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# A Guide to the Geology of

# ROCKY MOUNTAIN
# NATIONAL PARK

*COLORADO*

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# ROCKY MOUNTAIN NATIONAL PARK

## [ *COLORADO* ]

### By Carroll H. Wegemann

*Former Regional Geologist, National Park Service*

# Table of Contents

# INTRODUCTION

WERE WE composing a history of this country we would select certain events as markers of time—the Gold Rush, the War between the States, the Custer Massacre—and would point to the wagon ruts of an old trail, a ruined fort, or a cavalry sabre as relics of these events. Were all written history and tradition lost, we would still know, from the marks of the trail across the plains that a great migration had taken place, that the ruined fort indicated a battle, and that the old sabre, picked up on the Little Bighorn, meant the presence of cavalry.

So it is with the history of the earth, which we call geology. A great volcanic eruption took place long before the coming of man. We do not need tradition to tell us of the event; we see the crater and the hardened lava flow.

Most of us take the world for granted. We do not stop to consider the forces which produced the familiar landscapes nor the series of events which the hills and the rocks record. But for him who observes closely, and carefully pieces together his scattered observations, there gradually unfolds a picture of earth history so vast in its span of time that it staggers imagination. If the information presented in the following pages affords the visitor to Rocky Mountain National Park a brief glimpse of this history, revealing to him the origin of the grand scenery which he admires, it will have accomplished its purpose.

| Major divisions of time and their approximate duration | Dominant life | Events in Rocky Mountain National Park | |
|---|---|---|---|
| Cenozoic Era 60,000,000 years | Ice Age or Age of Man<br><br>Mammals | Erosion cuts canyons and lowers plains forming present Rockies<br>Lava flow and regional uplift<br>Erosion levels First Rockies<br>Uplift of First Rockies | |
| Mesozoic Era 140,000,000 years | Reptiles | Deposition<br><br>of marine and<br><br>fresh water<br><br>sediments | Cretaceous Period<br><br>Jurassic Period<br><br>Triassic Period |
| Paleozoic Era 400,000,000 years | Amphibians<br><br><br><br><br>First land animals and plants<br><br>First fishes<br><br><br>Shell fish | Deposition of Permo—Pennsylvanian and Permian sediments<br><br>Erosion levels mountains<br><br>Deposition of Fountain Formation<br><br>Mountains uplift<br><br><br><br>The region was a land area throughout much of the Paleozoic and there were no deposits before those of the Fountain Formation of the Pennsylvanian<br><br><br><br><br><br>Erosion levels mountains | |
| Pre-Cambrian Era 1,400,000,000 years | Primitive sea life | Mountain uplift, intrusion of granite Deposition in an ancient ocean of sediments which were later changed to schists | |

*Figure 1.*—Geologic Time Scale

# A Guide to the Geology of Rocky Mountain National Park

## BASIC FACTS ON GEOLOGY

AT THE outset we must know a few basic facts which we will use in our examination of the park. The features of the earth's surface, such as mountains, hills, and valleys, have been carved largely by the action of water and ice. Incredible as it may seem, streams can wash away entire mountain ranges. Their rushing waters first cut deep valleys, then widen their floors, then, through the action of tributaries, cut away the divides between, until at last the mountainous surface is reduced almost to a plain. If the process is interrupted by uplift of the land before the plain is completed, and the streams thereby given more fall, the cycle begins all over again with the renewed cutting of deep valleys.

Obviously, streams can work more rapidly in soft rock than in hard. The same stream may excavate a broad plain in easily eroded beds in the same time in which it can cut only a narrow gorge across a mass of granite. The excavation of the plain leaves the granite rising in hills or mountains above the stream-cut lowland.

Rocks may be divided into three great classes: Igneous, or those cooled from a molten state; sedimentary, or those deposited by water, wind, or ice; and metamorphic, or those formed by heat and pressure from the other two. The sedimentary rocks are derived from the igneous rocks through weathering and erosion, and, although originally deposited in horizontal layers, may later be folded into mountains by pressures within the earth. They and the igneous rocks are altered, by these pressures and the intrusion of molten rock, to coarse-grained gneiss and finer grained schist. The schists, in particular, which in Rocky Mountain National Park are formed from ancient sediments, can be distinguished by innumerable sparkling flakes of mica, which lie parallel to each other and cause the rock to split into thin layers.

Life has evolved slowly through the ages. That the remains of plants and animals may have become buried in the muds, limes, and sands, which later hardened into shales, limestones, and sandstones, is evident. As layer upon layer of sediment was deposited, animals which lived in

very ancient times were buried near the base of the series, whereas those which lived in later periods were buried near the top. It is possible, therefore, to determine the relative age of certain rocks by the fossils which they contain.

There was a time when the highest forms of life were shellfish, and later periods in which fishes and amphibians developed. All of these are grouped in the era of the Paleozoic or Old Life. The Paleozoic was succeeded by the Mesozoic or Middle Life in which reptiles, including the dinosaurs, were the dominant forms. This was succeeded in turn by the Cenozoic or Recent Life which is called the Age of Mammals.

The eras that have just been named are the ones concerning which we know most, for the record of the rocks is comparatively complete; but they account only for the last one-fourth of the earth's history. Before the Cambrian, which is the lowest division of the Paleozoic, the vast pre-Cambrian eras stretch into the dim past for perhaps 1,400,000,000 years (fig. 1).

Such estimates of the earth's age are not mere guesses. The discovery of radium has given a measure of time. Radioactive minerals undergo a very slow but constant change, the end product being lead. It is possible with such a mineral, which has been only partly changed to lead, to compare the weights of the lead and the unaltered mineral and to estimate the time required to make the change, thus determining the age of the deposit.

## THE OLDEST ROCKS OF THE PARK

WITH THE foregoing brief outline of geology we are now in position to examine with greater interest the park which is the object of our study.

The oldest rocks of this region are dark schists which carry innumerable sparkling flakes of black mica. At one time these rocks must have been deeply buried within the earth for they have been so changed by heat and pressure that their original nature is not easily determined. They represent the sediments of an ocean which covered this region almost a billion years ago, a time so vast that the human mind fails in comprehension of it.

Judging from exposures along Thompson Canyon on the Loveland Road, these beds are thousands of feet in thickness. In their formation enormous amounts of rock were eroded from some ancient land by streams and piled layer upon layer on a sea floor which sank slowly as the weight upon it increased. In that remote period there was no plant life upon the land to protect it against the fury of the floods, and erosion and deposition were probably more rapid than they are today. The beds which are now at the surface were thus buried by overlying sediments at depths of thousands of feet. Since their burial erosion has removed the sediments which once covered them, thus exposing them to view.

# THE FIRST MOUNTAINS

AGES OF deposition were followed, near the close of the pre-Cambrian era (fig. 1), by uplift of the ocean floor caused by forces within the earth which are but little understood. The sea receded and mountains began to rise where it had been. They were not the Rockies but ranges vastly older. The uplift took place very slowly, so slowly in fact that the only indication of it was an occasional earthquake as some rock bed cracked under the irresistible pressure of the folding. There may have been volcanic eruptions when molten rock from some reservoir deep within the laboring earth found its way to the surface, but there was no life upon the land to be conscious of such disturbances.

That molten granite was injected into the ancient sediments is known, for it can be seen today in the light-colored bands and stringers which penetrate the dark schist. In some places the granite has pushed aside the older rock or has enveloped fragments of it in its mass until it appears, to the casual observer, as if the granite were the original rock and the schist the intruder. There are excellent exposures of both rocks on Longs Peak, and the granite has been called Longs Peak granite (fig. 2). These ancient rocks form the bedrock over most of Rocky Mountain National Park, the lava flows of Specimen Mountain being the one exception.

## THE DESTRUCTION OF THE FIRST MOUNTAINS

Uplift and intrusion were followed by a long period in which, through millions of years, the solid rock of the mountains was slowly disintegrated



*Photograph by Carroll H. Wegemann*

*Figure 2.*—Longs Peak from the east. At the foot of the 1,500-foot cliff Chasm Lake occupies the bed of a glacial cirque, or collecting basin of a former glacier. Another cirque lies in the valley to the left. The white bands of rock on the walls of this valley are granite which, as molten rock, was forced between the layers of the darker beds. These dark rocks may be almost one billion years old.

3

and washed away by the agents of weathering and erosion. Streams cut deep mountain canyons which were widened into valleys, and the mountains between slowly lowered until their towering summits were reduced to a rolling plain. The formation by erosion of such a plain must have taken place at comparatively low elevation, otherwise the streams would have had sufficient fall to continue the deepening of their valleys and to produce a rough hilly country rather than a plain.

There is good evidence that a rolling plain was produced. In the foothills of the mountains the rock beds, originally horizontal, have been turned up on edge by the mountain folding so that their edges can be examined. The top of the pre-Cambrian rocks on which the younger sedimentary rocks lie is here seen to be a plane surface which cuts across the old schists and granites and is obviously erosional.

## NATURE OF PALEOZOIC DEPOSITS INDICATES PRESENCE OF SECOND MOUNTAINS

THIS REGION appears to have been one of the last parts of the old plain to be covered by the advancing seas, for the rocks, which, at the mouth of Thompson Canyon rest upon the ancient schists, are of the age known as Pennsylvanian or late Paleozoic. These Pennsylvanian beds dip away from the mountains and are overlain by progressively younger beds which outcrop farther east. The Pennsylvanian beds are of brick-red sandstone and conglomerate and are named the Fountain formation. They apparently represent sand and gravel washed out of mountain canyons and spread by streams along a seacoast at the base of the mountains. A range of mountains, therefore, must have been uplifted at that time. That the mountains were of considerable height is shown by the thickness of the deposits derived from them. It is from the nature of these beds that the presence of the mountains is inferred. Other evidence is lacking, for erosion entirely destroyed these mountains by the middle of the Mesozoic era at which time the entire area was covered by the Cretaceous sea.

