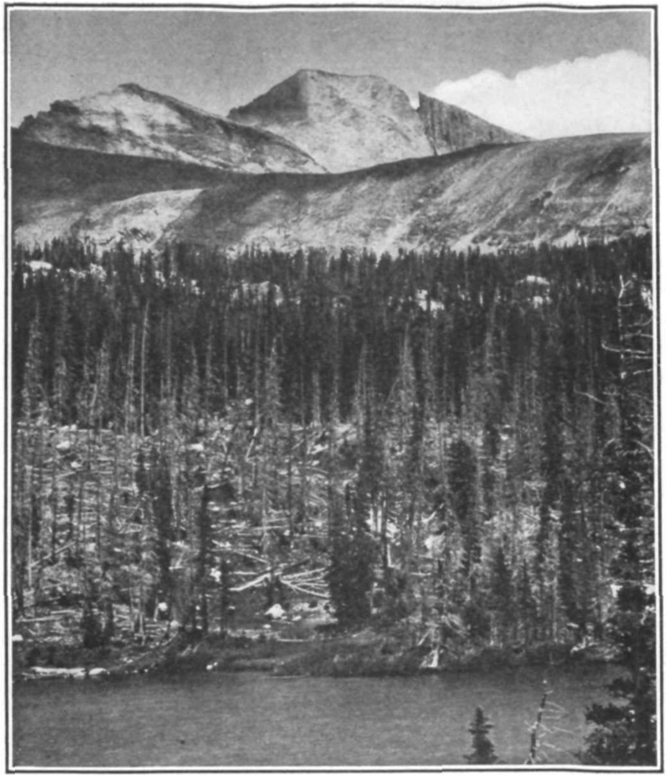
Copeland Lake Lodge is situated near the lower end of the melting basin of the Wild Basin Glacier, and a short distance west of this lodge at the side of the valley is Copeland Lake (Pl. XLIII, *A*), a small body of water occupying a depression in the morainal material. Normally the lake is fed by springs, but water from one of the streams tributary to the St. Vrain is diverted into it. The beavers who make their home on this stream seem to resent this interference with the natural flow as an unwarranted infringement of their rights. It is said that they repeatedly construct dams across the artificial inlet, turning the water back where it naturally belongs. So persistent and industrious are these creatures that the owners of the lake are not always able to keep the basin filled with water.

The nearly level floor of the melting basin (Pl. XLIII, *B*) contrasts sharply with the steep slopes of the high morainal ridges on either side. The one to the north, called Copeland Moraine, marks the northern extent of the great tongue of ice. The moraine south of the river is equally well defined but has not received a separate name. The character of these morainal ridges is readily recognized by their regularity in outline, the evenness of their cress, and their composition of various-sized bowlders. However, at the end of Meeker Ridge, south of Lookout, the mountain rock was not entirely covered by the ice-borne material.

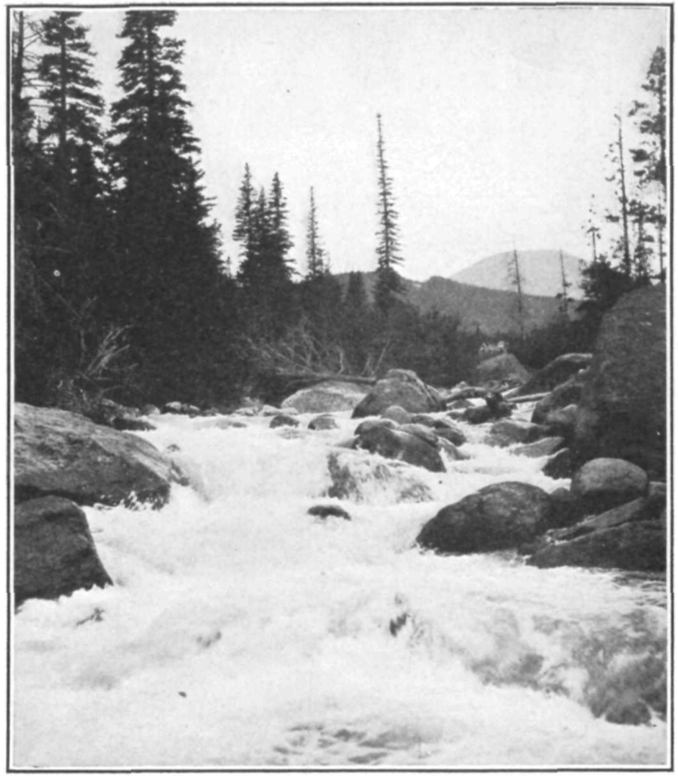
WILD BASIN.

