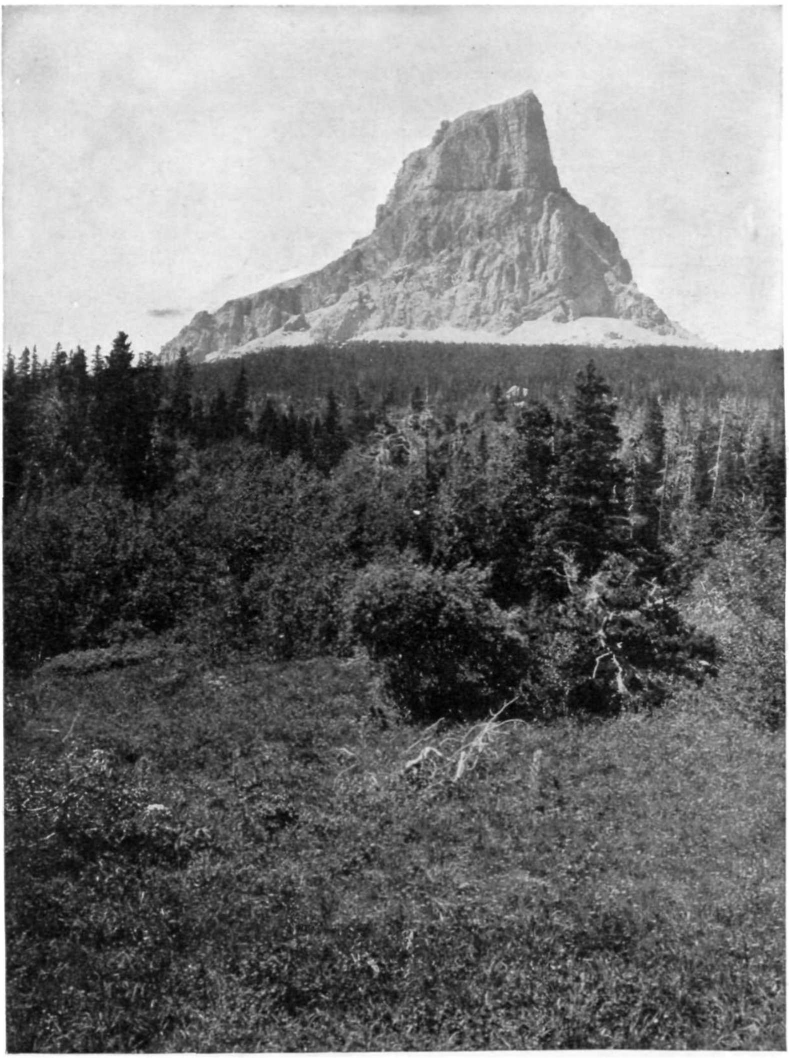
DEPARTMENT OF THE INTERIOR
ALBERT B. FALL, SECRETARY
NATIONAL PARK SERVICE
STEPHEN T. MATHER, DIRECTOR

ORIGIN *of the* SCENIC FEATURES *of the* GLACIER NATIONAL PARK



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THE NATIONAL PARKS AT A GLANCE.

[Number, 19; total area, 10,859 square miles.]

National parks in order of creation.	Location.	Area in square miles.	Distinctive characteristics.
Hot Springs...... 1832	Middle Arkansas......	1½	46 hot springs possessing curative properties—Many hotels and boarding houses—20 bathhouses under public control.
Yellowstone...... 1872	Northwestern Wyoming.	3,348	More geysers than in all rest of world together—Boiling springs—Mud volcanoes—Petrified forests—Grand Canyon of the Yellowstone, remarkable for gorgeous coloring—Large lakes—Many large streams and waterfalls—Vast wilderness, greatest wild bird and animal preserve in world—Exceptional trout fishing.
Sequoia........... 1890	Middle eastern California.	252	The Big Tree National Park—12,000 sequoia trees over 10 feet in diameter, some 25 to 36 feet in diameter—Towering mountain ranges—Startling precipices—Cave of considerable size.
Yosemite......... 1890	Middle eastern California.	1,125	Valley of world-famed beauty—Lofty cliffs—Romantic vistas—Many waterfalls of extraordinary height—3 groves of big trees—High Sierra—Waterwheel falls—Good trout fishing.
General Grant.... 1890	Middle eastern California.	4	Created to preserve the celebrated General Grant Tree, 35 feet in diameter—6 miles from Sequoia National Park.
Mount Rainier... 1899	West central Washington.	324	Largest accessible single peak glacier system—28 glaciers, some of large size—48 square miles of glacier, 50 to 500 feet thick—Wonderful subalpine wild flower fields.
Crater Lake...... 1902	Southwestern Oregon.	249	Lake of extraordinary blue in crater of extinct volcano—Sides 1,000 feet high—Interesting lava formations—Fine fishing.
Wind Cave....... 1903	South Dakota.........	17	Cavern having many miles of galleries and numerous chambers containing peculiar formations.
Platt............. 1904	Southern Oklahoma...	1⅓	Many sulphur and other springs possessing medicinal value.
Sullys Hill........ 1904	North Dakota.........	1⅛	Small park with woods, streams, and a lake—Is an important wild animal preserve.
Mesa Verde....... 1906	Southwestern Colorado.	77	Most notable and best preserved prehistoric cliff dwellings in United States, if not in the world.
Glacier........... 1910	Northwestern Montana.	1,534	Rugged mountain region of unsurpassed Alpine character—250 glacier-fed lakes of romantic beauty—60 small glaciers—Precipices thousands of feet deep—Almost sensational scenery of marked individuality—Fine trout fishing.
Rocky Mountain. 1915	North middle Colorado.	397½	Heart of the Rockies—Snowy range, peaks 11,000 to 14,250 feet altitude—Remarkable records of glacial period.
Hawaii........... 1916	Hawaii...............	118	Three separate areas—Kilauea and Mauna Loa on Hawaii; Haleakala on Maui.
Lassen Volcanic.. 1916	Northern California...	124	Only active volcano in United States proper—Lassen Peak, 10,465 feet—Cinder Cone 6,879 feet—Hot Springs—Mud geysers.
Mount McKinley.. 1917	South central Alaska..	2,200	Highest mountain in North America—Rises higher above surrounding country than any other mountain in the world.
Grand Canyon.... 1919	North central Arizona.	958	The greatest example of erosion and the most sublime spectacle in the world.
Lafayette......... 1919	Maine coast..........	8	The group of granite mountains upon Mount Desert Island.
Zion.............. 1919	Southwestern Utah...	120	Magnificent gorge (Zion Canyon), depth from 800 to 2,000 feet, with precipitous walls—Of great beauty and scenic interest.

ORIGIN OF THE SCENIC FEATURES OF THE GLACIER NATIONAL PARK.

By MARIUS R. CAMPBELL, *Geologist.*
United States Geological Survey.

INTRODUCTION.

The Glacier National Park comprises an area of about 1,400 square miles in the northern Rocky Mountains, extending from the Great Northern Railway on the south to the Canadian line on the north and from the Great Plains on the east to Flathead River [1] on the west.

Formerly this was a region visited by few except hunters in search of big game, and by prospectors eager to secure the stores of copper that were supposed to be contained in its mountain fastnesses. The dreams of mineral wealth, however, proved to be fallacious, and by act of Congress, May 11, 1910, it was created a national park in order to preserve for all time and for all generations its mountain beauties.

In general, the national parks so far created have been set aside and dedicated as playgrounds for the people, because they contain striking examples of nature's handiwork, such as the geysers and hot springs of the Yellowstone, the wonderful valleys, great granite walls, and cascades of the Yosemite, and the results of volcanic activity as exhibited in Crater Lake and the beautiful cone of Mount Rainier.

The Glacier National Park is no exception to this rule, for it contains some of the most rugged Alpine scenery to be found on the continent. Although the park was given its name on account of the many glaciers within its borders, these can hardly be considered its most striking feature. The traveler passing through it for the first time is generally impressed more by the ruggedness of the mountain tops, the great vertical walls which bound them, and the beauty of the forests, lakes, and streams, than by the glaciers, although the latter are numerous and probably the most easily accessible of any in the United States. To the scientist the glaciers are of the greatest interest, for they are the remaining diminutive representatives of the great rivers of ice that formerly flowed out from these mountains, scouring and scoring the valleys and giving to the mountains their rugged and beautiful characters.

As the average traveler is always curious and interested in knowing how the features of the landscape have been produced, especially

[1] This stream is sometimes locally called North Fork of Flathead River or the "North Fork."

FIG. 1.—UPPER TWO MEDICINE LAKE FROM SCENIC POINT, 2,000 FEET ABOVE THE LAKE.

Rising Wolf Mountain on the right. Trail to Dawson Pass crosses at the outlet and follows the opposite side of lake to its head, then climbs up ravine to right, crossing the summit just to left of Rising Wolf. Note U-shaped valley and Upper Two Medicine Lake in cirque in left center.

Photograph by M. R. Campbell.

where there is such striking scenery as in the Glacier Park, it has seemed desirable to present a general sketch of the region, together with a description of some of the most important events in its history, so far as they have been determined, and of the processes by which the scenic features have been formed. By this is meant not the recent history, since man became a factor in shaping and modifying the country, but the great history of this part of the globe reaching back into the dim and misty past that only the geologist is able to interpret. Consequently, the present paper will deal almost wholly with the causes that have been active in producing the surface forms and the various conditions which have modified and controlled the results.

MOUNTAIN BUILDING AND SCULPTURE.

There is a common misapprehension in the mind of the public regarding the mode of origin of mountains. Many people think of mountains as the results of great upheavals of nature by which the jagged peaks were forced up from the depths into their present positions, like the "spine" of Mount Pelee, or were formed by volcanic outbursts in which lava and ashes were poured out upon the surface, building up great chains and rugged peaks. Indeed, so common is this idea that almost every mountain of unusual form or composed of exceptionally red or black rocks is regarded as of volcanic origin.

It is true that many mountains in the United States show evidence of having been produced in this way, but when compared with the whole number of ranges or peaks, those of volcanic origin are few indeed. Among the most prominent may be mentioned the great landmarks of the Cascade Range—Mounts Baker, Rainier, St. Helens, Hood, Jefferson, and Shasta. Most of the other great mountain masses, such as the Rocky Mountains from the Canadian line to northern New Mexico, the Sierra Nevada, and the ranges in the Great Basin have been subjected to little or no volcanic activity, and their present forms are due entirely to other causes and conditions.

Although mountains are not generally the direct result of upheaval, they owe their form and height indirectly to movements in the earth's crust. In other words, there could have been no mountains if a portion of land had not been lifted above the surrounding region. Such uplifts may have taken place in one of three ways: (1) By the uplifting of a large region, like the entire Rocky Mountain province; (2) by a great arching of the rocky strata comprising the earth's crust; or (3) by the uplifting and tilting of a huge block of strata that previously had been broken and separated from the adjacent areas, much as a block of rock is broken from a cliff and tilted out of its original position. Each of these uplifts except the first seems to imply great disruption at the surface, but it is generally believed that the movement took place so slowly that erosion nearly or quite kept pace with it, resulting in little apparent local surface displacement or disturbance, but a general elevation of the region. It is probable, however, no matter how slowly the readjustment took place, that the crust of the earth was affected by earthquakes, which are the outward expression of slight movements of the rocks below. As soon as the mountain mass was lifted above the surrounding region streams began to cut channels in its upland surface. At first these were small and extended backward only a short distance into the range, but as time went on the streams became more active, cutting great gashes or V-shaped canyons and extending their activities almost to its center. A picture of the range in that stage of its dissection would show a net-work of deep branching canyons

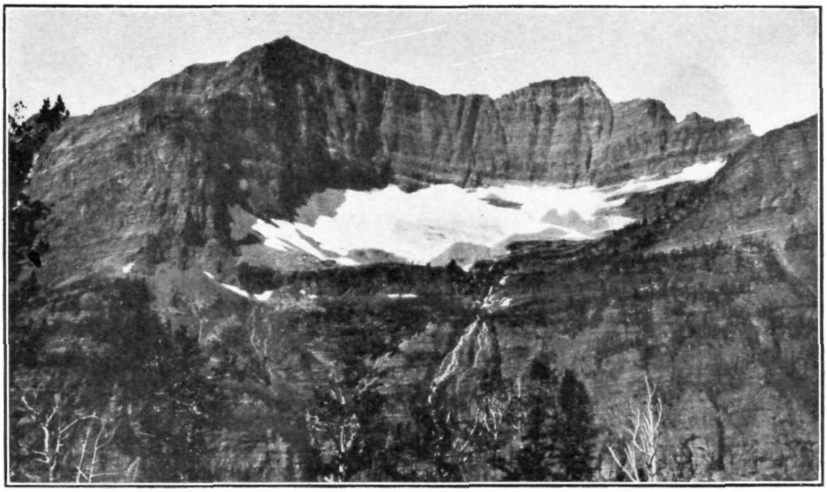


FIG. 2.—GLACIER AND CIRQUE NEAR HEAD OF CUT BANK CREEK.
This cirque is about 500 feet deep and is cut in the side wall of the valley.
Photograph by T. W. Stanton.

whose slopes were made up of straight lines from the tops of the spurs to the bottoms of the canyons with no trace of curves to relieve the angularity of their profiles. Between the canyons there would be left great residual masses of the mountain projecting as huge peaks with rugged barren slopes. From the outline given above it will be seen that mountains as such are not the direct result of uplift, but are brought out by the cutting around them of deep canyons or valleys in the uplifted mass.