## THE ROCKY MOUNTAINS

WE NOW come to a consideration of the formation of the Rocky Mountains, which are entirely distinct from the older mountains of the pre-Cambrian and Paleozoic, their only relation to the earlier ranges being that they were formed along the same zone of weakness in the earth's crust. It would have been possible to omit, in this brief account, all mention of the earlier mountains had it not been that their formation,
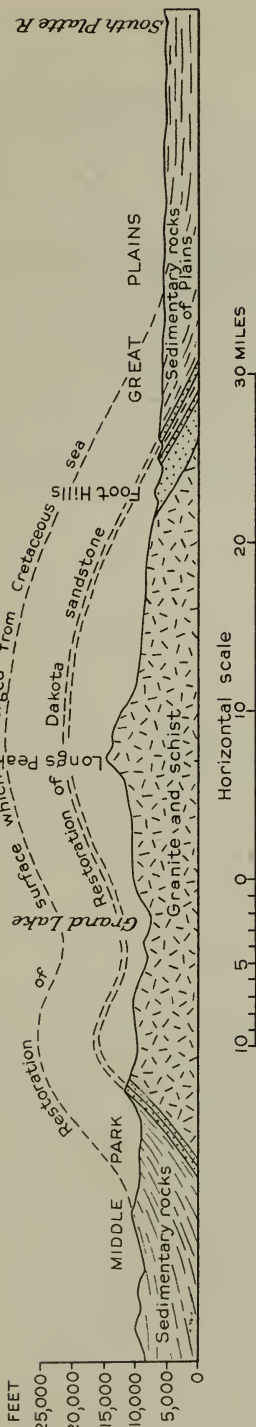
4

Figure 3.—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 dashes 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 dashes is the position that the base of the Cretaceous rocks—Dakota sandstone—might have assumed had it not been eroded away.

DIAGRAM BY W. T. LEE, WHICH APPEARED IN "THE GEOLOGIC STORY OF ROCKY MOUNTAIN NATIONAL PARK", PUBLISHED BY THE NATIONAL PARK SERVICE IN 1917.

particularly that of the pre-Cambrian ranges, explains the origin and presence at the surface of so large an area of the schists and granites which form the principal rocks of the park.

## TIME AND FORM OF THE MOUNTAIN FOLDING

The growth of the Rocky Mountains began about 60,000,000 years ago at the close of the Mesozoic era or the Age of Reptiles. In fact, the great changes in climate and vegetation produced by the mountain uplift may have had much to do with the extinction of the cold-blooded dinosaurs and the rapid development of the smaller but more intelligent and warm-blooded mammals.

The uplift of the mountains took place very slowly but was of magnificent proportions. It assumed the form of a great fold or arch (fig. 3) which involved not only the pre-Cambrian schists and granites but the thousands of feet of sedimentary beds which had been deposited upon them by the seas that repeatedly covered the region.

## EROSION FOLLOWED BY REGIONAL UPPIFT

No sooner had the first Rockies begun to rise than erosion began its work of destruction. During the uplift and in the long period which followed, some 10,000 feet, or a thickness of almost 2 miles of sedimentary rock, was washed away from the top of the arch, until the ancient schists and granites which formed the core were uncovered and carved by the mountain streams. This core was bordered on either side by the eroded edges of the sedimentary beds which were left dipping away from

5

*Figure 4.*—Ancient erosional plain (the Upper Flattop peneplain) southeast of Iceberg Lake on Trail Ridge Road. This plain is believed to have been formed at a much lower altitude, by streams, and to have been raised to its present elevation of 12,000 feet by the last uplift of the region. Terra Tomah Peak on right, Stones Peak in center, and Longs Peak in left distance. Note slight terracing of surface below road at left due to sliding of the wet soil on sloping bedrock.

the axis of the great arch of which they had formed a part.

The final result of this erosion was the formation of a rolling plain of moderate elevation, above which rose low, rounded mountains 1,000 to 2,000 feet in height. The disintegrated rock which was washed away by the streams was spread as a blanket of sand and clay east of the mountains and today forms part of the rocks of the Great Plains.

The erosion of so vast an amount of rock by streams may seem fantastic, but figure 3, page 5, illustrates the evidence upon which the statement is founded. It will be noted that the thickness of the sediments upturned along the flanks of the range can be measured. Most of these sediments belong to the Mesozoic era and, since they have much the same characteristics on both sides of the range, they probably were put down in the same body of water rather than in two separate seas divided by a land barrier. In other words, there were no mountains here when these sediments were laid down, and consequently the sediments were deposited across what is now the range. As they are 10,000 feet thick on the sides of the present range, they probably had about the same thickness over what is now the crest, and inasmuch as they are not found on the crest of the mountains, the entire 10,000 feet of rock must have been removed by erosion. The time required for so gigantic a task as the removal of a lofty mountain range is difficult to comprehend. It may well have been many millions of years.

The evidence that a rolling plain was developed by the erosion of the Rockies after their first uplift can be seen on the mountains themselves.

Trail Ridge Road above timber line traverses a rolling upland (fig. 4) which is in marked contrast to the rugged canyons cut into it from the east. Part of this upland surface forms the top of Flattop Mountain (fig. 5) and for this reason the entire rolling upland has been called the Flattop peneplain, the term meaning almost a plain. There are really two surfaces, an upper and a lower, closely related in origin (p. 10). They are evidently erosional and appear to have been cut by streams which were flowing at a lower elevation and consequently had but little fall. As the surfaces now stand from 11,500 to 12,000 feet above the sea, they must have been raised from the lower level at which they were formed to their present elevation by a series of uplifts which did not greatly fold or distort them. These uplifts affected not only the Rockies but also the adjacent Great Plains.

In observing the Upper Flattop surface one should try to forget the deep canyons which now dissect it and imagine the old surface as it must have been before the uplift which brought it to its lofty position and inaugurated the present cycle of canyon cutting. That the surface had not been entirely leveled to a plain, at least where the former mountains stood, is evident. Rounded hills perhaps 2,000 feet in height, the stumps of these mountains rose above this surface and are today represented by the higher summits of the range.



*Photograph by H. Raymond Gregg*

*Figure 5.*—Ancient erosional plain (Upper Flattop peneplain) from Flattop Mountain, elevation 12,200 feet. Longs Peak in distance at left and Halletts Peak in left foreground, with snow at head of Tyndall Glacier.
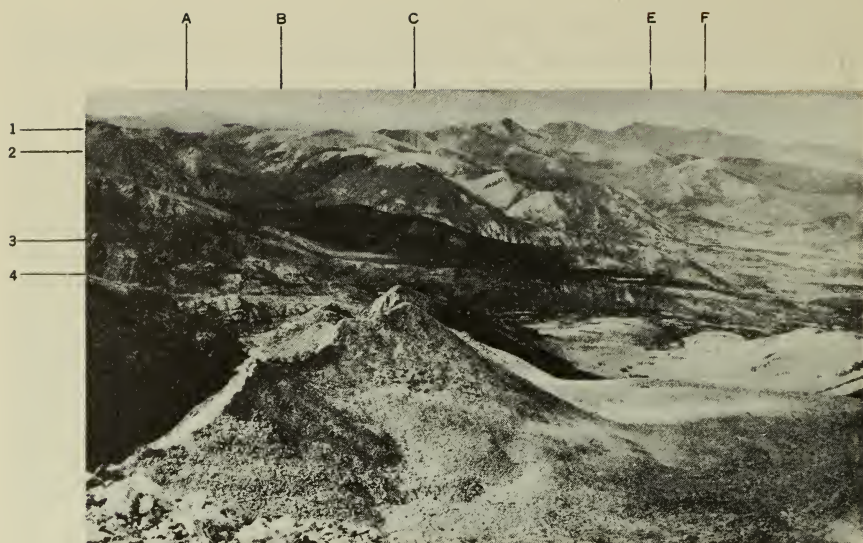
*Figure 6.*—View northwest from Longs Peak. To the right is the Mummy Range (C. F), and to the left in the distance the Never Summer Mountains (A). Between them, above timber line, is the smooth rolling surface of Trail Ridge, the higher part of which (B–1), is part of the Upper Flattop peneplain (p. 7). The southeast end of the ridge (C–2) at timber line is a lower erosional surface corresponding to the bench at the head of Forest Canyon (p. 24). This surface can be traced northeast along the crests of the ridges (E–2, F–2). Sloping surfaces in lowland on right are glacial moraines (F–3) on one of which lies Bierstadt Lake (E–4).

It is possible that the present elevation of some of these hills above the old surface has been increased by faulting or bending of the surface during the long period of uplift to which the region has been subjected. For example, the peculiar flat top of Longs Peak, which is considered by some authorities to be part of the old surface, lies some 2,000 feet above that surface and may owe its elevation to greater movement in the vicinity of the peak than has taken place in the adjacent area.