Wild Basin is usually entered from Copeland Lake Lodge. Near the head of this basin the valley narrows to a steep-walled gorge, the floor of which rises steeply to the west. Here the stream from Sandbeach Lake descends from the north over the rim of the moraine where a great landslide has occurred. Much of the morainal material has here slid into the bottom of the valley. The bowlders, added to those already in the bed of the stream, cause a series of rapids which add pleasing variety to the landscape. The trail is close to the stream in a few places where some of the most picturesque rapids occur, and such scenes of beauty as that depicted in Plate XLIV, *B*, are not uncommon.

West of the mouth of Cony Creek the trail becomes steeper, and the character of the surface changes from that of the bowlder-filled valley to the erosional type formed by the glacial ice moving over the solid rock. The rounded and polished surfaces are numerous and beautifully exposed (Pl. XLII, lower right) on the steep slope west of the mouth of Ouzel Creek. Above this steep slope we find one of the large parklike openings so common at high altitudes, the center of which is occupied by Thunder Lake (Pl. XLV). It is a large glacial cirque, and the steep slope on which the polished surfaces are so conspicuous is the path down which the rocks, gouged out of this cirque, were dragged by the moving ice. Its character is not so obvious to the casual observer as is that of some others in this park, because of the dense forests which obstruct the view.