As the elevation of the mass increased, the moisture-laden winds striking the slopes were forced up into the higher and cooler atmosphere and much of the moisture was precipitated in the form of snow. Where the conditions were such that the amount falling each winter was in excess of that which melted during the succeeding summer the snow accumulated and changed to granular ice, forming glaciers, which, by their erosive action, materially changed the form and contour of the mountains. At the head of nearly every tributary of these glaciers an amphitheater or cirque was cut out of the solid rock by the ice. These, as their name implies, are generally semicircular, have flat bottoms, and are bounded on the back by nearly vertical walls. Their form and position on the side of mountain ridges are well illustrated by figure 2, which represents a small cirque containing a glacier near the head of Cut Bank Creek.

Space does not permit of a detailed description of the manner in which such cirques are excavated by glaciers, but a description of the glaciers and glacial phenomena of the park will be found in a corresponding paper by Mr. W. C. Alden, entitled "Glaciers of Glacier National Park."[1] The long-continued action of a glacier resulted in its cirque being greatly enlarged and cut back far into the mountain mass. Where two glaciers were located on opposite sides of a dividing ridge the mountain crest between them was reduced in places to a thickness of a few feet, forming an exceedingly rugged saw-tooth ridge, or was cut through, forming a comparatively low pass.

The great rivers of ice flowing down the mountain valleys scoured them out, changing them from the sharp V-shaped canyons that result from stream erosion to rounded U-shaped valleys, as shown in figure 3.

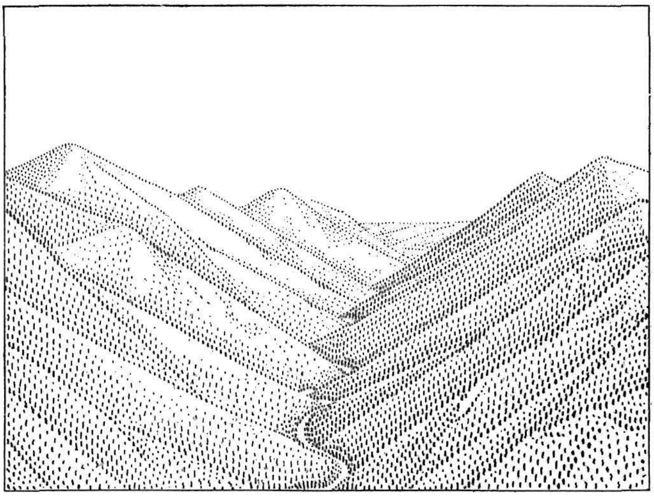
The glaciers also caused the formation of many lakes and ponds, either by the gouging out of rock basins or by the damming of valleys or other depressions in the surface. Of the rock basins the greater number lie in the cirques and are due to the wonderful power that a glacier has to dig out the floor of the cirque below the level of its "lip" or outlet. Other lakes in rock basins occur farther down the mountain slopes, where, owing to the less resistant character of the rock, or to the peculiar configuration of the valleys, the erosive action of the ice streams was more intense than in adjacent parts of the valley, and rock basins were formed. In all cases as soon as the ice melted away the basins were filled with water-forming ponds or lakes.

As a rule the large lakes in a mountain country are the result of damming of valleys by outwash of sand or gravel from the ice or by the terminal moraine or ridge of coarse material which a glacier almost invariably builds around its outer extremity. Such dams are in many places of great height and extent, and large deep lakes are formed behind them as soon as the ice disappears.

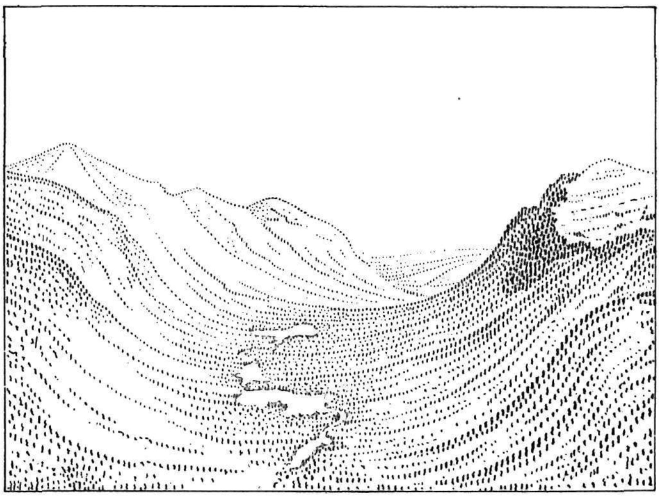
All lakes, however, are transient features, as geologists measure time, and sooner or later their basins are drained and the lakes dis-

[1] For sale by the Superintendent of Documents, Government Printing Office, Washington, D. C., for 15 cents.

appear by the cutting of stream channels through the obstructions that hold the water in place. Although this process may be a slow one when measured in years, it must be remembered that the streams



A.



B.

FIG. 3.—DIAGRAMS SHOWING EFFECT OF STREAM AND GLACIAL EROSION.

A. V-shaped valley cut by running water. *B.* Same valley after it has been occupied by a glacier and reduced to a broad, flat U in cross section.

are always active; they are at work day and night cutting the rocks over which they flow. At times of low water the streams carry only a small amount of sediment and they have little cutting power, but in times of flood they are extremely active. As the volume of water and velocity increase the carrying power of the streams is greatly

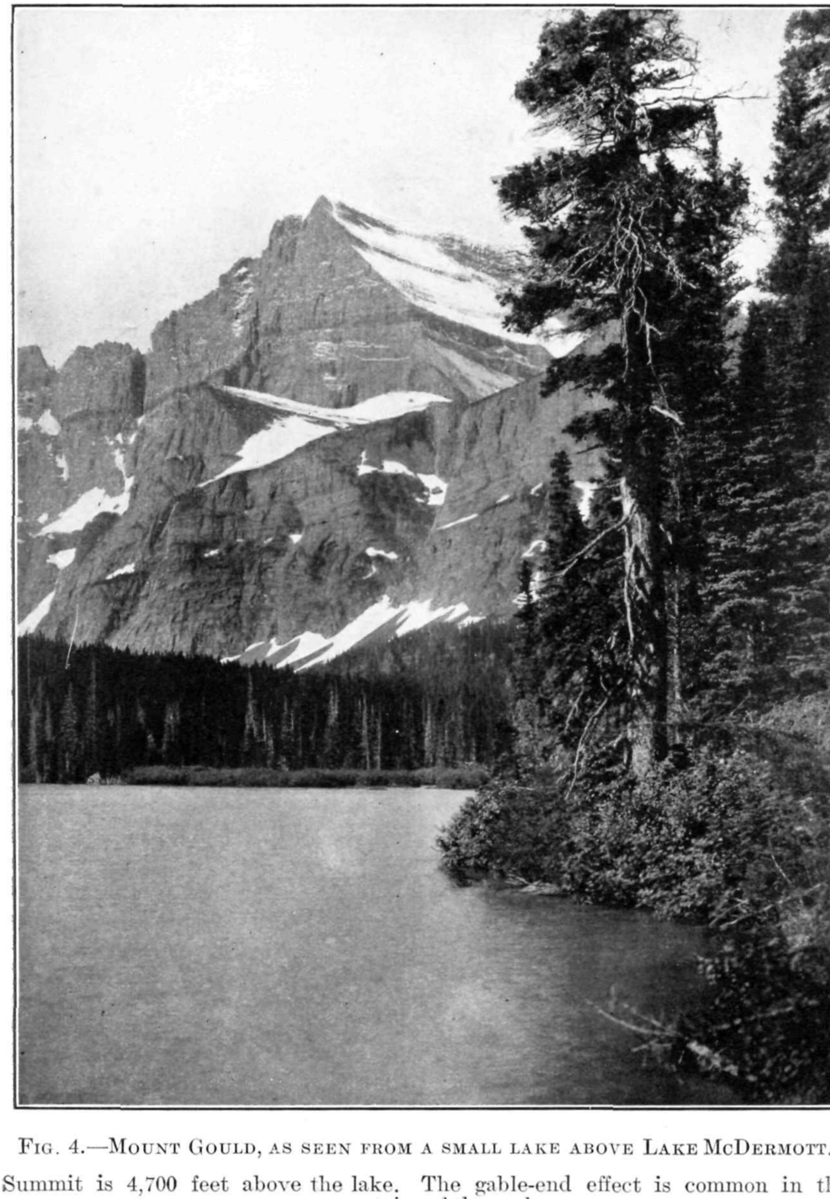


FIG. 4.—MOUNT GOULD, AS SEEN FROM A SMALL LAKE ABOVE LAKE McDERMOTT.

Summit is 4,700 feet above the lake. The gable-end effect is common in the mountains of the park.

Photograph by Bailey Willis.

augmented, and they pick up immense quantities of mud, sand, and gravel and even roll along by the force of the current large blocks of rock that the water can not lift. All this rock material acts like a huge rasp cutting the rocky ledges over which the streams flow, no matter how hard or massive they may be.

The constant tendency of streams and glaciers in a mountainous region is to deepen the valleys, and thus to make the region more rugged and picturesque and to increase the apparent heights of the mountains. Many persons think that it is the real height of mountains above sea level that makes them impressive, but such is not generally the case, unless the observer can view them from the ocean shore. The magnitude and grandeur of a mountain are determined almost entirely by the height of its summit above the adjacent lowland, for this is the height that is apparent to the eye and by which the amount of relief of the mountain is measured. Nothing can be more impressive than the view of the east end of Mount Gould from one of the lakes farther down the valley, as shown in figure 4. Although this mountain is not classed among the high ones of the park, it is more imposing in this view than many of the highest summits, for the reason that it stands 4,700 feet above water level, and the distance between it and the lake is so small that it seems to rise directly out of the water.

In viewing mountain scenery, except in volcanic regions, the traveler should remember that many, if not all, of the causes that have produced it are active to-day and are going on before his eyes. All that is required to produce the stupendous results is time, and nature has been in no hurry.

During the early stages of mountain sculpture the effect of erosion is to increase the relief, but although at first the process is comparatively rapid it is gradually retarded, and, finally, if no change occurs in the crust of the earth, the process becomes inactive, and then the tendency is to reduce the relief and to obliterate the results previously attained. Hence the stage of reduction that is marked by the most beautiful results is an intermediate one, in which the mountain forms are still in their youthful ruggedness without any trace of the softening influence of old age that marks the later stage of their existence.

BRIEF DESCRIPTION OF THE SURFACE FEATURES OF THE PARK.