### EVIDENCES OF INTERMITTENT UPLIFT

As to the nature of the uplift which followed the formation of the Upper Flattop peneplain some interesting observations may be made. About three-fourths of a mile northwest of Iceberg Lake on Trail Ridge Road the highway turns abruptly to the northeast. From the observation point at the turn there is an excellent view to the southwest across the head of Forest Canyon (see p. 24, point 1.0 mile). On the southwest side and extending to the rim of the canyon is a broad bench at an elevation of about 11,500 feet or about 500 feet below the average level of the higher plain. This lower level appears also on the southeast end of Trail Ridge just above timber line (fig. 6, C–2) and on the crests of several ridges southeast of the Mummy Range (fig. 6, E–2). It is evidently an erosion surface, similar to that of Flattop, and has been termed by Van Tuyl and Lovering

*Figure* 7.—Chasm Lake and valley from Longs Peak. The valley was once occupied by a glacier which excavated the cirque in which the nearer lake lies and deposited the great lateral moraine on the left up which the trail runs. From this trail the view shown in figure 2 was taken. Note that the distant mountains rise to a common level which represents one of the old erosion surfaces described on page 10.

9

(p. 32) the Lower Flattop surface. Its presence may be interpreted as follows: After the formation of the Upper Flattop surface the general region was raised gradually about 500 feet. This uplift increased the fall of the streams and enabled them to begin the erosion and destruction of the Upper Flattop surface which they themselves had made. Their work progressed rapidly in the soft rocks east of the mountains, but proceeded more slowly in the mountain granites. The streams had already deepened their valleys as much as fall would permit, and were widening the valley floors through side cutting in their winding channels, when renewed uplift forced them to begin once more the deepening of their valleys. The bench at the head of Forest Canyon is part of one of the broad valley floors formed after the initial uplift.

During the many millions of years which have elapsed since the formation of the Flattop surface the cycles of uplift and erosion have been repeated a number of times. In Rocky Mountain National Park remnants of several erosional surfaces are preserved in the level tops of certain mountains and plateaus. For example, the summits of Deer Mountain (fig. 15) and The Needles are parts of an old erosion surface which now stands at an altitude of about 10,000 feet. The plateau west of Gem Lake, north of Estes Park, and the top of Prospect Mountain just south of the village are parts of another erosion surface which has been raised to 9,000 feet. The even-topped summits 10 miles east of Longs Peak (fig. 7) are at the same level. The top of Castle Mountain represents a surface 300 feet lower at 8,700 feet. Each of these surfaces marks a pause in the great uplift which has raised the Rockies and the western Great Plains to their present altitudes.

Today a comparatively recent uplift, which began sometime in the Pliocene and may even now be continuing at intervals, has given the streams power to deepen the mountain canyons, and at the same time plane down the soft rocks of the lowland, which lies east of the mountain front. The mountains tower above the lowland because their rocks are hard and resistant to erosion, and because the broad uplift of the region has given the streams power to wash away the soft rocks of the lowland.

## THE GREAT ICE AGE

WE HAVE now brought our history of the park down to a series of events which took place in comparatively modern times, geologically speaking; that is, within the last million years. This epoch is called the Ice Age, or the Pleistocene.

About one million years ago the climate of the earth grew cold—just why is not known. Probably it was owing to a combination of causes, one of which may have been a variation in the amount of the sun's heat due to sun spots. It was cold enough so that in regions of heavy snowfall,

like that around Hudson Bay, the snows of one winter did not entirely melt in the following summer. Snow fields began to accumulate, and as they grew in depth the snow was turned to ice by compaction.

## CONTINENTAL GLACIERS

The great fields resembled the present ice caps of Greenland and the Antarctic. They were thousands of feet thick, and the ice at the base, unable to support the weight of the ice above, was squeezed out in all directions, gradually spreading until it covered much of the northern part of the continent. These great ice sheets were known as continental glaciers. The force of their flow was determined by the thickness of the ice in their areas of accumulation; they could not move into the higher altitudes and so never reached Colorado.

There were five separate cold periods and five different advances of the ice sheets, separated by extended warm periods in which the glaciers melted back or entirely disappeared. These interglacial periods had durations of from 25,000 to 325,000 years.

The last or Wisconsin Ice Sheet as it is called, melted away only 25,000 years ago, and the world today may be experiencing an interglacial period. In this case another ice advance is to be expected sometime in the distant future.

## VALLEY GLACIERS

At the time that the great ice sheets were spreading over the northeastern part of North America, valley glaciers accumulated in the mountain gorges of the Rockies and moved down these stream-cut valleys as rivers of ice. They were in no way connected with the continental ice sheets, except that they accumulated during the same cold periods and presumably can be correlated with them. To these ancient ice rivers is due much of the magnificent scenery of the present mountains, particularly the perpendicular cliffs, towering peaks, and the beautiful lakes which lie between.

Only two of the possible five different advances of the valley glaciers can be definitely recognized in the park by differences in the weathering and decay of the gravel and boulders which the ice carried frozen in its mass and which were deposited when the ice melted. This is true because the last glaciation destroyed all evidences of the earlier advances, except in places where the earlier glaciers extended beyond the limits of the last advance of the ice. But we are getting ahead of our story; we should begin by describing the accumulation and flow of valley glaciers.

Snow will accumulate to the greatest depths where the snowfall is greatest and where the temperature is sufficiently cold to prevent melting. Such conditions are found near the heads of mountain valleys. Here, even in the comparatively mild climate of the present, the snow is drifted by the strong

west winds of winter into the heads of valleys east of the divide where it feeds such modern glaciers as Tyndall and Andrews. If you have time by all means visit these glaciers which lie about 5 miles from Bear Lake. You may need horses, but the trip is well worth while.

Let us assume that you have climbed up the trail to the Flattop peneplain, covered with its angular boulders, and stand on the edge of the cirque of either Tyndall or Andrews Glacier. The cirque is the great bowl-shaped depression cut by the ice at the head of the valley. In it the snow accumulates and by its own pressure is hardened into ice. As the snow and ice increase in depth, their weight proves too much for the strength of the ice at the base and this is squeezed outward and begins its flow down the steep valley floor. Bear in mind that the valley was first cut by streams and that the glacier is merely taking advantage of the channel thus prepared for it.

On the valley floor underneath the ice are loose rocks and boulders. The great weight of the ice above presses the basal ice around these until they are enveloped by it and carried down the valley as the ice advances. As they are scraped along over the bedrock they grind and polish it, leaving long scratches which indicate the direction of the ice flow. The grinding rocks are themselves ground smooth on the side which is down, and occasionally, striking some obstruction, may be turned over in the moving ice and ground on another side. Thus, instead of being rounded as in a stream, they are ground with angular sides or facets and are termed "faceted boulders." The grinding of the rocks upon each other produces a white powder or "rock flour" which gives to the waters that flow from the melting ice a peculiar white chalky appearance. Upon reaching the first lake below the glacier the coarser particles settle out and the remaining suspended particles cause the water to appear blue in color.

As the glacier grinds down the valley, sweeping away projecting points of rock and straightening its course, the cliffs are undercut and rock slides pour masses of earth and rock fragments upon the surface of the ice. As the ice continues its flow it comes into lower and warmer altitudes until finally the point is reached at which the ice melts as rapidly as it advances. Here the load of boulders, gravel, and sand which it carries is piled in a ridge along its melting front. Such a ridge is called a terminal moraine. The material which is plowed up and dumped along the sides of the glacier is called the lateral moraine (fig. 7).

If the general climate grows warmer after a terminal moraine is formed, the ice front melts back until it stands at a higher altitude. At this point where melting and rate of advance just balance, another terminal moraine is built. Such a moraine is called a recessional moraine. Most of these moraines form natural dams across the valleys, producing the lakes for which this mountain country is famous (fig. 16). Where several recessional moraines are present a series of lakes may be formed, such as the series in the valley below Tyndall Glacier (fig. 9). At the foot of Andrews Glacier is the lake of figure 8. The recessional terminal moraine forming the dam

12

Figure 8.—Andrews Glacier from the terminal moraine below the lake. This small glacier extends but little beyond the cirque or rock basin in which its snow and ice accumulate. That the movement of the ice is greater in the center than on the sides is shown by the curved lines formed by dust upon the surface.

Figure 9.—Dream Lake with Hallett Peak on the left and Flattop Mountain on the right. In the center is the valley below Tyndall Glacier. This was originally stream-cut but has been reshaped by the glaciers of the Ice Age. Note that the valley is U-shaped in cross section, that it has been smoothed and straightened by the grinding away by the ice of projecting points of rock, and that its floor is covered with glacial boulders.

13

*Figure 10.*—Map of Rocky Mountain National Park.

S T

R O O S E V E L T

N A T I O N A L

F O R E S T

Thompson
Dickinson
174

BLACK CANYON CREEK DRAINAGE
BASIN is source of water supply for
Estes Park Village. Help protect its
purity by keeping out.

DEVILS GULCH

The Needles
10,076     Gem Lake

ESTES PARK VILLAGE
SUPERINTENDENT'S OFFICE
Hotels-Camps-Stores
Post Office - Garages
Pack Animals

THOMPSON RIVER
ENTRANCE

Twin Sisters
11,456

LARIMER CO.
BOULDER CO.