A. LONGS PEAK AS SEEN FROM THUNDER LAKE.

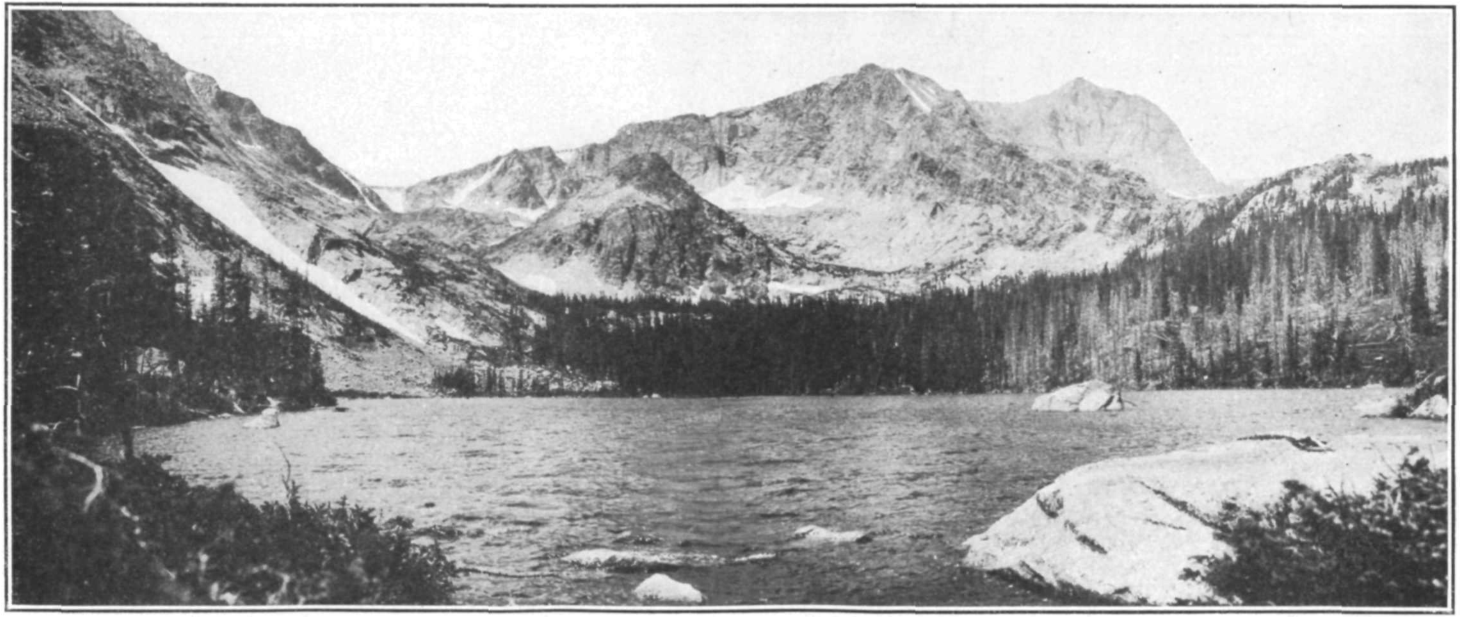


B. RAPIDS IN NORTH ST. VRAIN RIVER.

Where a large volume of glacial material slid into the valley from the lateral moraine of Wild Basin Glacier.

VIEWS IN WILD BASIN.

Photographs by Willis T. Lee, United States Geological Survey.



THUNDER LAKE AND MOUNT ALICE.

The lake lies at an altitude of 10,570 feet and has an area of 15 acres. It is used to some extent as a reservoir in which water is conserved for irrigation on the distant plains. The altitude of Mount Alice is 13,310 feet.

Photograph by Willis T. Lee, United States Geological Survey.

Wild Basin is appropriately named. It is so irregular in outline that to obtain good views of it one must ascend some commanding peak, such as Lookout (10,744 feet). From such a point of vantage it appears to equal, in varied beauty and wild splendor, the choicest scenery of the better-known parts of the park. Only a few of its scenic features can now be reached by trail, including Sandbeach Lake, Ouzel Lake, and a few others. When adequate trails are built and lodges established for the accommodation of tourists, Wild Basin will probably be one of the most attractive places in the Rocky Mountain National Park.

AN APPRECIATION.

Robert B. Marshall, chief geographer of the United States Geological Survey, says of this park: "This region as a whole is as beautiful as any to be found in the United States, or indeed in the world." He was not the first to entertain such views. F. V. Hayden, one of the best known pioneer geologists of the West, who visited the park in September, 1871, says of it in his report for 1875 (p. 437):

> We will scarcely be able to find a region so favorably distinguished as that presented by Estes Park. Not only has nature amply supplied this valley with features of rare beauty and surroundings of admirable grandeur, but it has thus distributed them that the eye of an artist may rest with perfect satisfaction on the complete picture presented. It may be said, perhaps, that the more minute details of the scenery are too decorative in their character, showing, as they do, the irregular picturesque groups of hills, buttes, products of erosion, and the finely molded ridges in the very center of the park. Although this arrangement separates the otherwise broad expanse into a number of small areas, the total effect is pleasing in the extreme.

But geologists and geographers are not the only ones who have been attracted by the beauties of the Rocky Mountain National Park. It has appealed as strongly to the artist and to the poet as to the scientific observer. The work of the landscape painter Albert Bierstadt has been mentioned, and the following verses, read by Huston Thompson at the National Parks Conference in Washington, January, 1917, express something of the inspiration derived from the noble summits of this park:

> I sigh for your peaks, your canyons and trees,
> Where the rain, the sun, the mist, and the breeze
> Slowly fashion God's dreams with infinite grace,
> Forever unconscious of man's fevered pace.
>
> Your vistas are not like those by the sea
> Where questions unanswered roll back from the lee;
> No Sphinx's riddle you leave in the soul,
> But joyously point each heart to its goal.

INDEX.

V.

W.

Y.