Glacier Park includes the portion of the great Front Range of the Rocky Mountains lying between the Great Northern Railway and the Canadian line. Curiously enough, few if any, of its striking features can be seen from the railroad, and probably thousands of persons have passed along this line without seeing any more of its beauties than here and there in the distance a snow-capped peak and without realizing that just over the ridge is a mountain region full of big game and abounding in all the beauties of the Swiss Alps.

At the other extremity of the park the international boundary line cuts Waterton Lake and crosses the main summit in some of the most rugged and beautiful scenery to be found in the region. This is well illustrated by figure 5, which shows the rugged character of the high mountains in the vicinity of Brown Pass, a few miles south of the line. Although this part of the park is still remote from lines of transportation and, on account of its broken character, difficult of access, it was the part first to be explored. The earliest pioneers were the surveyors of the international boundary line, who began work on the Pacific coast and in 1861 set the stone monument shown in figure 6 on the summit west of Waterton Lake.

Between the two borders of the park mentioned above there is a bewildering maze of rugged peaks, glaciers, and beautiful valleys

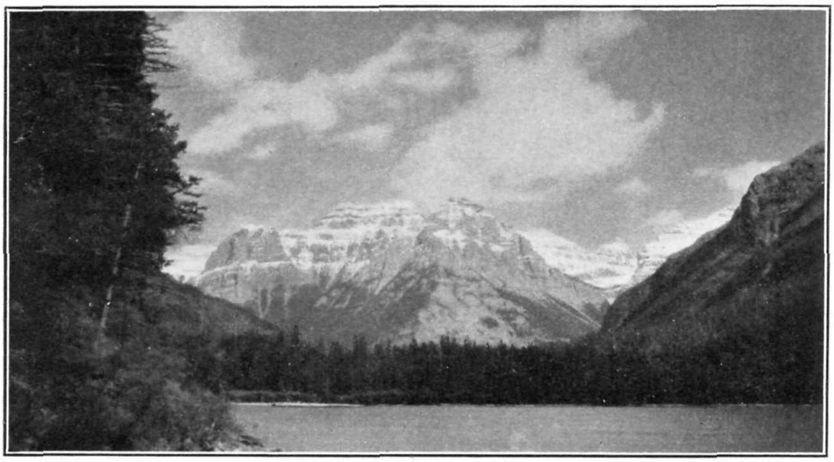


FIG. 5.—VIEW FROM HEAD OF BOWMAN LAKE, SHOWING RUGGED COUNTRY IN VICINITY OF BROWN PASS.

Photograph by W. C. Alden.

studded with innumerable lakes. The traveler may well imagine that the particular valley he has seen is the most beautiful spot in the park, but upon visiting others he will learn that each one has its own peculiar charm, and when he becomes familiar with them all he will be loath to say that one is more beautiful than another, but he will learn that all are wonderful and that they combine to form an incomparable setting for the high peaks that tower in rugged grandeur far above them.

The dominant feature of the park is a broad mountain range trending in a northwest-southeast direction. On both sides of this range are areas of low relief, the Great Plains on the east and the broad valley of Flathead River on the west. On the west the ascent to the top of the mountain is gradual, passing through a series of ridges and spurs of greater and greater altitudes until finally the crest of the range is attained, but on the east the change is abrupt from the even surface of the gently sloping plains to the rugged heights of the mountains. In most other regions there is a wide belt of foothills through which the traveler has to pass before he reaches the moun-

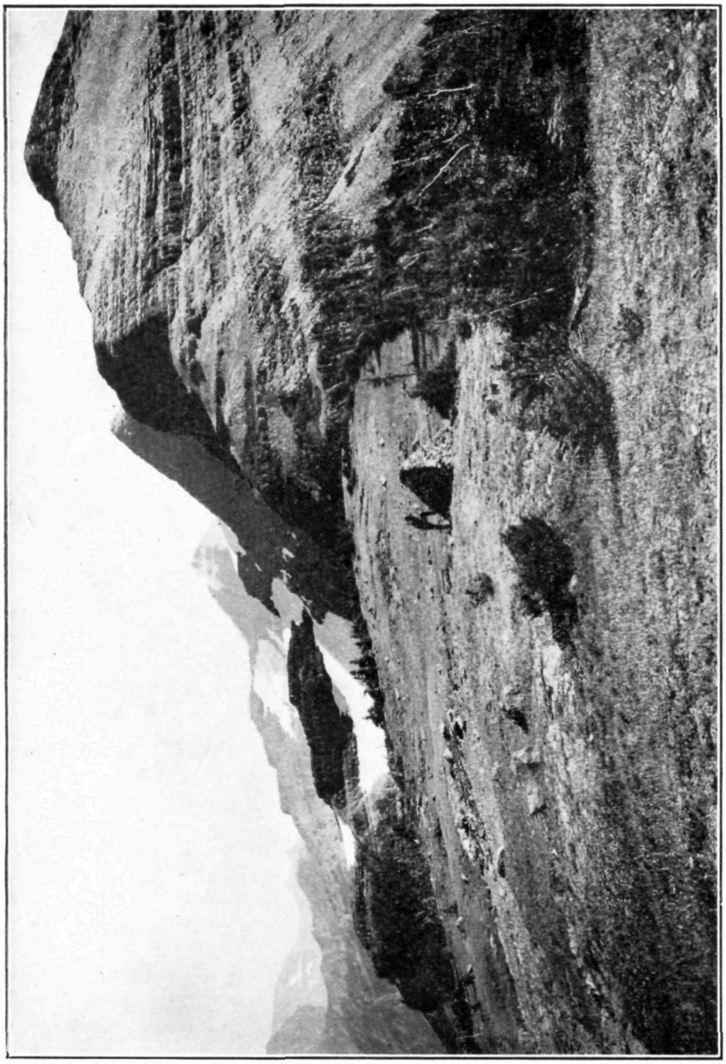


FIG. 6.—MONUMENT WHERE INTERNATIONAL BOUNDARY LINE CROSSES THE CONTINENTAL DIVIDE NORTH OF BROWN PASS.

View from the Canadian side looking southeast into the United States.

Photograph by Bailey Willis.

tains proper, but on the east side of the Front Range in the Glacier Park there are no such features to consume the traveler's energy, and he passes at once from the smooth, treeless plains to alpine scenery, embracing rugged peaks, glaciers, waterfalls, and beautiful lakes nestling in every valley heading into the range.

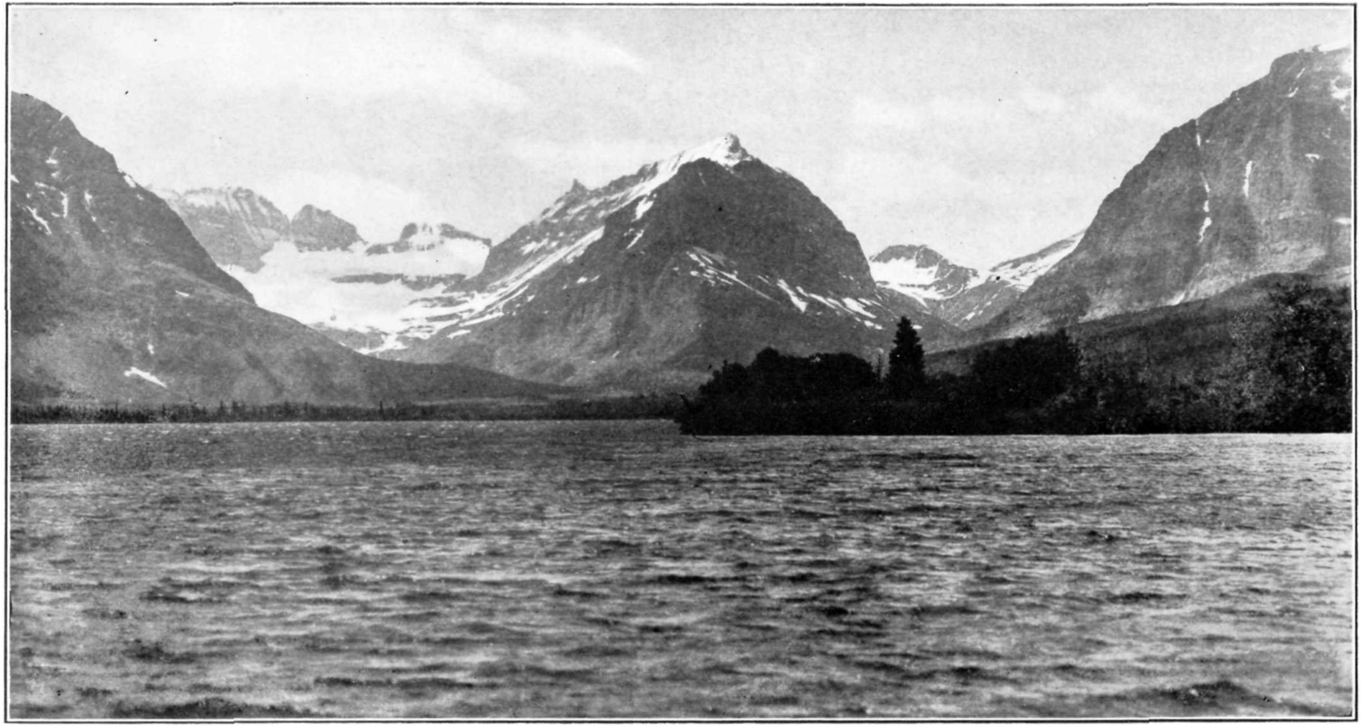


FIG. 7.—EASTERN FRONT OF THE MOUNTAINS, AS SEEN FROM SHERBURNE LAKE.
Grinnell Mountain and Grinnell Glacier with the Garden Wall at its back shown in left center; Swiftcurrent Pass on right. Overthrust fault at foot of cliffs on both right and left; crosses valley in the distance.
Photograph by Bailey Willis.

The abruptness of the mountains is well shown in figure 7, which is a view from Sherburne Lake, in Swiftcurrent Valley. The bold front, although somewhat sinuous in outline, is well shown in the photograph as it towers several thousand feet above the valley floor. Grinnell Mountain occupies the center of the picture, Grinnell Glacier with the Garden Wall at its back shows on the left, and Swiftcurrent Pass can almost be seen at the head of the valley on the right.

Many people conceive of a mountain chain as consisting of a single narrow ridge with steep slopes on both sides and a narrow, more or less regular saw-tooth crest. Such a conception may be true in a few cases, but generally a range is many miles in width and consists of a maze of ridges and high spurs, in some cases as prominent as the main dividing watershed. The mountain range which crosses the park is of this character, and it varies in width from about 18 miles in the southern part to 25 miles in the northern part. Into this broad mountain mass the streams from both sides have cut deeply, crowding the water parting or Continental Divide from one side to the other and forming a very irregular crest line. In fact, the mountains have been regarded by some writers as composed of two distinct ranges, the Lewis on the east and the Livingston on the west. The Continental Divide follows the crest of the Lewis Range from the Great Northern Railway to a short distance beyond Ahern Pass, and there it crosses Flattop Mountain to the summit of the Livingston Range on the west.

The two mountain crests just described form a sort of rim around an inclosed basin of comparatively level land known as Flattop Mountain, which stands at an altitude of about 6,500 feet. Although this constitutes the top of the mountain and forms the Continental Divide for a distance of about 20 miles, it is in effect a great topographic basin, as it is rimmed round by a wall of mountain peaks (figures 8 and 19) which rise to heights of from 1,000 to 4,000 feet above the general level. If the observer on one of the adjacent peaks could see in imagination the present valleys filled to a depth of 1,000 to 2,000 feet, he would then obtain a realistic picture of this basin as it must have been when it was formed long ago, before the present valleys were excavated. It was then as now a beautiful park with a rolling or undulating surface that stretched up to and blended with the slopes of the surrounding rocky rim, as shown in figure 19. Some of the old gently rolling surface is still preserved on Flattop Mountain, which with its cover of open forest forms a beautiful natural park, as shown in figure 8. Through this park the traveler can ride at will, and he can find many beautiful camping sites, especially early in the season, when water is plentiful.