R O O S E V E L T     N A T I O N A L     F O R E S T

ALLENS PARK VILLAGE
Hotel - Camps - Stores
Post Office - Garage
Pack Animals

St. Vrain Creek

N

P

S

LEGEND
Fire Lookouts
Emergency Telephones
Ranger Stations
Shelter Cabins
Public Campgrounds
Museums
Amphitheaters
Park Boundary
Primary Roads
Secondary Roads
Trails (Horse & Foot)

N. P. R. M. 7011  Feb. 2, 1942

# Points of Interest Along Park Roads

THE TRAVELER, without knowledge of geology, should read what has gone before if he would understand fully the descriptions starting on page 18, road logs. One fact in particular has been stated several times and should be kept constantly in mind: the mountains and valleys have been carved by water and ice, and in the process thousands of feet of rock have been removed from the surface so that, with the exception of the lava flows, the bedrock now at the surface was at one time deeply buried within the earth.

We are now prepared to apply our knowledge in examining points of interest as we drive along the major park roads. A convenient place of beginning is the Thompson River Entrance on the east side of the park. Set your speedometer at 0.0 at the checking station, which is about 3.5 miles southwest of the town of Estes Park. (See Road Logs, p. 18.)
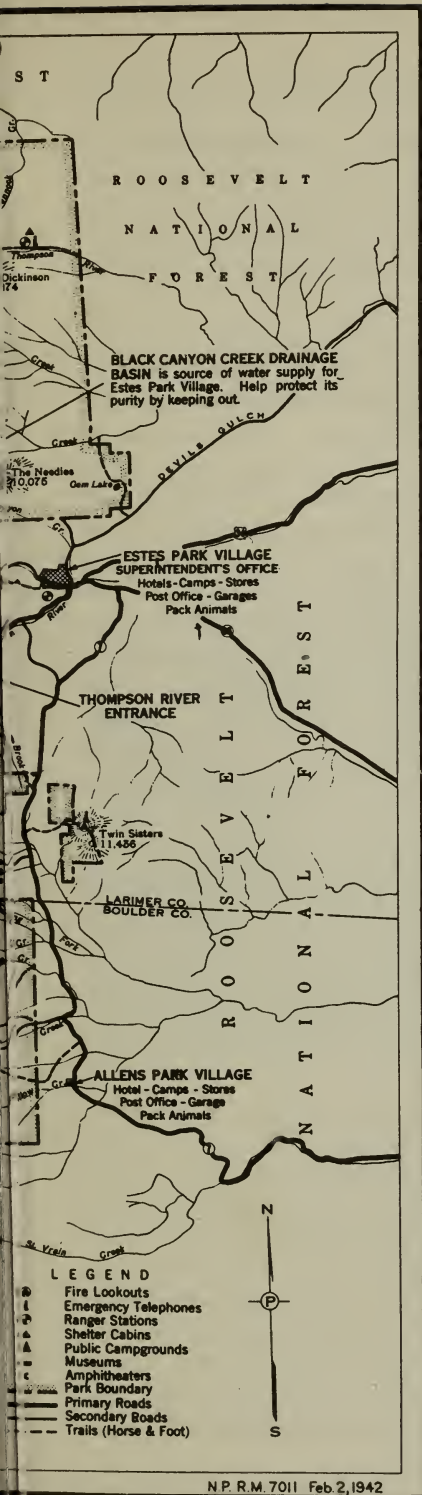
of sand, gravel, and boulders which impounds this lake can be clearly seen from the cliff above the glacier.

The peculiar shape of the valleys below Tyndall and Andrews Glaciers may be noted. Although originally stream cut, they no longer have the typical V-shape of stream-cut canyons, but are U-shaped in cross section. This shape is typical of glaciated valleys and is due to the gouging action of the ice, which lowers the floor of the valley at the same time that it grinds out its sides (fig. 9).

Let us now turn our attention to the surface of the ice itself. Dust and dirt have accumulated on it and, as the ice moves, these have been concentrated in streaks which bend downward near the middle of the glacier showing that the flow is more rapid in the middle than on the sides because of friction against the rock walls (fig. 8).

The valley floor beneath the glacier is apparently uneven, and the ice therefore moves forward over a series of levels and steep slopes like a river cascading over rapids with smooth reaches of water between. This peculiarity of glaciers is much more apparent on long glaciers than on such small ones as we are examining, and it is responsible for the formation of cracks or crevasses which occur where the ice breaks as it flows over the crests of the steep slopes. These crevasses, where covered and concealed by drifting snow, are extremely dangerous to one traversing the surface of a large glacier. They lead downward to depths of 50 feet or more and in some places open into ice caves through which sweep streams of water formed from the melting ice.

Irregularities in the rock floor over which the glacier moves may be caused by differences in hardness of the bedrock or by the presence of zones of fractures in the ancient rocks of the mountains. Such zones weaken the rocks and make them less able to withstand erosion. Water from the melting ice on warm days seeps into the fractures and on freezing tends to loosen fragments of the rock. These fragments are plucked out by the pressure of the moving ice, thus lowering the valley floor in the fracture zones more than in the unfractured rock and causing the steep inclines. Where two glaciers join, the increased amount of ice below the junction increases the erosive power of the glacier and produces the same effect.

Mention has been made of the cirque or basin-like depression at the head of a glacier. Apparently this is formed by the plucking action of the ice, just described. It is the point at which the glacier begins its work, and it is the last retreat of the shrinking mass of ice as it melts away when the climate changes. In brief, it is the point at which glacial action is longest continued. As the ice plucks out more and more of the loosened rock fragments which its freezing waters pry apart, the glacier eats its way back into the mountain at the head of the valley and in doing so produces a cliff by undermining. After the ice entirely melts away the peculiar shape of the basin or cirque thus formed is apparent.

One of the finest examples of such a cirque is that above Chasm Lake

on the northeast side of Longs Peak (fig. 2). The vertical cliff which forms the wall of this cirque is more than a quarter of a mile in height. During the Ice Age, Longs Peak was surrounded by several glaciers, the cirques of which cut back into the mountain on all sides. The spectacular scenery of the peak's lofty cliffs is due entirely to this cutting by ice. Another fine example is the cirque on Sundance Mountain to be seen from Trail Ridge Road just above Rainbow Curve (fig. 11). These are cited merely as examples, for cirques are to be seen almost everywhere in the higher parts of the park.

Whether the glaciers of today date back to the Ice Age is a difficult question to answer. They may be the last remnants of those ancient rivers of ice, slowly dying in the warmth of the present climate; or, due to some change in temperature or wind direction, they may be newly arrived in the valleys left vacant by their predecessors. One likes to believe that the first interpretation is the true one.



*Photograph by Carroll H. Wegemann*

*Figure 11.*—Sundance Mountain from Trail Ridge Road above Rainbow Curve. The basin cut into the mountainside is the cirque or gathering basin of a former glacier. In its formation water freezing in crevices of the rock pried off fragments by its expansion and these, enveloped by the glacial ice, were carried away as the ice moved. The cirque was thus constantly enlarged and the great cliff at its back maintained by rock falls due to undercutting. Most of the cliffs in the park are the work of former glaciers.

17

# Road Logs

*Miles*

0. 0   Thompson River Entrance, Rocky Mountain National Park.  Just beyond the entrance the road to Bear Lake turns abruptly left, crossing Thompson River to Camp Woods in Tuxedo Park.  Keep straight ahead on road to Moraine Park. The gravel and boulders on the right belong to the moraine of a glacier older than the last or Wisconsin stage of glaciation.  This glacier flowed down the Thompson Valley and spread its deposits beyond the limits of the later glacier (see p. 19, point 2.4 miles).

0. 1   Steep grade around the base of Eagle Cliff.  Dark schist with intrusions of white pegmatitic granite (granite containing large crystals) is exposed in road cut on right.  Note the shining crystals of black mica in the schist which lie in parallel planes and cause the rock to cleave readily in those planes.  The granite has been intruded in thin layers along the cleavage planes of the schist and in places has broken across them.  At bend in road is exposed a mass of granite which has welled up into the schist and is disintegrating due to the breaking down by weathering of the feldspar crystals which are present in it.  Just beyond, a lense of pink and white granite from 2 to 6 feet thick has been intruded between the planes of the schist and dips to the east.  Its color is due to the presence of both pink and white feldspar crystals.

0. 3   Crest of terminal moraine of the great glacier which during the Wisconsin or last stage of the Ice Age covered Moraine Park.

0. 5   Road follows base of terminal moraine which is banked against the foot of Eagle Cliff.  Here the advance of the ice was halted by the cliff, and the gravel and sand carried by the glacier were deposited in a ridge as the ice melted.

0. 7   Junction with road to Stead's Ranch. Keep right.  To the south rises the pine-covered south lateral moraine of the former Thompson Glacier.  Its height indicates the height of the glacial ice which decreased toward the east as the ice melted in the warmth of the lower altitude.  At the end of the former glacier the lateral merges with the terminal moraine.

To the north, beyond the groves of aspen, stretches the pine-covered north lateral moraine, its western end banked against the mountain at the mouth of the canyon down which the ice flowed.  The top of this moraine, like that of the south lateral, slopes to the east, the inclined line of its crest being plainly visible against the mountain side.

The flat valley of Moraine Park (fig. 12) was the melting basin of the glacier and was occupied as the ice melted back by a glacial lake.  The waters of this lake, impounded by the terminal moraine, were later drained away when the outlet cut through this natural dam.  The present stream swings in broad meanders across the flat which was the lake bed, because it does not have enough fall to give direction to its waters.  Rising from the flat in the distance is a rock island which the glacier was unable to destroy, although it ground down the west side to a gentle slope.