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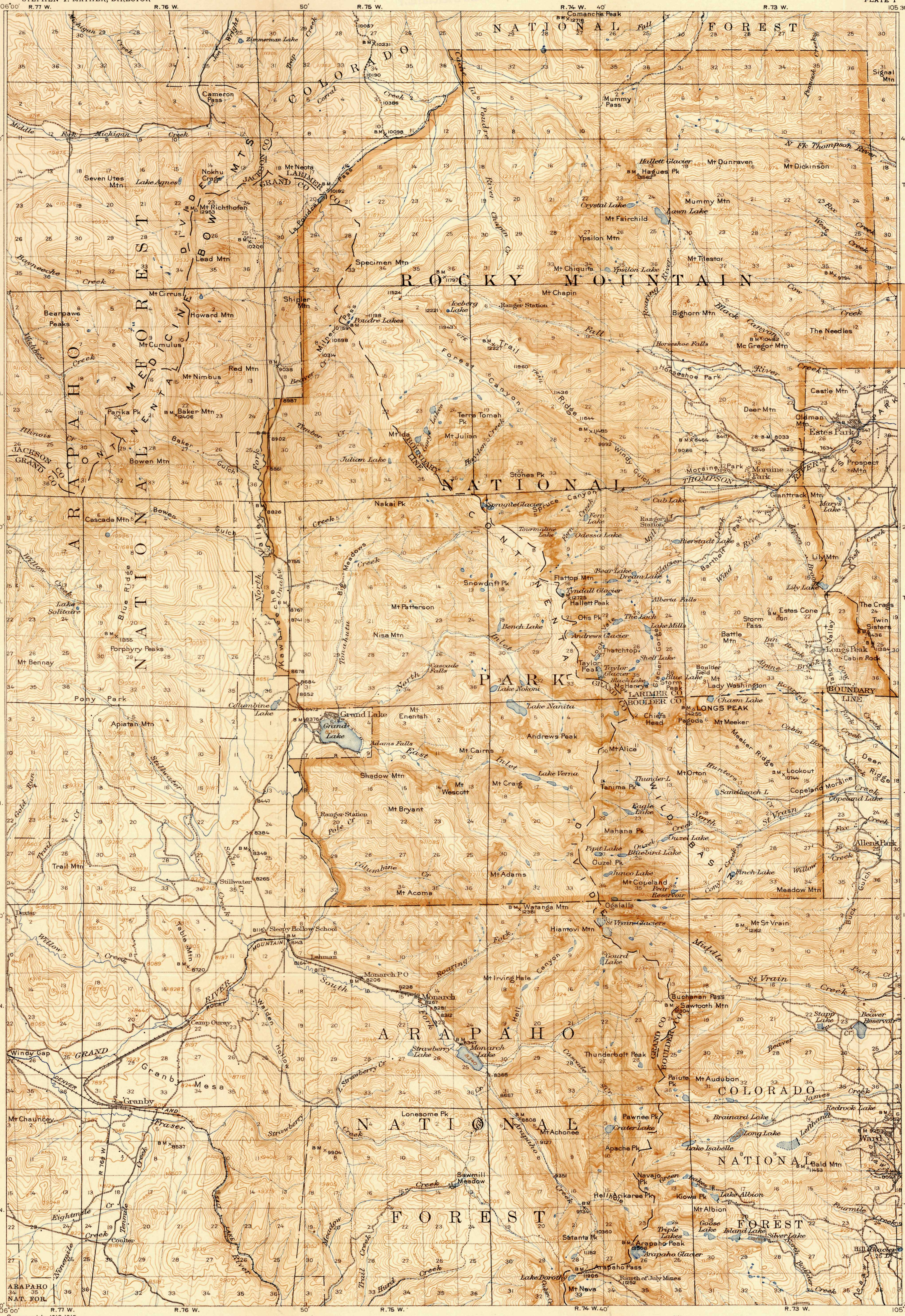
DEPARTMENT OF THE INTERIOR
FRANKLIN K. LANE, SECRETARY
NATIONAL PARK SERVICE
STEPHEN T. MATHER, DIRECTOR

PLATE I



LEGEND

Park Limits

RELIEF *(printed in brown)*

Figures *(showing heights above mean sea level instrumentally determined)*

Contours *(showing height above sea, horizontal form, and steepness of slope of the surface)*

Cliffs

DRAINAGE *(printed in blue)*

Stream

Irrigation ditch

Lake

Intermittent lake

Glacier

CULTURE *(printed in black)*

Village

Roads and buildings

Church and school house

Secondary road

Trail

Railroad

Bridge

U.S. township and section lines

Township and section corners recovered

Dams

County line

Reservation line

Village line

Triangulation station

Bench mark

Bench mark (temporary)

Surveyed in 1912-1915.
R. B. Marshall, Chief Geographer.
U. S. Geological Survey

Scale 1/125000

1 ½ 0 1 2 3 4 5 Miles

1 ½ 0 1 2 3 4 5 Kilometers

Contour interval 100 feet.
Datum is mean sea level.

APPROXIMATE MEAN DECLINATION 1913.

1917

MAP OF THE ROCKY MOUNTAIN NATIONAL PARK, COLORADO