Flattop Mountain is a striking topographic feature, but as its origin is to be sought in the erosive processes that have gone on in the past a discussion of its mode of formation must be deferred to that part of the paper dealing with the geologic and physiographic history of the park.

The high peaks grouped around the basin of Flattop Mountain constitute the rim previously mentioned. In other parts of the park

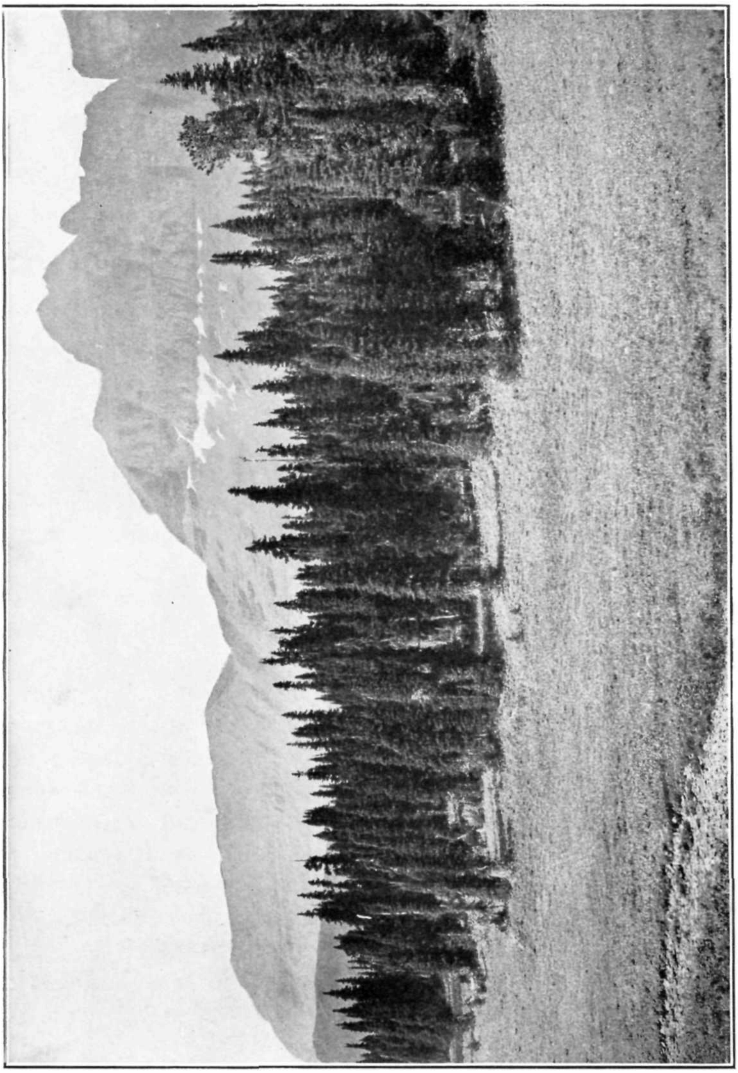


Fig. 8.—Beautiful park-like country on Flattop Mountain near the site of Kipp's cabin.
The background shows part of the mountain rim that surrounds the basin.
Photograph by Bailey Willis.

they have no particular arrangement, except that they occur along the Continental Divide and on the high spurs that project on both sides from this irregular watershed. The map shows the high barren parts of the mountains; it also shows the locations of the highest peaks, those rising above 10,000 feet being as follows: Cleveland Mountain, 10,438 feet above tide level; Stimson Mountain, 10,155 feet; Kintla Peak, 10,100 feet; Jackson Mountain, 10,023 feet; Siyeh Mountain, 10,004 feet.

The most rugged topography is on the north and east sides of the high ridges and peaks, for the present glaciers are generally located on these sides and the ancient glaciers, although present on all sides, were most active in their work of excavation on the north and east slopes. The difference in the appearance of the two sides of the mountains is striking and the traveler can readily determine in which direction he is looking by the ruggedness or smoothness of the slopes and crests. If he looks north or east he sees generally rounded slopes and dome-like crests, which seem to present little or no difficulty to the climber and he might readily imagine that reports of the ruggedness of the mountains had been exaggerated, but if he turns about he will see that these gently rounded crests are cut by nearly vertical walls which no mountain climber, no matter how hardy he may be, can scale, and that the slopes are rugged in the extreme.

The ruggedness of the north side of the main dividing ridge is well shown in figure 16, which is a view of the upper end of the valley of Middle Fork of Belly River. Enormous cirques were cut by the ancient glaciers in every ravine opening into the main valley, leaving the sharp pyramid seen in the center of the picture towering up to a height of over 3,000 feet. It also shows the smaller cirque cut by the present (Shepard) glacier.

As explained more fully in Mr. Alden's paper describing the glaciers of the park, the glaciers have eroded, in the peaks and ridges, great cirques with nearly vertical walls ranging in height from a few hundred to three or four thousand feet. Such amphitheaters are extremely abundant, nearly every valley terminating at its upper end in such a feature, with countless smaller cirques high up on the mountain slopes. In many places the existing glaciers have cut so deeply into the range that the ridge behind the cirque is reduced to a "knife-edge," and the presence of such features at other points along the main crest and on the high spurs shows clearly that the old glaciers which long ago occupied these summits were even more active than their modern representatives. Probably the best example of a "knife-edge" crest is the Garden Wall back of Grinnell Glacier, which is shown in figure 9. This is a conspicuous feature when viewed from Swiftcurrent Valley on the east or from Granite Park on the west, and can readily be seen on a clear day from any part of McDonald Lake.

No matter which route the traveler selects he will see these great cirque basins quarried out of the mountain side. If he crosses the range from Two Medicine Lake he will see no existing glacier, but he will find cirques cut by the ancient glaciers that swept down this and neighboring valleys. If he climbs the trail to Dawson Pass he can not fail to see the beautiful cirque in which lies the upper lake and also the shallow basin up which the trail ascends to the crest.

At the head of Cut Bank Creek he will see many little lakes or ponds, each of which lies in a little cirque of its own, while they all form a group in a broad cirque platform at the extreme head of the valley. When he reaches the summit he can look into a small cirque on the northeast side of Stimson Mountain, and if he descends the trail beyond the narrow spur projecting into the valley of Nyack Creek he will see an immense cirque or shelf on which once lay a large glacier that found an outlet to the west down Nyack Creek.

FIG. 9.—PART OF THE GARDEN WALL BACK OF GRINNELL GLACIER.

Only the upper end of Grinnell Glacier shown in the picture, with a miniature glacier hanging on a shelf on the left. Wall fully 1,000 feet high at the right of the small glacier.

Photograph by T. W. Stanton.

On the summit crossed by the trail from Red Eagle Lake to Nyack Creek the traveler will find himself surrounded by evidences of the former existence of great glaciers which have cut deeply into the upper slopes and have formed a broad platform in a corner of which the Red Eagle Glacier now finds a resting place. He can also see the shelf which Pumpelly Glacier has cut on the southeast side of the crest, besides many smaller cirques on the slopes around him.

In the trip up the valley of St. Mary River, which most travelers take, many cirques can be seen on the south side, but few if any on the north side. In the distance the traveler catches beautiful glimpses of Fusilade Mountain, which seems to be a sentinel watching his approach. This mountain has a smooth regular slope on the south, but a nearly vertical wall on the north. The traveler will soon learn that such a wall means that a glacier is lying at its foot, or if not present now that one formerly occupied this position, and the steep wall is a part of the cirque it has formed. On traversing the trail leading to Sperry Camp he will find that Gunsight Lake and Lake Ellen Wilson [1] on the opposite sides of the summit both occupy cirques, and that below the lake on the west there is still another lake occupying a cirque whose walls are almost 1,000 feet high.

On Piegan Pass the traveler will find many similar features showing that long ago the glaciers were very active in this region and that many cirques were formed as a result of their activities.

A lake at the head of Canyon Creek occupies an enormous cirque which has been largely excavated in the north flank of Siyeh Mountain. The peak is cut almost in half, and the depth of the cirque below its crest is fully 4,100 feet.

In Swiftcurrent Valley large cirques abound. One of the most noted is that which holds Iceberg Lake. This ideal cirque is described on page 38. Well up on the main trail to Granite Park the traveler can not fail to note the great cirques both to the north and the south of the trail. He is conscious of the steepness of the bounding wall of the cirque on the south as he painfully labors up the trail in its steepest place, but this is easy compared with the nearly sheer ascent of the back wall where the present little glacier almost overhangs the lip of its own small cirque 1,500 feet above the floor of the larger one. West of the crest he sees only smooth regular slopes which by contrast seem almost flat.

On the main trail across Flattop to Waterton Lake the traveler sees cirques only at a distance, and he may imagine that he is beyond the limit of their development. If, however, he wishes to learn the truth he has only to climb the ridge on his right and he will find himself standing on a crest cut, on the opposite or northeastern side, by a number of glaciers to such an extent that he may wonder whether the thin crest will bear his weight or whether it will crumble, precipitating him down hundreds of feet onto the blue ice of the glacier or into the still deeper blue of the glacial lake. As he looks around he will see immense cirques now abandoned by the glaciers that carved them, but giving rise to some of the most rugged scenery in the park.

On the trail from Waterton Lake across Brown Pass to Bowman Lake the traveler can see many well-developed cirques, especially on the south side of the trail. Here again there is a striking difference in the scenery on the two sides of the valley. On the south there is a succession of deep cirques, several of which are now occupied by glaciers, and between the cirques there stand out prominent

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[1] This lake is sometimes locally called Lake Louise.

projecting spurs that are rugged in the extreme. On the north side of the valley there is only one insignificant cirque, and the valley wall is smooth and regular, but should the traveler be curious and climb this regular wall he will find that it also is deeply notched on the farther side by cirques opening into Boundary Creek and that

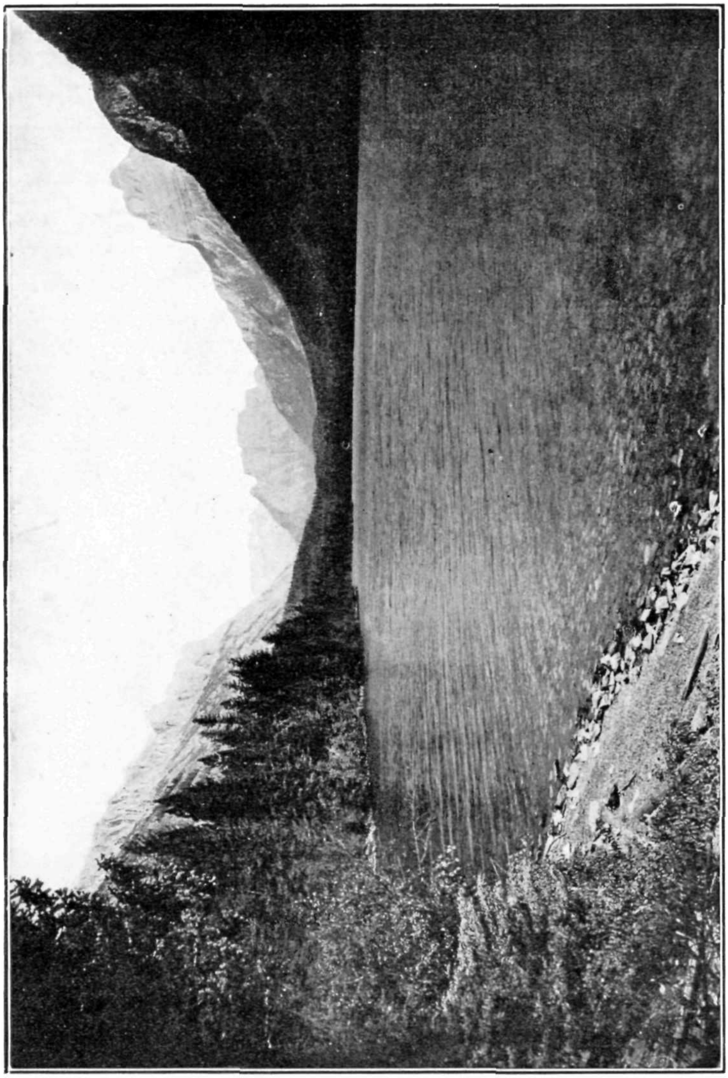


FIG. 10.—KINTLA VALLEY, LOOKING UP FROM LOWER KINTLA LAKE.
The curve in the outline of the valley has been produced by the glacier that formerly flowed out by this route from the mountain center.
Photograph by Bailey Willis.

the crest which looks so smooth and regular from the trail is a mere "knife-edge" bounded on the farther side by nearly vertical walls.