Around the east side of the lake the road follows what appears to be an old lake

18

Photograph by Carroll H. Wegemann

*Figure 12.*—Moraine Park from the museum. The even-topped pine-covered ridge on the left is the south lateral moraine, or deposit of boulders, gravel, and sand, left by the former Thompson Glacier. Its height indicates the height of the glacial ice. The flat is the bed of a former lake, impounded as the glacier melted, by the terminal moraine which the glacier threw across the valley. Note the U-shaped gorge, in distance on right, down which the glacier moved.

*Miles*

terrace or shore line formed by the waves when the lake stood at its initial high stage before the lowering of its outlet. As the outlet was deepened and the waters drained away, the lake established a new and lower shore line leaving the old terrace dry, to be cut away, in part, by the waves and stream erosion.

1.1 Moraine Park Museum, on right, contains exhibits illustrative of Indian life, pioneer history, wildlife, and glacial geology.

1.4 Begin climb of north lateral moraine (Wisconsin stage or last glacial advance) of Thompson Glacier. The open air amphitheatre is on the south side of the road.

1.9 Road curve on crest of moraine.

2.1 North base of lateral moraine (Wisconsin stage).

2.3 Cross Beaver Brook.

2.4 Road emerges from aspen grove in Beaver Park. Ahead are scattered pine trees growing on a low gravel and boulder ridge which is the north lateral moraine of an earlier glacier than that of the Wisconsin stage, the moraine of which has just been crossed. The older glacier was larger than its successor. It flowed down the Thompson Valley and occupied Moraine Park, but all evidence of it has been obliterated by the later glaciation except in Beaver Park and Tuxedo Park, where its moraines lie outside the area covered by the later ice. The gravel in these old moraines is very much weathered. In fact some of the stones can be crumbled in the fingers. The gravel has obviously been subjected to weathering for a period several times as long as that to which the practically unweathered gravel in the moraines of the last ice advance was subjected. The old lateral moraine can be traced for a short distance down the valley until it merges with the old terminal moraine which turns south and is banked against Eagle Cliff. The road follows the south side of the old moraine to the west.

2.7 Curve to the right across the old moraine which is so low at this point as to be scarcely recognizable.

19

*Miles*

2. 8  Dirt road leads left to Upper Beaver Park.  Keep to the main road.

3. 1  Sharp curve to left on shoulder of Deer Mountain.  From this point an excellent view can be had of the several moraines just described.

3. 3  Rock cut.  A light-colored granitic dike containing large crystals of shiny mica, which separate in thin sheets, is well exposed on left and can be seen also on right. The dike represents molten rock which was intruded into the older rock at great depth and cooled so slowly that the large crystals had time to form before the molten rock solidified.  Erosion has lowered the surface and exposed the granite.

4. 6  Second rock cut is through rusty colored granite which here stands in a ridge because it is harder than the rock on either side.  From this point one may view the even-crested north and south moraines of the last Thompson Glacier.  Longs Peak is the highest flat-topped summit dominating the skyline on the south.

### DEER RIDGE JUNCTION TO FALL RIVER PASS VIA FALL RIVER

5. 3  Deer Ridge Junction.  The left road is the usual route taken to Fall River Pass via Trail Ridge.  The right road leads to the same pass by way of Horseshoe Park and Fall River.  It is a narrow winding mountain road, but is safe for experienced mountain drivers.  Beyond Chasm Falls it is open only to cars going up.  By taking it one can make a circle trip, returning down Trail Ridge to Deer Ridge Junction.  For this circle trip over the Fall River Road keep right.  If you decide to take the Trail Ridge Road, keep left, and turn to page 29, point 5.3 miles using the left-hand mileage column and reading the descriptions of the various points in reverse order.  In other words, read up on the pages.

5. 9  In the road cut on left large glacial boulders are seen resting on poorly exposed bedrock which originally formed the south side of the Fall River Valley.  When the glacial ice moved down this valley it deposited its lateral moraine against the bedrock and the road cut has exposed the basal boulders.  Some of these have been moved to protect the bank against erosion, but their position still marks the base of the moraine.  Just beyond, the road crosses Hidden Valley Creek, the origin of which will be described from Rainbow Curve (see p. 27, point 9.3 miles) on the Trail Ridge Road.

6. 8  Base of lateral moraine on south side of Horseshoe Park.  The flat valley, like that of Moraine Park, is the bed of a glacial lake impounded by a terminal moraine which crosses the valley 2 miles farther down.  This stop is on an old lake terrace built by the waves when the lake stood at one of its higher stages.

6. 9  Edge of terrace, against which the waves broke after the lake level had been lowered by the deepening of the outlet through the terminal moraine.

7. 1  Cross Fall River.  Just ahead the road forks.  Take left road up valley, leaving Route 34.

7. 5  Fall River Lodge.

7. 8  Roaring River.  The rapid fall of such side streams is due to lowering of the Fall River Valley by the last glacier.  This left the mouths of the side valleys, which contained smaller glaciers or no glaciers at all, "hanging" so that their waters now reach the main valley by a series of cascades.  It is evident that the valley of Fall River must have been lowered some 400 feet by the gouging of the glacial ice.

8. 5  Point of granite on right projects into valley.  Below this point the road follows the foot of the north lateral moraine of the Fall River Glacier.  In the narrow valley above, however, there is no moraine because the ice was so confined and flowed under such pressure between the granite walls that no gravel was dropped along the base of the cliffs.  Nevertheless, some morainal material was banked high up on the valley sides.

20

9. 0  Road to Endovalley Campground. Keep right.

9. 4  Chiquita Creek. Before the last glacier had deepened the valley of Fall River and thrown its lateral moraines across the mouths of its side streams, Chiquita Creek joined the main valley without a fall like any normal stream. Now, due to the work of the glaciers of the Ice Age, it cascades down to the main valley in a series of falls. The rock is coarse reddish granite.

9. 6  The granite ledge just above the road has been smoothed and polished by the stones frozen in the base of the glacial ice and ground across it by the glacier's flow.

9. 7  Pot hole on right next to road. This circular hole 2 or 3 feet in diameter was drilled by stones revolving in a whirlpool in some side stream which probably flowed at this level during, or just after, the last glaciation. Note that the main stream is several hundred feet below.

10. 0  First switch-back.

10. 2  Glacial polish on ledge just above road similar to that at 9.6 miles.

10. 4  Chasm Falls. The beautiful waterfall is about 25 feet in height and is drilling, at its foot, a pot hole similar to that at point 9.7 miles. From this the water drops about 5 feet into a second hole, the half-round side of which may be seen in the cliff above the water. About 20 feet downstream from the base of the main fall the remains of a third pot hole are to be seen. It is evident that the stream is literally drilling out its narrow gorge in the solid rock by revolving loose boulders in its whirlpools. As the cataract recedes, the upstream side of the last pot hole is cut away so that the half-round hollows in the walls of the gorge are ·all that remain.

There is glacial polish on the rock ledge just above the parking area.

10. 7  Here a perpendicular face of granite, some 20 feet long and 12 feet high, rises above the road. Its top is rounded and polished by the gravel and sand frozen in the ice of the former glacier. The rock was jointed or cracked during the uplift of the mountains and, after the polishing of the upper surface, large blocks were broken off along joint planes and carried away by the moving ice, leaving the smooth face of the joint exposed. This was later polished by the ice.

11. 0  Glacial polish is visible about 150 feet above the road showing the height of the former glacier.

11. 8  In line with the road is Mount Chapin. The banding of the old dark schist and the lighter granite, which as molten rock was intruded into the schist when both lay deep within the earth, is plainly seen. Mountain uplift and erosion have brought the rocks to the surface and erosion working along joint planes has carved the peculiar spires and pinnacles.

11. 9  Granite broken into blocks by joints. These were produced by the pressures and strains under which the rocks were placed during the mountain uplift.

14. 0  Surface of schist and intrusive granite beside the road. These rocks have been ground smooth by the glaciers for they formed the floor of the old glacial valley. The present stream flows in a gorge which it has cut since glacial time, leaving part of the old valley floor as a bench along which the road has been built.

The schist and granite were at one time so deeply buried within the earth that the pressure upon them from all sides exceeded the crushing strength of the rock. Under such conditions no crevasses could form and during earth movement the rocks bent and flowed like thick tar. Note that much of the bending took place after the intrusion of the light granite. At one point a band of granite has been folded and the fold, by continued lateral pressure, has been overturned, broken, and one side thrust over the other. This type of thrust-folding and faulting is characteristic of the mountain building which took place at the end of the Meso-

*Figure 13.*—Canyoncito from Fall River Road. There is glacial polishing on the surface of the rocks to the right, but the rugged gorge shows no sign of glacial action. It is evident that the gorge has been cut in the 10,000 years since the ice melted from this part of the valley

*Miles*

zoic era when the Rockies were first formed. It often happens that a single rock may show in miniature a type of folding which is characteristic of an entire mountain range.

14. 2 Canyoncito (fig. 13). This little canyon has been cut by the stream in the valley floor since the retreat of the last glacier. Note that glacial grinding is evident on the terrace over which the road runs, but that there is none in the little canyon. If we assume that the glacial ice began to melt back from the valley below Horse-shoe Park some 25,000 years ago and retreated steadily to the cirques of Fall River Pass, then it may have left this part of the valley some 10,000 years ago. If this reasoning is correct, it has required about 10,000 years for the stream to cut Canyoncito.

15. 2 Willow Park. This meadow was the bed of a small lake impounded by a terminal moraine which marked a pause in the retreat of the glacial ice. Such a moraine is known as a recessional moraine.