The foregoing paragraph describes a few of the cirques to be seen by the traveler on the summit trails that are now open. As new trails are built other parts of this wonderful region will become accessible and the traveler will find on each new trail features very similar to those along the old and well-known routes, but having individual characteristics and beauties all their own.

In places the backward cutting of the glaciers has extended so far, especially where cirques were developed on opposite sides of a ridge, that the wall between them has been removed so that the basins coalesce and form a low pass. It seems probable that all of the better known passes in the park, such as Gunsight, Swiftcurrent, Ahern, Brown, and Jefferson, were formed in this manner by glaciers that formerly occupied them, but have long since disappeared.

Forests add greatly to the beauty of the park, for the trees grow only on the lower more gentle slopes, forming as it were a foreground or setting for the higher peaks, which, by contrast, look much more rugged than they would were the surface entirely barren of vegetation. The mountain ranges of the Great Basin of Nevada, Utah, Arizona, and southern California are almost devoid of vegetation, but they are forbidding and have no more picturesqueness than an artificial pile of barren rock. In Glacier Park the vegetable cover sweeps down with long gentle curves to the bottoms of the valleys in which there nestle scores of lakes varying from mere ponds to sheets of water 9 or 10 miles in length and a mile or more in width. Where these lakes receive the wash from the glaciers they are milky white in color, but in other locations the water is clear and pure and reflects all the varying phases of the sky and clouds above. On a clear day they are beautifully blue, but when storm clouds gather the color of the water changes to darker and darker shades which make it look dangerous and forbidding.

The larger and more prominent lakes are McDonald, Logging, Upper Quartz, Bowman, and the Kintla on the west side of the range, and Waterton, Upper St. Mary, and Two Medicine on the east side. Views of Bowman and Lower Kintla Lakes are shown in figures 17 and 10, and of Two Medicine and Waterton Lakes in figures 1 and 22. Many of the lakes have been sounded, and the deepest water recorded is as follows: McDonald Lake, 440 feet; Upper Quartz Lake, 254 feet; Bowman Lake, 256 feet; Waterton Lake, 317 feet;[1] and Upper St. Mary Lake, 292 feet.[1]

Of all the factors that add attractiveness and beauty to the park, the streams are by no means the least. The clear cold water glistens in the sunshine as it ripples over the variously colored pebbles in the bottom of the stream bed or breaks in feathery torrents from the summits of precipitous cliffs that abound on every hand. In this connection it is interesting to note that the mountains of the

[1] Sounded by Prof. Morton J. Elrod. Only a few soundings were made by Prof. Elrod in Waterton and Upper St. Mary Lakes, and it is not at all certain that the point of greatest depth was ascertained. See "Some lakes of Glacier National Park," Washington, 1912, sold by the Superintendent of Documents, Government Printing Office, Washington, D. C., for 10 cents.

park constitute not only the Continental Divide between the Atlantic and the Pacific, but also between these systems and Hudson Bay. A small peak lying between Cut Bank Creek on the east, Nyack Creek on the west, and Red Eagle Creek on the north is the exact point on which the waters divide, and for this reason it is called Triple Divide Peak. (Fig. 11.) Of the streams mentioned above as draining this culminating point of the continent Cut Bank flows eastward into Missouri River and thence into the Gulf of Mexico, Nyack flows west into the drainage basin of Columbia River and the Pacific Ocean, and Red Eagle Creek flows north into Saskatchewan River and Hudson Bay.

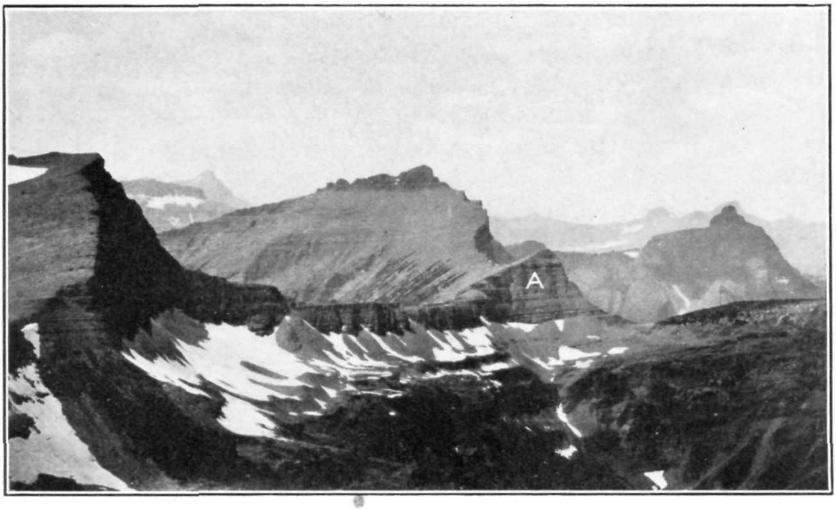


FIG. 11.—TRIPLE DIVIDE PEAK.

A marks the small peak on which the waters divide. Great vertical cirque walls abound on north side of every peak and ridge.

Photograph by T. W. Stanton.

ORIGIN OF THE TOPOGRAPHIC FORMS.

EFFECT OF GEOLOGIC STRUCTURE AND HARDNESS OF THE ROCKS.

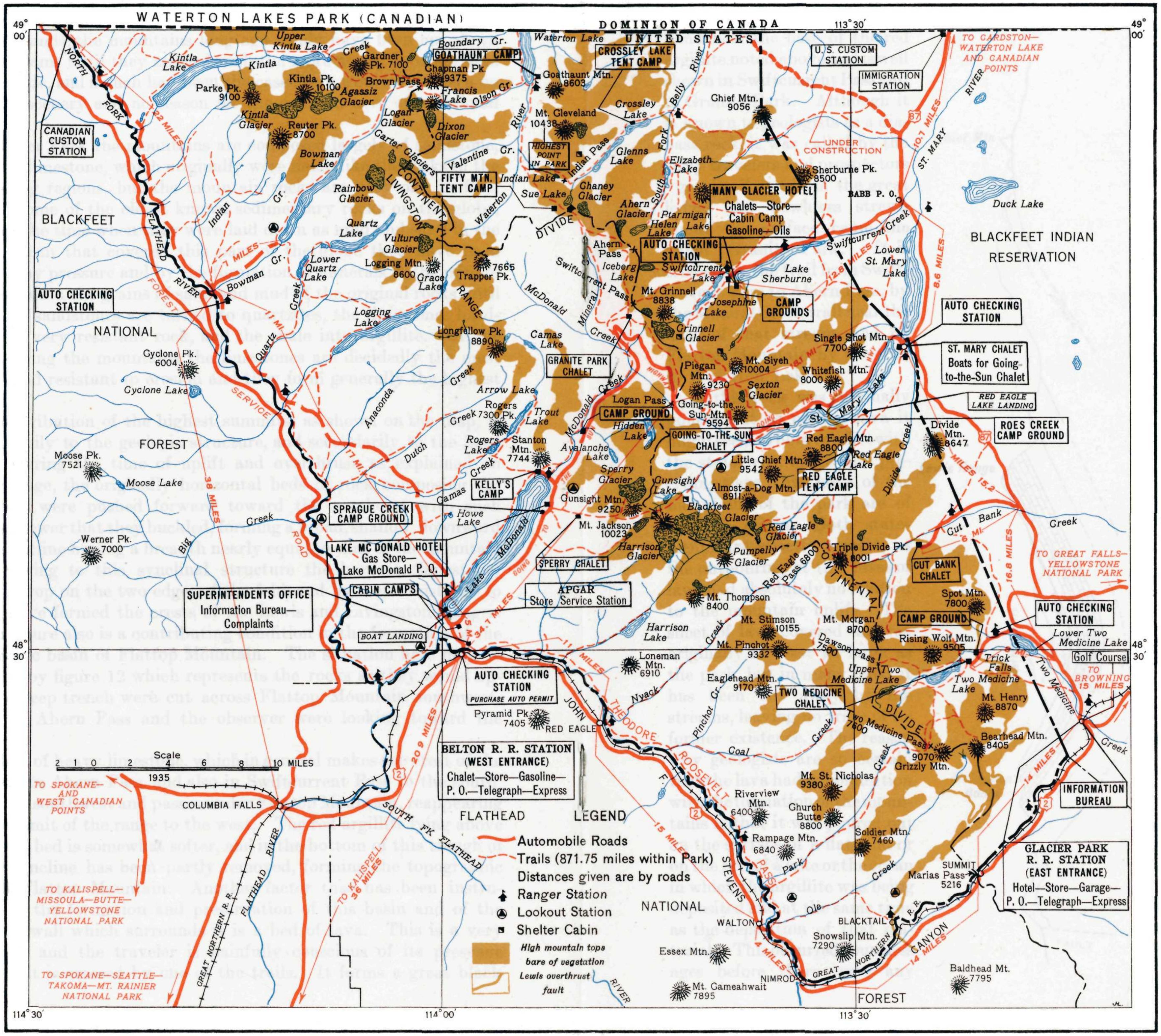
As the mountains in the Glacier National Park have been carved by streams and glaciers from an uplifted land mass, it follows that the forms which they have assumed as well as their height above drainage level depend largely on the kind of rock and its ability to withstand the action of the elements.

In a general way the mountain range is composed of harder, more resistant rocks than either the plains on the east or the valley of Flathead River on the west. In fact, the very existence of a range of mountains here is due to that difference in hardness, for if the rocks of the mountains had been as soft and as easily eroded as the rocks of the lowlands, the mountains long ago would have been cut down by the streams until they merged with the more nearly level surfaces on either side, and if such had been the case there would have been no mountain scenery and no reason for the creation here of a national park.

In Glacier Park the mountains are composed largely of sandstone, shale, and limestone, which originally were much like the rocks in the surrounding regions, but the mountain rocks are very old; in fact, they are some of the oldest known sedimentary rocks on the globe, and since the time when they were laid down as mud and sand in the ancient ocean that covered this part of the globe they have been hardened by pressure and by the formation of minerals in the minute spaces between the grains of sand and mud of the original rocks until to-day the sandstones are turned to quartzites, the limestones hardened to a very resistant rock, and the shale into argillite. Of the rocks forming the mountains the limestones are decidedly the most massive and resistant to erosion and they form generally the highest peaks.

The distribution of the highest summits, as shown on the map, is due primarily to the geologic structure, and secondarily to the hard rocks. During the time of uplift and overthrust, as explained on another page, the originally horizontal beds of rock composing the mountains were pushed forward toward the northeast with such resistless power that they buckled, forming a broad, shallow, downward fold or syncline having a breadth nearly equal to that of the mountain mass. Owing to this synclinal structure the hardest (limestone) rocks outcrop on the two edges of the fold, and by their resistance to erosion have formed the crests of the Lewis and Livingston Ranges. This structure also is a contributing condition in the formation of the topographic basin of Flattop Mountain. The situation here may be explained by figure 12 which represents the rocks as they would appear if a deep trench were cut across Flattop Mountain southwestward from Ahern Pass and the observer were looking toward the northwest.

The bed of heavy limestone, which in general makes the crest of the mountain in Ahern Pass, and also in Swiftcurrent Pass to the south, dips to the southwest and passes under Flattop Mountain, reappearing in the summit of the range to the west. The red argillite lying above this heavy bed is somewhat softer, and in the bottom of this trough of rock or syncline has been partly removed, forming the topographic basin of Flattop Mountain. Another factor that has been instrumental in the formation and preservation of this basin and of the mountain wall which surrounds it is a bed of lava. This is a very hard rock and the traveler is painfully conscious of its presence wherever it is crossed by one of the trails. It forms a great black



MAP OF GLACIER NATIONAL PARK

band near the base of the red argillite noted above and is well shown in Swiftcurrent Pass and in Granite Park. Although it is known to geologists as a diabase rock, it was called by the early travelers and prospectors "granite," and from the great ledges and bowlders strewn about the surface came the name "Granite Park." It is crossed by the trail from Swiftcurrent Pass to Ahern Pass, by the Mineral Creek trail near the head of that stream, and on Flattop Mountain by the trail to Waterton Lake.

As this rock was originally poured out as molten lava it might seem to be in conflict with the statement, made on a preceding page, that none of the mountains of the park are of volcanic origin. Both statements are strictly correct, as the outpouring of this mass of lava had absolutely no relation to the mountain uplift. The sheet of lava covered an area originally at least as large as the park, but in many parts it has been cut away by the streams, leaving no trace of its former existence. The reason why geologists are so certain that the lava had no connection with the formation of the mountains is that it was poured out on the surface of a flat land or on the bed of a lake or the ocean in which the argillite was being deposited and at the same time as the deposition of that material. This occurred countless ages before there were any

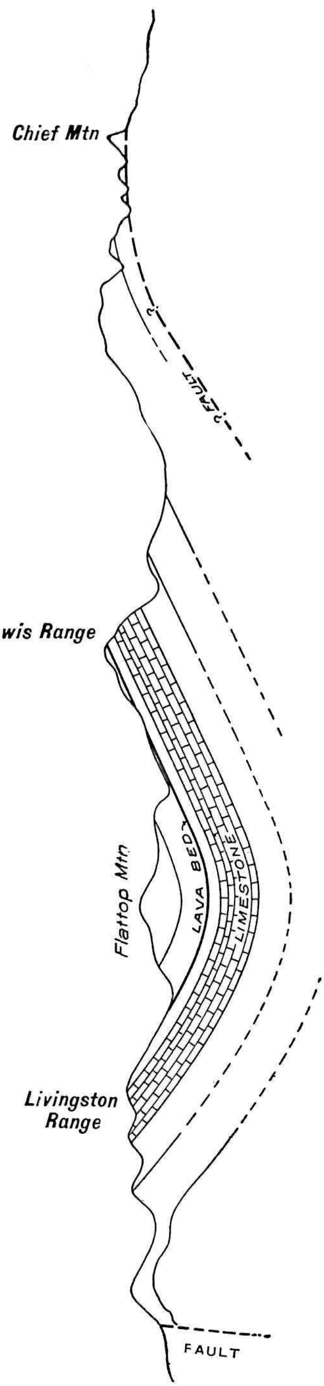


FIG. 12.—SKETCH CROSS SECTION THROUGH FLATTOP AND CHIEF MOUNTAINS SHOWING BROAD SYNCLINE UNDER FLATTOP AND THE FAULT UNDER CHIEF MOUNTAIN.

Vertical scale greatly exaggerated.

mountains in this region, and since that time the sheet of lava has been bent and folded with the limestone and argillite. The evidence that it was originally a surface flow is to be found in the vesicular or porous texture, the ropy structure, and flow lines so well shown in Granite Park and on Flattop.

In Gould Mountain, Wilbur Mountain, and at various other places in the park the traveler will also notice another black band, which may be confused with the lava bed mentioned above, but which has a very different history. Although originally it came from the earth's interior it was not poured out on the surface like the sheet of lava, but while molten was forced into the rocks from below wherever it could find a place. Generally it formed a layer between the other beds of rock, but in places where it is now exposed, as on the steep part of the Swiftcurrent trail, it cuts vertically through the beds for several hundred feet, forming a dike. This rock is called a diorite, and it is hard, like the lava, and where present at the surface renders trail making difficult. The intrusion of this mass occurred long before the existence of the mountains, and hence, like the lava, had nothing to do with their formation.

East of the Lewis Range the spurs composed of green argillite are somewhat lower than the main crest, for that rock is softer and more easily eroded than the limestone which gives to the crest its altitude and its ruggedness. As the green argillite forms the outer points of all these spurs, it gives rise to a sort of high terrace along the mountain front, but below the terrace and separating it from the plains there is in general a very steep slope, in places a precipitous wall of massive limestone which is one of the most pronounced topographic features of the park. It is well shown on Swiftcurrent Creek and in Flattop Mountain[1] lying between Boulder Creek and Upper St. Mary Lake (figure 13). It is also conspicuous in Yellow and Chief Mountains (title-page) farther north. The limestone forms such a precipitous front because it is underlain by very soft shale or sandstone that weathers much more rapidly than the limestone, which consequently is undermined and tends to break off in large blocks, leaving vertical or nearly vertical faces. The soft shale and sandstone underlying the hard limestone do not belong to the group of rocks forming the mountains, but are the same strata that form the plains and are much younger geologically than the mountain series. The abnormal relationship of the older rocks lying upon the younger rocks is due to a great thrust fault, or break in the strata, which has completely changed the order of succession of the rocks and has caused much of the beauty of the mountain front. The mode of formation of this great fault or break in the strata is illustrated by figure 14, which represents the rock strata as they would have appeared in a deep east-west trench provided the spectator could have

[1] This must not be confused with Flattop Mountain west of the Continental Divide.

watched long enough, possibly thousands of years, to have seen the movement take place. The spectator is supposed to be looking north, and in section A he sees the edges of the rock strata lying flat as they were originally deposited in bodies of water, some in the ocean and some in shallow lagoons and lakes.

After the rocks were laid down in a horizontal position great pressure was exerted from the west and what is now the mountain mass was crowded forward or eastward against the immovable rocks of the plains. As the force was resistless, there was no escape except by

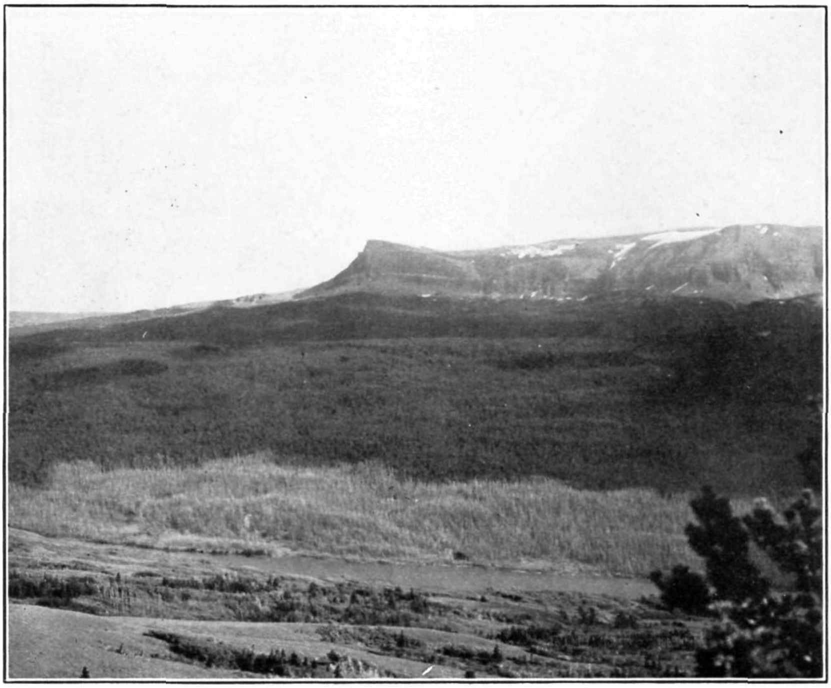


FIG. 13.—FLATTOP MOUNTAIN ON EAST SIDE OF THE RANGE, AS SEEN FROM THE RIDGE NORTH OF SWIFTCURRENT VALLEY.

The fault is located at the base of the cliffs.

Photograph by Bailey Willis.

bending and wrinkling, and it is supposed that one large fold and several minor ones were produced, as shown in section B.

The pressure, though relieved slightly by the corrugation, still persisted, and the folds were greatly enlarged, as shown in section C. At this stage the folds had nearly reached their breaking limit, and had the pressure continued the tendency would have been for the rock strata to break along the lines of least resistance, which is indicated in the various folds by broken lines. As time went on, the pressure continued and the strata broke in a number of places, as indicated in the diagram, and the rocks on the west side of the folds were pushed upward and over the rocks on the east, as shown in section D. What are now the mountain rocks are represented by patterns of cross lines; these rocks have been shoved over the plains rocks (represented in white), producing an overthrust fault.

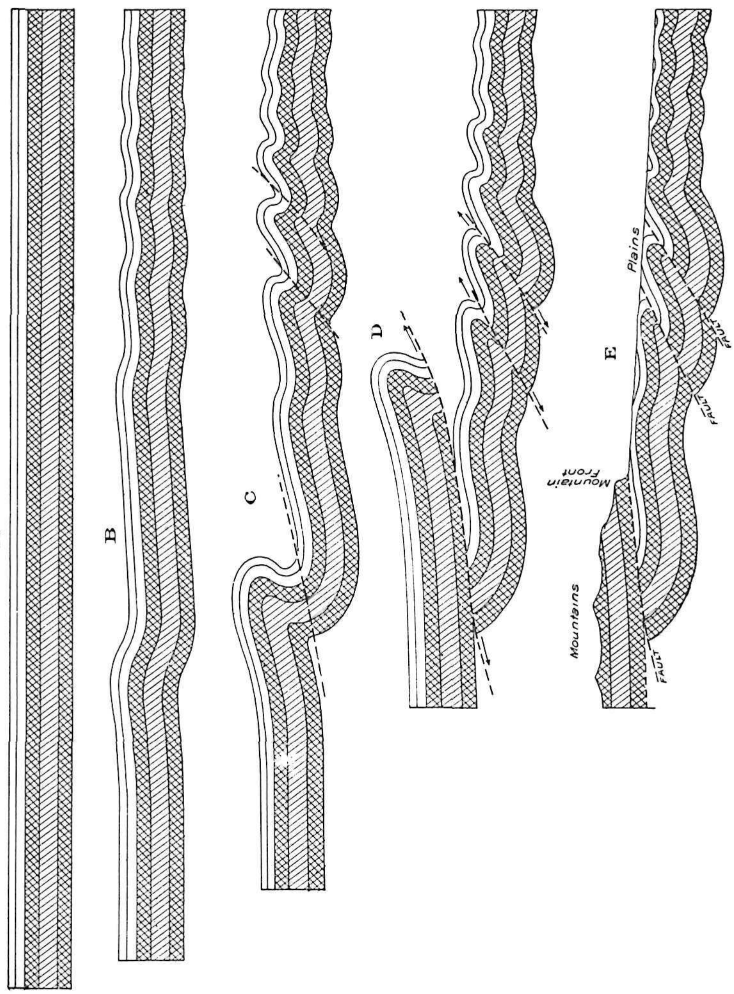


FIG. 14.—DIAGRAM REPRESENTING PROBABLE MODE OF ORIGIN OF THE OVERTHRUST FAULT ON THE EAST SIDE OF THE MOUNTAIN RANGE.

As the rocks at the west were thrust eastward and upward they made, in all probability, a mountain range, but they did not at any time project into the air, as indicated in diagram D, because as soon as the rocky mass was uplifted above drainage level, streams began to wear it away and to cut deep canyons in its upland surface, and they also reduced the soft rocks of the plains to a nearly level surface. The rocks of the mountains, owing to their more resistant character, still tower above the plains, and where they overlie the soft rocks the mountains are terminated by a vertical wall of limestone (as shown in section E). This explains the absence of foothills, which is such a conspicuous feature of this mountain front and one in which it differs from most mountain ranges.

Naturally on such an abrupt and exposed front the streams have cut deep gorges through the hard mountain rocks and down into the soft plains rocks that underlie them, so that the actual trace of the fault on the surface is an irregular line zigzagging out and in from spur to valley, forming a saw-tooth outline.