In the next mile are numerous intrusions of coarse-grained granitic rock known as pegmatite. The molten rock, deep within the earth from which these intrusions solidified, probably contained, under great pressure, much steam which made it thinly fluid. It cooled slowly deep below the surface, giving the large crystals time to grow.

17. 0 Large mass of pegmatitic granite several hundred feet wide which has been intruded into the schist.

From this point an excellent view is to be had of three cirques or basins in which glacial snow and ice accumulated at the head of Fall River. From these the great glacier flowed down the valley.

NOTE.—*Left hand column of figures below is for the use of travelers coming up from Poudre Lakes.*)

4.5    18. 4 Parking area at store and museum on Fall River Pass. The cirques previously mentioned lie to the south, and beyond them the ridge is capped by the remnants

22

of an old lava flow which is better exposed at Iceberg Lake (see p. 25, point 2.0 miles).

## FALL RIVER PASS TO POUDRE LAKES

There is not time on this circle trip to drive to Grand Lake, but if you have an hour to spare turn right on the road to Grand Lake, and use the right hand column of figures in log. Drive down as far as Poudre Lakes on the Continental Divide. If you do not care to take this trip but wish to go east down Trail Ridge Road, turn to page 24, point 0.0 miles in right-hand column.

4.0  18.9  Overlook. Specimen Mountain, 3 miles to the west across Cache la Poudre River, appears to be an extinct volcano and the probable source of the lava previously mentioned. The mountain is situated on the Continental Divide 2 miles north of Poudre Lakes and can be reached by a trail from the Lakes. Erosion has long since destroyed the old crater, which stood above the highest point of the present mountain.

That the mountain was a volcano may be inferred from the nature of the rocks which are exposed on its top and sides. Like many volcanic cones, the mountain is built up of alternating layers of black volcanic glass (pitchstone), lava, white volcanic ash, mud flows, breccia, and pumice (fig. 14). Notes on the formation of these rocks follow:

*Volcanic glass* is produced when molten rock flowing out upon the surface is chilled so quickly that mineral crystals do not have time to form in it.

Ordinary *lava* is cooled more slowly, but not slowly enough for the rock to become completely crystalline like granite, which is cooled very slowly far below the surface.

*Volcanic ash* is rock dust blown out by the terrific explosions of the eruption.

*Mud flows* are formed when this dust is washed out of the atmosphere by the torrential rains which frequently accompany the eruption, the rains being due



*Photograph by Carroll H. Wegemann*

*Figure 14.*—Volcanic Rocks of Specimen Mountain, and the Never Summer Range, Specimen Mountain is an extinct volcano, its sides, as shown in the foreground, formed by black pitchstone or volcanic glass, white volcanic ash, fragments of rock blown out by the explosions, and mud flows. The ancient crater has been destroyed by erosion.

to the condensation of clouds of steam emitted from the volcano.

*Breccia* is formed of fragments of the sides of the crater, blown out during the explosions.

*Pumice* is lava charged with gas, the bubbles of which expand when the pressure upon the lava is reduced as it reaches the surface. The resulting small cavities when filled with air cause the pumice to float on water.

All these rocks are to be seen on Specimen Mountain, mute reminders of a time, in the distant past, when volcanoes were active in this region.

The mountain was probably named for the opal, agate, and delicate crystals of topaz which are found lining some of the small cavities in the volcanic deposits.

1. 2  21. 7  Exposed on the south side of the road, about 400 feet beyond the end of the retaining wall, is greenish gray soft rock which represents an old mud flow from the volcano. At higher and lower levels along the road are the ancient rocks of the pre-Cambrian era, and it is evident that the valley of the Cache La Poudre and the lava flow at Iceberg Lake present interesting relationships. Assuming that lava flowed from Specimen Mountain to Iceberg Lake, it could not have done so had the valley of the Cache La Poudre been present at the time of the flow. It is possible that the lava at Iceberg Lake flowed from a vent other than that of Specimen Mountain, but there is no evidence of such a vent. A possible explanation is that the volcanic deposits from Specimen Mountain completely filled an old valley which had been cut in pre-Cambrian rocks at the location of the present valley of the Cache La Poudre; that, in one of the last eruptions of the volcano, lava flowed across this fill to what is now Iceberg Lake; and that subsequent erosion excavated the present valley in the filling of the former valley, exposing some of the old mud flows which were part of the filling and the much more ancient rocks which formed the south side of the old valley. The mud flows, therefore, are merely a veneer partly covering the more ancient rocks.

0. 0  22. 9  Parking area at Poudre Lakes. These lakes are on the Continental Divide although in a valley much lower in elevation than Fall River Pass. A glance at the park map will show that because of peculiarities of stream development the highest mountain peaks are not always along the Continental Divide.

(NOTE.—If you have entered the park from the west, set your speedometer at 0.0 at the parking area at Poudre Lakes and read paragraphs in reverse order up to 4.5 in the left-hand column of figures. At Fall River Pass reset at 0.0 and continue as below.)

Returning to Fall River Pass, reset the speedometer at 0.0 and use the right-hand column of figures. The left-hand column is for the use of those driving in the opposite direction.

## TRAIL RIDGE ROAD BETWEEN FALL RIVER PASS AND DEER RIDGE JUNCTION

22. 9  0. 0  Road junction just southwest of museum and store at Fall River Pass. If you are traveling east, keep right on Trail Ridge Road.

21. 9  1. 0  Overlook on curve. To the west, across the head of the valley of the Colorado River, rise the Never Summer Mountains, 7 miles away. This overlook is at 12,000-feet elevation on the Upper Flattop peneplain, an old erosion surface formed not far above sea level and raised to its present elevation during the last uplift of the region. Directly to the south, across Forest Canyon, rises the cone of Mount Julian, the next prominent point to the west being Mount Ida, the long northwest slope of which merges with the Upper Flattop surface. Across the canyon and extending to its very rim is a bench about 500 feet below the Upper Flattop surface, the origin of which was described in detail on page 10. It represents

the beginning of a lower erosion surface which was cut by the stream after the initial uplift of about 500 feet had taken place. Its presence records a considerable pause in the uplift of the land before further elevation finally brought the mountains to their present height.

20. 9   2. 0   Iceberg Lake. The rock which forms the wall of the cliff back of the lake is reddish brown and differs in appearance from the old pre-Cambrian rocks seen at other points on the road. It is the same lava flow which was observed south of Fall River Pass.

Looking north along the ridge, which is a continuation of the cliff, it will be noted that there is pre-Cambrian rock next to the lava and that it forms the north end of the ridge, being rather poorly exposed in, and below, the north point on the skyline. Across the highway, just south of Iceberg Lake, pre-Cambrian rock is also exposed. The pre-Cambrian, therefore, borders the lava on both sides. It is evident that the molten lava which solidified to form the rock of the cliff must have flowed down a valley cut in the older rock.

Southeast from Iceberg Lake there is an excellent view of the Upper Flattop peneplain (fig. 4). When it was formed it was not quite a plain, for above it rose a line of low rounded mountains, the remnants of the first Rockies. The Mummy Range to the northwest was part of the line. The northwest side of this range shows the old erosion surface merging with the mountain slope. This surface is, however, being rapidly destroyed by the streams which are cutting canyons into it from the east. Farther to the south the group of mountains— Ida, Julian, and Terra Tomah—appear to have been one rounded mountain rising above the plain before the erosion of water and ice cut the canyon of the Gorge Lakes into its heart. Stones Peak may have been part of the same mass before it was separated from it by the cutting of the gorge of Hayden Creek, the next gorge to the east.

On Trail Ridge, about half a mile to the southeast, where the road follows the narrowest part of the ridge, the slopes on either side look as if they were roughly terraced. The soil is but a few feet thick and rests on a sloping surface of bedrock. In the spring when the snow melts, or during heavy rains, the soil becomes saturated with water which not only increases its weight but makes it slippery. Masses of soil, bound together by plant roots, tend to slide gradually for a few inches, or a few feet, down the slope, breaking away from the turf above and overlapping the turf below, thus producing the terraces.

18. 6   4. 3   Rock Cut, 12,110 feet elevation. To the southeast is the gorge of Hayden Creek. Directly south across Forest Canyon the view is up the canyon of the Gorge Lakes. There are six of these lakes in the canyon proper. One, at an elevation of 12,400 feet, is the highest lake in the park. It occupies an old glacial cirque, the cliffs of which shelter it from the sun's rays so that it is never free of ice. The gorge itself was originally cut by streams but has been entirely reshaped by the ice of former glaciers. It contains numerous cirques. Its rugged outlines are in marked contrast to the old erosion surface which, as already mentioned, forms the summits of the surrounding mountains. Nor is it difficult to reconstruct in imagination the shape of the rounded mountain mass before erosion gashed it with cirques and canyons. The landscape of the old plain with its low mountains must have been monotonous. The spectacular scenery of today is due to the comparatively recent uplift of this region and to stream and ice erosion.

15. 6   7. 3   Road crosses to Hanging Valley on north side of Trail Ridge. There are three stone cabins north of road. To the south, across Forest Canyon, is a view of Hayden Creek with several abandoned glacial cirques, the collecting basins of former glaciers, near its head. West of its mouth a great cirque has been cut into the side of Terra Tomah, partly destroying the old erosion surface which forms the top of this mountain.

14. 9   8. 0  The bark on the spruce, fir, and pine trees at timber line where exposed to the wind-driven snows of winter and the sand blasts of dry weather is worn off the windward side.