In places along the fault line the streams have cut through the overthrust mass, leaving isolated outliers of the hard mountain rocks far from the main line of the range. The most noted example of this kind is Chief Mountain, on the northeastern boundary of the park, shown on the title-page of this paper, which is formed of a single block of the mountain limestone completely isolated from other rocks of its kind and resting directly on the soft sandstone and shale of the plains. The plane of the fault is clearly indicated in the photograph by the upper line of the forest. The mountain stands as a single monolith 1,500 feet in height, facing the plains as though it were a sentinel standing guard over the hunting ground of the Red Man. The Indians called this mountain the "Old Chief," from its commanding attitude, and it is still known by this name.

Near the south line of the park Debris Creek, flowing to the west, has been so active that it has cut entirely through the overthrust mountain mass and is now flowing for a distance of 3 miles on the underlying soft plains rocks. In other words, the stream has eaten a hole through the mountain rocks to the younger strata beneath.

As shown on the map the fault separates the mountain from the plains rocks along the eastern front throughout the entire extent of the park. It crosses the Great Northern Railway at Fielding on the west side of the summit and it passes into Canada where the North Fork of Belly River crosses the international boundary line. Although it is present everywhere along this line it is much more conspicuous in the northern than it is in the southern part of the park, because in the north the limestone which immediately overlies it is much thicker than in the south; in fact, in many places at the southern end of the park the limestone is wanting and at other points it is so inconspicuous that it may not be noticed by the traveler if his attention is not specifically directed to it.

At Summit station the traveler sitting on the north side of the car can see the fault as a nearly horizontal line about two-thirds of the distance from the base to the top of the mountain. The rocks above and below the fault are dark argillite and shale, but here and there the fault between them is marked by thin irregular masses of yellow limestone which in certain views are very conspicuous.

From the railroad northward the limestone becomes more prominent and beyond Two Medicine Valley it is everywhere present, forming precipitous slopes or perpendicular walls. It is this limestone which crosses the valley below Upper Two Medicine Lake, the fault occurring at its base just below Trick Falls. In Cut Bank Valley it is very prominent, making the rugged cliffs which surround the Great Northern camp and a picturesque fall in the creek 1¾ miles above the camp. This limestone, with the fault at its base, is very conspicuous in Divide Mountain; it makes the rocky rim that holds Red Eagle Lake in place and forms the barrier over which the stream cascades below the lake.

One of the most striking displays of this bed of heavy limestone is seen at The Narrows on Upper St. Mary Lake. The softer rocks above and below have been cut away by the streams and glaciers, leaving the two points of this resistant bed projecting from the shores. The great fault is just at the base of the limestone and passes under the site of the Great Northern camp.

Much of the beautiful scenery of Swiftcurrent Valley is due to this massive bed, which forms nearly vertical cliffs on each spur and ridge, ranging in height from 500 to 1,000 feet. The perpendicular front of Flattop Mountain is particularly impressive from the trail connecting Upper St. Mary and Sherburne Lakes. The fault swings in just at the base of the cliff on Point Mountain and crosses Swiftcurrent Valley just below the falls at the outlet of Lake McDermott. It then runs diagonally up the ridge on the north, everywhere marked by the base of the cliffs and separating the yellow limestone from the black shale of the plains rocks underlying it.

From Swiftcurrent Valley north the limestone forms a barrier to every stream it crosses. It rises as a wall several hundred feet high where it crosses both forks of Kennedy Creek and the three forks of Belly River, and it makes almost unscalable mountain fronts on the spurs and ridges between these streams. The limestone composing Chief Mountain has already been mentioned, and it is almost as prominent and striking a feature in Yellow Mountain and in the mountain masses bordering the valley of Belly River.

Although the evidence regarding the existence and character of this fault is incontrovertible, there is still one question unanswered, and this is, "How far has the overthrust mountain mass moved?" To those who think of the "everlasting hills" as one of the immutable features of this earth such a question may seem startling indeed, but to the geologist it is the normal question, for to him all surface features are in a state of change and the only reason we do not see them change is because the action is so slow that to ordinary senses it is imperceptible.

That the mountain mass of the park has been thrust far to the northeast from its original position is clearly shown by the diagram on page 26, but the full extent of that movement may never be known, for it is difficult, if not impossible, to locate the original place from which the mass was overthrust. Nevertheless some idea of the extent of the movement may be obtained by measuring the distance between the point where the fault line is cut by one of the

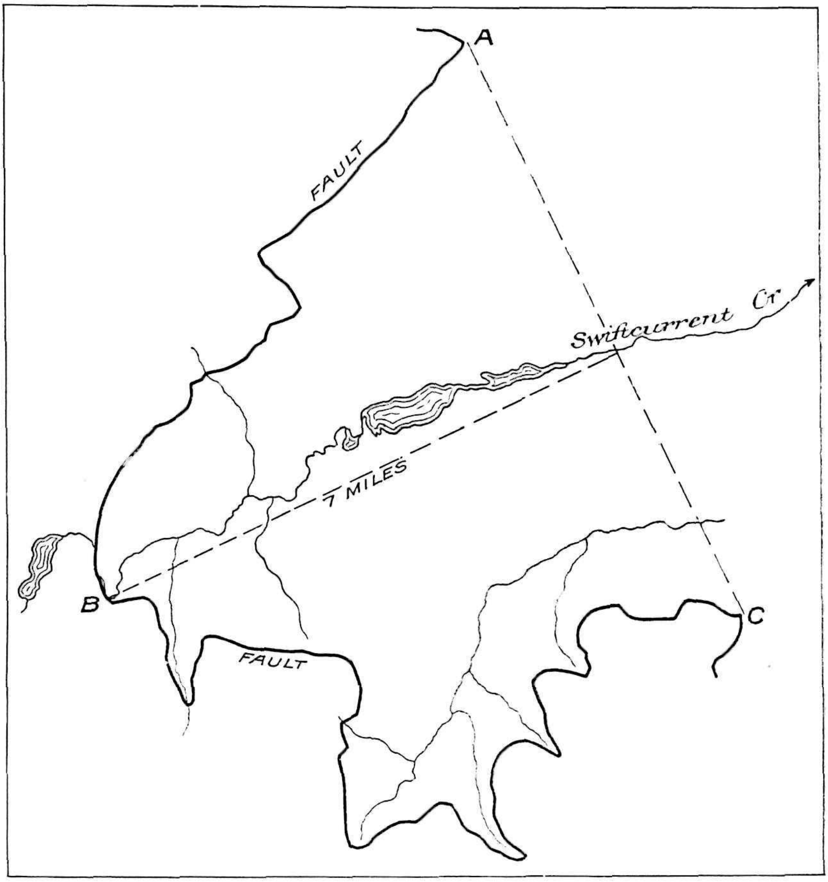


FIG. 15.—DIAGRAM ILLUSTRATING THE METHOD BY WHICH THE AMOUNT OF VISIBLE OVERTHRUST ON SWIFTCURRENT CREEK WAS DETERMINED.

streams (B, figure 15) and a line connecting the easternmost termination of the fault on the spurs of the mountains. In figure 15, B is the point where the fault crosses Swiftcurrent Creek, C represents the position of the fault on Flattop Mountain, and A represents the position of the fault on Yellow Mountain. The distance from B to the line AC as measured by Mr. Bailey Willis in 1901 is 7 miles. The limestone bed originally lay deep in the earth and much farther to the southwest than the point B, but how much farther is a question that can never be answered. Geologists feel certain, however, that it has been pushed from its original position to point B and then 7 miles farther northeastward to its present position on Yellow and Flattop mountains.

Recently the writer has calculated the extent of the movement in Marias Pass, along the line of the Great Northern Railway, and found

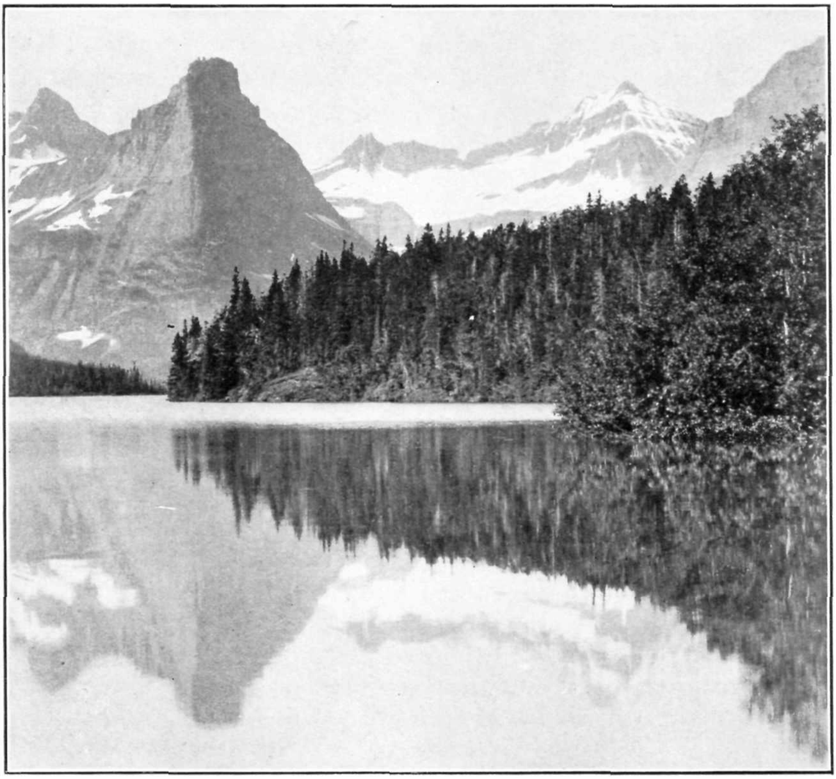


FIG. 16.—SHEPARD GLACIER, AS SEEN FROM UPPER GLENNS LAKE ON BELLY RIVER.

Steep slopes form the bounding walls of great cirques cut at the head of the valley.

Photograph by Bailey Willis.

it to be at least 15 miles. From these measurements it is certain that the whole mass involving rocky strata thousands of feet in thickness and weighing countless millions of tons has been shoved toward the northeast at least 15 miles, and were the original position of the mountain mass known it might prove to be a much greater distance.

In other parts of the world as great or greater overthrusts are known to geologists, but in no case is there one so extensive in which the observer can actually see the trace of the fault throughout the greater part of its length. On account of the great movement and the excellency of the exposures this great fault, known to geologists as the Lewis overthrust, is remarkable and destined to become a classic in geologic literature.

CAUSES THAT HAVE PRODUCED THE PRESENT TOPOGRAPHY.

The effect of hardness of rocks and the geologic structure on shaping the topography of the park has been that of a quiescent condition, simply modifying or controlling the active forces that have done the real work of carving the uplifted mass into deep valleys and cirques and leaving sharp peaks, serrate ridges, and flats at high altitude. The processes that have been thus active are weathering, erosion by streams, and erosion by glaciers.

Weathering.—By weathering is meant that slow change that is constantly taking place in the outer shell of the earth's crust due to the solvent action of the moisture in the atmosphere, the solution by percolating waters, and the mechanical breaking down of the rocks by changes in temperature. The moisture in the atmosphere is continually affecting the rocks by dissolving their more soluble constituents and there are practically no rocks that are free from its action. The process is a slow one as measured by years, but everyone can doubtless recall many cases of polished marble or even granite monuments losing their luster when exposed to the weather and in course of time the deeply cut inscriptions upon them. This process is constantly in operation and, although it is most active at or near the surface, it causes the decay of the rocks in many regions to a depth of a hundred feet or more below the surface. In high rugged mountains the actual decay of the rocks is seldom noticeable, for each mineral grain as it is loosened is swept away by the wind and nothing except the roughened surface remains to tell the tale. The mechanical breaking up of rocks on the high barren summits by changes in temperature from the warmth of the midday sun to the freezing cold of night is much more noticeable, and usually the traveller is greatly impressed by what seems to him an unseen and unknown power that is capable of breaking and splintering the most massive rocks so that in time they can be removed by the wind.