14. 0   8. 9  Guard wall. To the west is Sundance Mountain with a remarkably fine example of a glacial cirque cut into its eastern flank (fig. 11). To the north across Fall River Valley the switchbacks on the Fall River Road are visible.

13. 6   9. 3  Rainbow Curve affords a magnificent panorama. To the north lies the Mummy Range. Its peaks, northeastward from Fall River Valley, are: Mount Chapin, Mount Chiquita, Ypsilon Mountain, Fairchild Mountain, and Hagues Peak, with Mummy Mountain southeast of Hagues. Note on Ypsilon Mountain the banding of the dark schist and the white granite which, as molten rock, was intruded into it when both lay deep within the earth.

      Below lies Horseshoe Park in the broad valley of Fall River. Beyond the treeless meadow in the distance, which is a former lake bed, a low wooded ridge crosses the valley (fig. 15, C–4). This is one of the terminal moraines of the Fall River Glacier (Wisconsin stage). It was this natural dam which impounded the lake waters and through which the outlet finally cut its channel, draining the lake and leaving several small ponds in the irregularities of its bed.

      On either side of the meadow rise the abrupt gravel slopes of the lateral moraines, 800 feet in height, the tops of which indicate the height of the ice in the valley (fig. 15, A–4). They slope eastward to the point where they merge with the crest of the terminal moraine (see p. 29, point 8.2 miles).

      From the north end of the terminal moraine the north lateral moraine can be traced to the point where it crosses the valley of Roaring River. This valley also



*Photograph by Carroll H. Wegemann*

*Figure 15.*—Horseshoe Park from Rainbow Curve, Trail Ridge Road. A–1, Big-Horn Mountain; A–4, crest of north lateral moraine of former Fall River Glacier, slopes east; B–2, The Needles, part of an old erosional surface at 10,000 feet elevation; B–6, bed of former lake impounded by terminal moraine; C–3; McGregor Mountain; C–5, terminal moraine of Fall River Glacier; C–7; south lateral moraine which merges at east end with terminal moraine; D–3 Castle Mountain, part of old erosional surface at 8,700 feet elevation; D–7, beaver pond in Hidden Valley; E–2, flat top of Deer Mountain, part of same erosional surface as that of The Needles.

was occupied by a glacier, but one which apparently lacked the cutting power of the longer and straighter Fall River Glacier. It was unable to lower the bed of its valley as rapidly as did the glacier of Fall River, and the mouth of the side stream was left hanging 400 feet above the bed of the major stream to which it falls by a series of cascades. It is probable that the glacier of Fall River continued its flow longer than its smaller tributary, for it seems to have thrown its north lateral moraine across the Roaring River Valley. After the glaciers disappeared the stream was able to cut away part of this obstruction.

Note that almost no morainal gravel or sand was deposited on the point of Bighorn Mountain which projects into the valley and which felt the full force of the ice movement. The ice did drop its load, where it was moving with less power, in the more sheltered parts of the valley both above and below this point.

Turning now to the south lateral moraine (fig. 15, C-7), it is evident that this also threw a dam across the mouths of the side valleys coming in from the south. These valleys did not carry glaciers. Their waters were impounded by the moraine, back of which the road now runs, and were forced to flow eastward south of the moraine. The moraine is lower in this direction and the stream, which is called Hidden Valley Creek, at length reached a point where its waters could overflow the barrier and cascade down the moraine to the floor of the main valley. This little stream is crossed on the road from Deer Ridge Junction to Horseshoe Park. The beaver have built several dams across the stream back of the moraine, their ponds (fig. 15, D-7) being plainly visible from this point.

The flat-topped mountain in line with the road is Deer Mountain, along the base of which the road from Deer Ridge Junction to Beaver Park is located. Its top and the top of The Needles are parts of an old erosion surface similar in origin to the Flattop peneplain, but formed somewhat later. A remnant of a still lower plain of erosion is to be seen on the top of Castle Mountain, beyond and just to the left of Deer Mountain. As explained on page 10, these old erosion surfaces were formed, when the region stood at lower altitudes, by stream which had reached their limit of down cutting and were widening their valleys. These erosion surfaces have been for the most part destroyed by the streams which produced them, after further uplift gave the streams more fall and enabled them once more to deepen their valleys.

| | | |
|---|---|---|
| 12. 7 | 10. 2 | Sign 2 miles above sea level. |
| 10. 7 | 12. 2 | A dike several feet wide of dark rock known as dolerite has been intruded into the lighter granites and is well exposed at the side of the road. The same dike is believed to have been encountered in the Colorado-Big Thompson Diversion Tunnel which passes under the Front Range. The molten rock that formed the dike was forced into a fissure which apparently extended in a straight line for several miles. What appears to be the same dike can be seen on the south side of Mount Chapin. |
| 9. 3 | 13. 6 | Many Parks Curve. The description of the Fall River Valley as given from Rainbow Curve (see p. 26, point 9.3 miles) applies equally well here. Note the excellent view of Longs Peak to the southeast and of Moraine Park shut in on north and south by the great timbered ridges of its lateral moraines. At the eastern end of Moraine Park rises Eagle Cliff. From the flat floor of the park rises the little granite island which is noted from point 0.7 miles. (See p. 18.) The treeless area to the north of Moraine Park is Beaver Park, bordered on its north side near the lower end by a narrow tree-covered ridge. This ridge is the lateral moraine of an older glacier which once flowed down the Thompson Valley. (See description at point 2.4 miles, p. 19.) This lateral moraine can be traced farther west by the thin line of trees which divides Upper Beaver Park. |

27
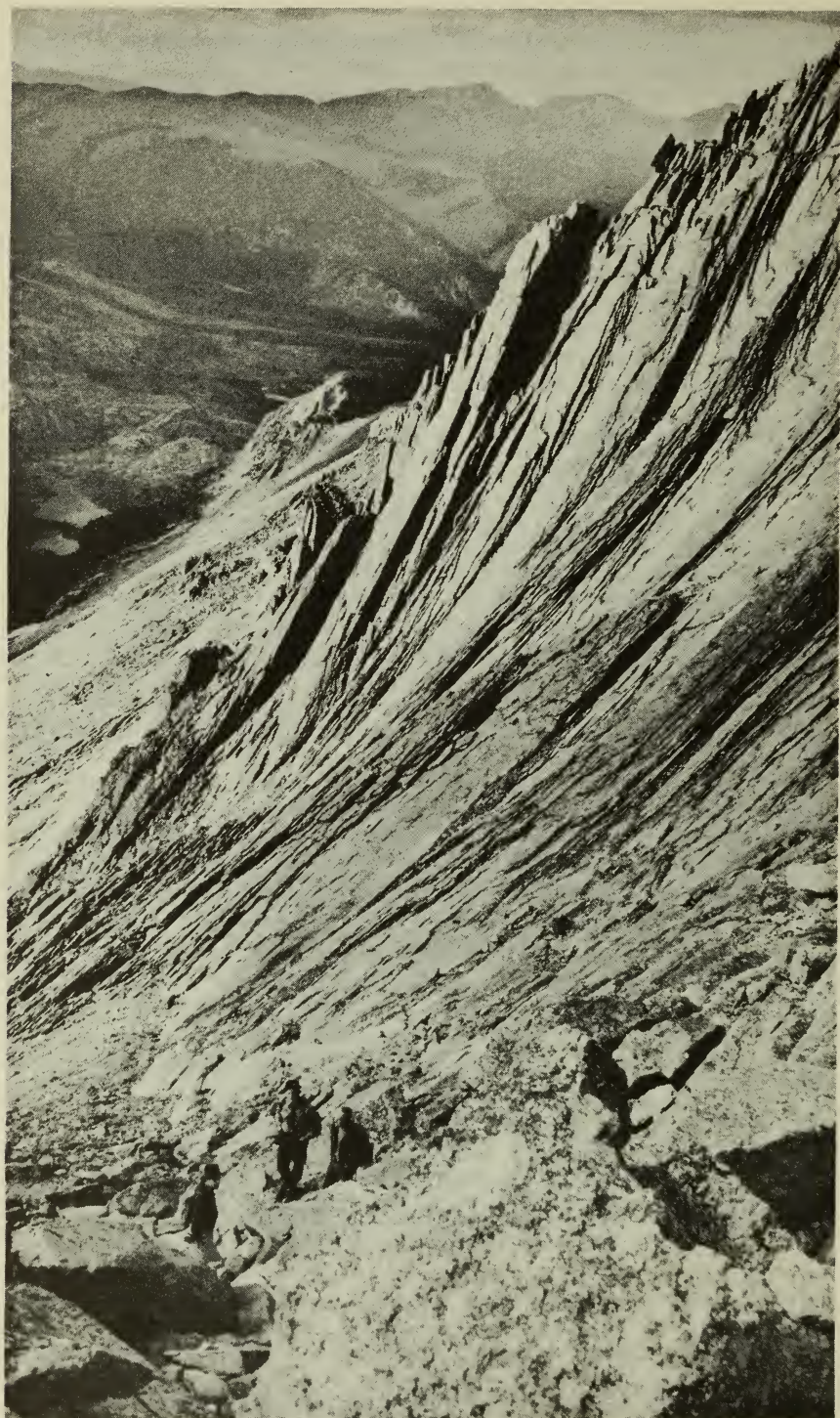
*Figure 16.*—West side of Longs Peak with Glacier Gorge below.

7. 8   15. 1   Curve into Hidden Valley.  To the north lies the south lateral moraine of the Fall River Glacier which has dammed Hidden Valley and forced its waters to flow east as Hidden Valley Creek along the south side of the moraine.  The road also follows the moraine.

7. 6   15. 3   Beaver dams.

6. 8   16. 1   Cross Hidden Valley Creek.  The gravel and sand of which the moraine is built are exposed in the road cut on the left.

6. 0   16. 9   Hidden Valley Creek has cut through a low point in the moraine on the left and drops by a series of cascades (not visible from this road but noted at point 5.9 miles (page 20) some 400 feet to the bed of Horseshoe Park.

5. 3   17. 6   Deer Ridge Junction.  This completes the circle trip.  You may return to Estes Park by the paved road to the right or by Route 34 to the left.  If the latter route is taken, set the speedometer at 5.3 miles.

## DEER RIDGE JUNCTION TO FALL RIVER ENTRANCE
## VIA HORSESHOE PARK

5. 3   Deer Ridge Junction.  Take road to left (north).  For details of the log between this point and point 7.1 miles below see page 20.

7. 1   Junction in Horseshoe Park with road to Fall River Pass.  Keep right on Route 34.

7. 3   Sheep Lake, a shallow pond in a depression in the floor of the ancient lake.  Just beyond, the road climbs to one of the old lake terraces described at point 6.8 miles, page 20.  There is another terrace 25 feet higher.  These terraces are old shore lines formed when the former lake stood at high levels.

8. 2   Terminal moraine (Wisconsin stage) which impounded the ancient lake until the outlet cut its channel through it, draining the lake waters.

8. 4   Studio of David Stirling.

8. 8   East base of terminal moraine.

8. 9   Road follows, and cuts into, a north lateral moraine of what appears to be a glacier older than the Wisconsin, and which extended some distance farther down the valley than did the Wisconsin ice.

9. 2   Fall River Entrance to Rocky Mountain National Park.

9. 3   Side road to Bryson Cottages crosses the valley on recessional moraine.

9. 5   Small meadow, probably the bed of a former lake, lies between two recessional moraines which here cross the valley.  McGregor Mountain on north shows, in its bare dome-shaped crest, the typical weathering of granite, the surface of which spalls off in convex slabs.

9. 8   Fish hatchery and bridge.

11. 0   Approximate end of glaciation.  Below, the valley narrows abruptly and is apparently unglaciated.

13. 9   Estes Park.

## BEAR LAKE ROAD

A short but interesting drive is that to Bear Lake.  Set your speedometer at 0.0 miles.

0. 0   Thompson River Entrance to the park.  Take left hand road inside entrance and cross Thompson River to Camp Woods.

0. 4   Tuxedo Park.   Road follows the outside base of the south lateral moraine of the Thompson Glacier (Wisconsin stage).   South of this moraine the surface of Tuxedo Park is covered by very old morainal deposits of a glacier much older than the Wisconsin as shown by the disintegrated condition of the morainal gravel.   This glacier was wider than was the Wisconsin Glacier and its deposits, therefore extend beyond those of the Wisconsin ice.

0. 5   In repairing a washout on the north side of the road at this point in 1935, human bones believed to be those of a woman were found several feet below the surface. They are said to have been scattered and mixed with charcoal and rested on a bed of white sand which may have been glacial outwash.   The body was apparently cremated on the surface of the outwash from the glacier and the remains later covered by material washed down from the morainal ridge to the north. The information is insufficient to warrant positive conclusions, but the bones were probably very old.   The skull is preserved in the Moraine Park Museum.

1. 5   Across the stream flat to the left is the terminal moraine of the former Bartholf Glacier which flowed down the valley of Glacier Creek.

1. 7   Stream cuts through this moraine.

2. 0   Fork.   Keep left, crossing Mill Creek, and climb the east slope of the terminal moraine of Bartholf Glacier.

2. 5   Crest of moraine.

2. 9   West base of terminal moraine.   Road follows the south side of the north lateral moraine of the Bartholf Glacier.

3. 3   Fork.   Take left road to Glacier Basin Campground, a broad treeless flat which was the melting basin of the Bartholf Glacier.   From this flat there is a commanding view of the Continental Divide and of the high, even-topped ridge formed by the north lateral moraine of the Bartholf Glacier.

   The ridge ends on the west against the side of Flattop Mountain for which the Upper Flattop peneplain has been named.   From this observation point it is difficult to appreciate fully the flatness of the mountain's top.

   The first sharp peak on the skyline to the left of Flattop Mountain is Hallett Peak and in the cirque to the right of it lies Tyndall Glacier.

   Left, or south of Hallett Peak, is Otis Peak, and just left and back of the latter, but hidden from view in the gorge, lies Andrews Glacier.

   Note that the smooth side of Otis Peak slopes to the north and that a similar surface on Hallett Peak slopes to the south.   These smooth surfaces appear to be the sides of one of the old erosion valleys cut in the Flattop peneplain after the initial uplift of that surface when the bench was formed at the head of Forest Canyon (see point 1.0 mile, p. 24).   A similar surface appears on Thatchtop Mountain which is the second peak south of Otis and is nearer this point.   To the right of Thatchtop and farther away is Taylor Peak and between them is the glacial valley of Loch Vale, U-shaped in cross section, containing a series of glacial lakes and Taylor Glacier hidden from view at its head.

   East of Thatchtop Mountain lies Glacier Gorge, and east of that is Half Mountain against which rests the west end of the south lateral moraine of the Bartholf Glacier which rims Glacier Basin on the south.   Beyond the long even crest of the moraine rises in majestic grandeur the flat summit of Longs Peak, 14,255 feet in elevation.   Its perpendicular cliffs are the walls of ancient cirques.

   Returning from Glacier Basin Campground to the main road, reset the speedometer at 3.3 miles.   Turning left (west), continue the log.   On the right rises the long ridge of the north lateral moraine of the Bartholf Glacier.

3. 6   Road cuts across a jutting point of this moraine.

*Miles*

4. 0   Road to Sprague's Lodge.   Keep straight ahead.

5. 1   Trail to Bierstadt Lake which is on top of the great accumulation of moraine lying north of the Bartholf Glacier.

6. 1   Prospect Canyon.   The old tunnel, driven in a futile search for minerals, is at the edge of an intrusive dike, here poorly exposed.   Prospect Canyon is a small but abrupt gorge cut by the stream since the retreat of the glaciers from the valley.

6. 9   Glacier Gorge parking area, from which road climbs moraine.

7. 2   View of head of Glacier Basin Valley, its surface strewn with the deposits of former glaciers.   These deposits have been trenched by recent streams since the retreat of the ice.

7. 7   Parking area at Bear Lake.   This beautiful body of water occupies a depression between the rock cliffs which rise on its west side and the moraines of various ice advances on the north and east and south.   It lies in the line of flow of the former Tyndall Glacier.

This is the end of the road and you must return down the valley by the same road up which you came.

## CONCLUSION

We have come to the end of our study of the geology of Rocky Mountain National Park.   We might continue our investigations indefinitely, always finding some new point of interest to attract our attention and to open up new lines of thought.   Future work will undoubtedly add much to our knowledge and change some of our conclusions.   Let us hope, however, that these changes will not be vital to the main facts of our story and that the reader under the guidance of this booklet, has been led along the right trails in his study of one of the most interesting areas on the American Continent.

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## REFERENCES

BLACKWELDER, ELIOT.   Origin of the Colorado River: Geol. Soc. Am. Bull., Vol. 45, 1934.

BOOS, MARGARET FULLER.   Notes on the Geology of the Rocky Mountain National Park Region.   Unpublished manuscript, 1929.

CHAMBERLIN, R. T.   Building of the Colorado Rockies: Jour. Geol., Vol. 27, 1919.

HEATON, ROSS L.   Ancestral Rockies and Mesozoic and Late Paleozoic Stratigraphy of Rocky Mountain Region: Am. Assoc. Petrol. Geol. Bull., Vol. 17, No. 2, Feb. 1933.

————.   Contribution to Jurassic Stratigraphy of Rocky Mountain Region.   Am. Assoc. of Petroleum Geologists Bull., Vol. 23, No. 8, August 1939.

Lee, W. T.   The Geologic Story of the Rocky Mountain National Park, Colorado. Washington, D. C., Government Printing Office, 1917.

————.   Peneplains of the Front Range and Rocky Mountain National Park, Colorado.   Washington, D. C., Government Printing Office, 1922.   (U. S. Geol. Survey Bull.   730–A).

Quam, Louis.   The Morphology of Landscape of the Estes Park Area, Colorado.   Unpublished thesis submitted to the University of Colorado.

Schuchert, Charles, and Dunbar, Carl O.   Textbook of Historical Geology.   New York, John Wiley & Sons, Inc., 1933.

Van Tuyl, F. M., and Coke, J. M.   The Late Tertiary Physiographic History of the High Plains of Colorado and New Mexico.   Colorado Scientific Society Proceedings, Vol. XIII, No. 1, 1932.

———— and Lovering, T. S.   Physiographic development of the Front Range: Geol. Soc. America Bull., Vol. 46, No. 9, pp. 1291–1350, 1935.

————.   and others.   Guide to the Geology of the Golden Area, Colorado.   Colorado School of Mines Quarterly,   Vol. XXXIII, No. 3, 1938.

Wahlstrom, Ernest E.   Hydrothermal Deposits in the Specimen Mountain Volcanics, Rocky Mountain National Park, Colorado.   Am. Mineralogist, 26: 551–561, 1941.