The constant effect of weathering is to smooth off the rougher portions of the mountains and gradually reduce their surfaces toward a plain, but the process is so slow that it is scarcely appreciable and in high mountains is more than offset by other processes that tend for a time to increase the ruggedness of the region and to accentuate the mountain forms. These processes will now be described.

Erosion by running water.—Running water is the most powerful agent known in carving mountains and other features of high alti-

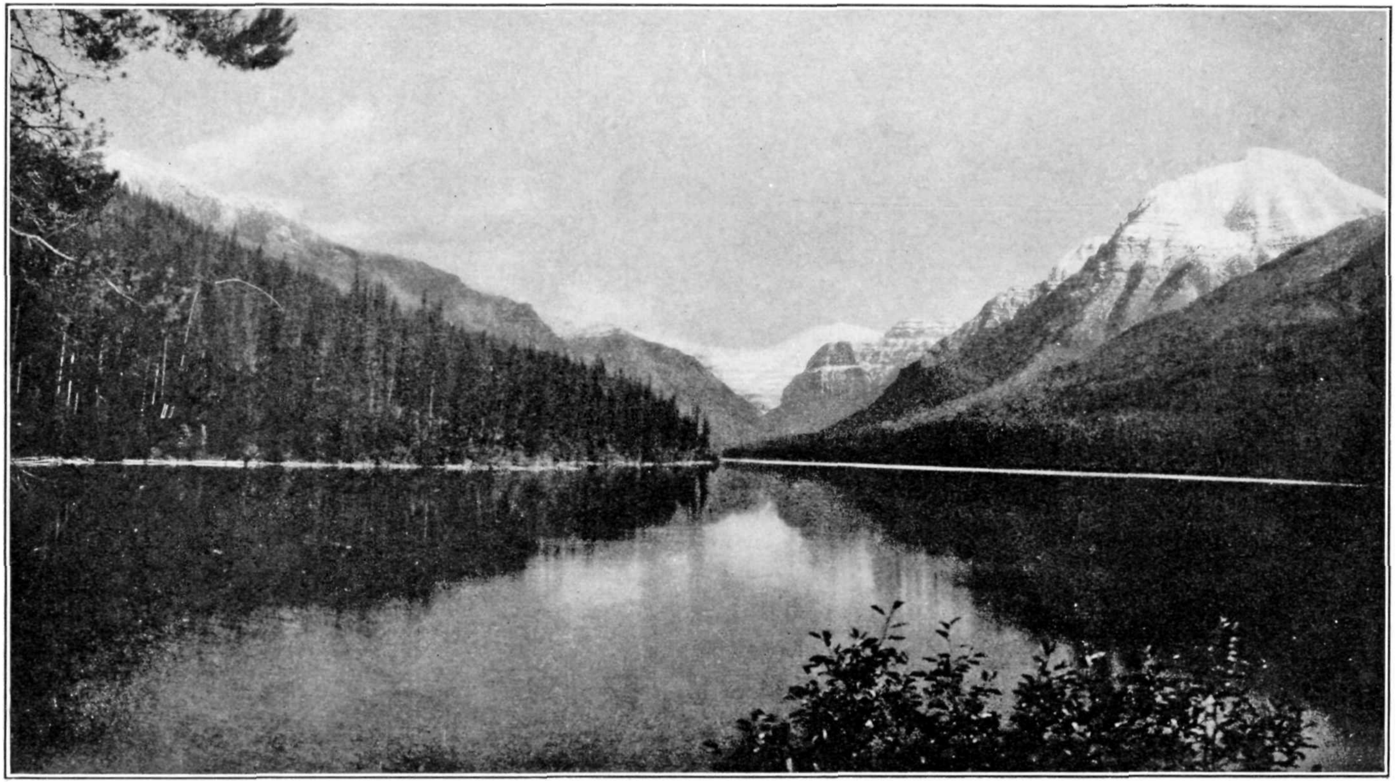


FIG. 17.—BOWMAN LAKE, AS SEEN FROM NEAR THE OUTLET. RAINBOW PEAK ON THE RIGHT.
Photograph by M. R. Campbell.

tude. Where the streams have a sharp descent the cutting is rapid, but it decreases slowly and becomes less effective as the grade is reduced until the stream becomes sluggish and then it ceases and the stream builds up instead of cutting down its channel. This operation may be witnessed by anyone in small rills or brooks after a hard rain. Each stream is swollen with water which, if the ground or rocks are soft, is heavily charged with mud and sand that act as scouring agents, effectively deepening the channelof the stream. Where the stream reaches a lowland or pond the coarser sediment carried by the water is deposited, being spread out over the immediate flat land or built out as a delta in a pond or lake. Usually the deposition of such material by a stream has little effect other than to fill up ponds and to build up and smooth over the bottoms of the valley, but under certain conditions the amount of material carried by the streams is so great that important changes of the topography are produced. Thus it seems probable that at one time the St. Mary Lakes did not exist, or, if they were present, that they were very much smaller than they are to-day. At that time the valley below the lakes was very much deeper than it is now, but the sand and gravel brought down by Swiftcurrent Creek was dumped into the valley, filling it up to its present height. This delta of Swiftcurrent made an effective dam, and behind it the water accumulated. When the barrier was first built there was a single body of water filling the valley in what is now the Upper and Lower lakes, but later these were separated in the same manner by deltas built out by Divide Creek from the south and by Wild Creek from the north. In times of flood these creeks carry a large amount of sand and gravel which in former times was dumped into the lake, building out deltas or points of land from both sides, and as these points were nearly opposite, they soon coalesced, separating the lake into two parts. The relationship of these deltas can be seen from high up on the ridge on the north side of the valley where it is crossed by the trail from Lower St. Mary to Sherburne Lakes.

The process of stream erosion, to many readers, may seem to be a slow one, but in reality it is rapid, for the streams, especially in a mountainous country, are constantly at work. There is no cessation, no relief from the constant rasping of the sand grains on the beds of the streams, and as a result the hardest and most massive rocks are rapidly worn away, the streams cutting deep V-shaped gorges. If conditions are just right the gorges at first may have nearly vertical walls and be true canyons, but in a region of considerable precipitation they will sooner or later take on in cross section the shape of a V.

If the valleys and canyons of Glacier Park are closely studied, either on the ground or by means of the contour map published by the United States Geological Survey,[1] it will be seen that only a few of the minor ones show the cross section noted above as indicative of stream erosion. Instead of a sharp V-shaped profile in cross section their bottoms are distinctly flattened and broadened, taking

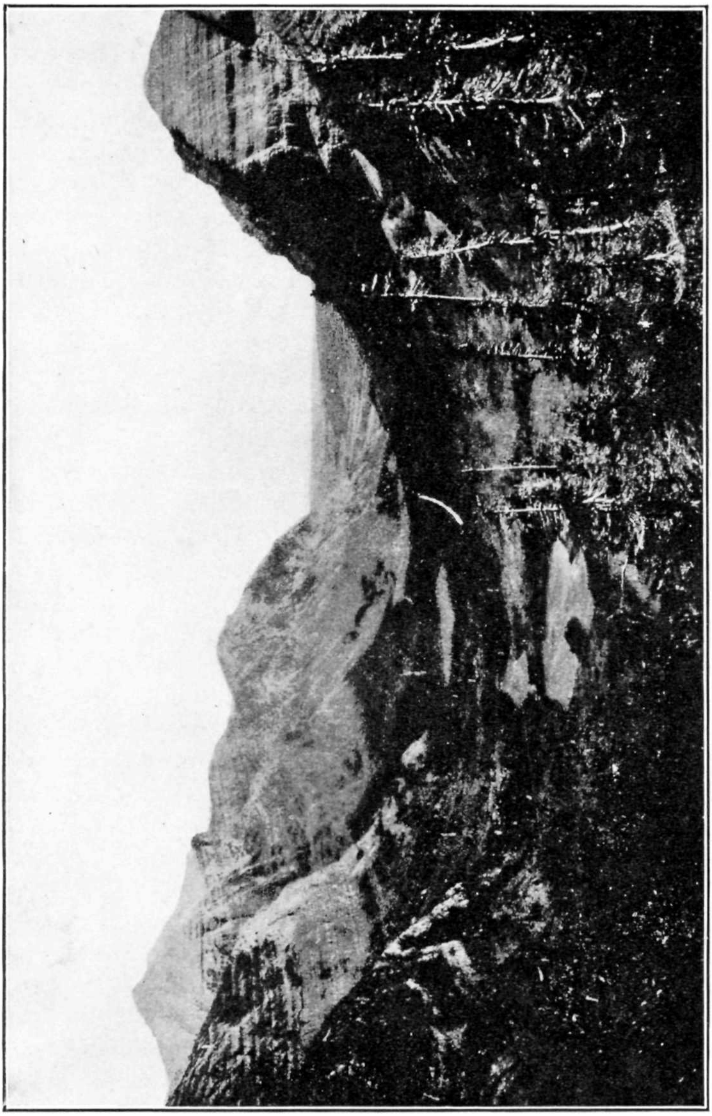


FIG. 18.—SWIFTCURRENT VALLEY, LOOKING DOWN FROM NEAR THE PASS.

Grinnell Mountain on right and Appekunny Mountain on left. Valley was originally V-shaped, but has been scoured out by the old glacier until it is a perfect U in cross section.

Photograph by M. R. Campbell.

on the form characteristic of glacial erosion. The rounded contour of valleys that have been glaciated is shown in figure 18, which is a view down Swiftcurrent Valley from a point a little below the pass.

[1] This map may be purchased from the Director of the United States Geological Survey, Washington, D. C. for 30 cents.

Despite the fact that practically all the valleys in the park are of this form, geologists do not hesitate to say that all of the valleys of this region were cut to approximately their present depths by streams and that the rounding has been simply a modification of their forms due to the scouring action of ice as explained under the heading "Glacial erosion." In a few places minor valleys and gulches show the V-shaped form due entirely to stream erosion, but these are recent features and have been cut since the ice retreated from the main valleys, leaving the streams free to carve their valleys in their own way.

As noted on a previous page the result of stream erosion on a recently uplifted mountain mass is to increase the ruggedness, but after a long time, if there is no more uplift, the streams will have cut as deeply as their outlets permit and then their work is the broadening rather than the deepening of the valleys. The work goes on more slowly than before; but if conditions remain undisturbed the valleys will become broader and broader, the intervening highland more and more reduced, until finally a fairly even surface results. This is the apparent explanation of the topographic basin of Flattop Mountain described on page 14. In the comparatively soft rocks in the center of the syncline the streams long ago widened their valleys until they coalesced, but the hard limestones forming the bounding rim (shown in fig. 19) resisted the action of the elements and remained unreduced. When this basin was formed it is probable that the altitude of the range was not so great as it is at the present time, or else that the surface of the surrounding region was much higher than it is to-day.

Erosion by ice (glaciers).—Opinions differ somewhat regarding the ability of glaciers to erode. Some maintain that a glacier has little erosive power, whereas others ascribe much of the work done in a mountainous region to ice. It seems probable that neither view is entirely correct and that ice has considerable erosive power, but only in modifying the form of gorges previously cut by running water.

Nearly all of the valleys in Glacier Park show by their forms that they have been occupied by ice, although in many cases no glaciers exist in them at the present time. The form of a valley after it has been modified by moving ice is well illustrated by figure 18. Such valley forms could have been produced only by moving ice which filled the valleys to considerable depths and covered most of the lower lands of the park. There is abundant evidence in the forms of the valleys and in the scratches left by the moving ice to prove that it was at least 2,500 feet deep in the larger valleys and that the crests alone remained above its level. This, of course, means that immense glaciers must have originated in these mountains and flowed out in all directions, extending 20 or 30 miles onto the Great Plains on the east and down the valley of Flathead River on the west. The present glaciers are only the diminutive remnants of the earlier ones, and if the mean annual temperature were raised slightly or the amount of precipitation decreased it is probable that they would entirely disappear. As it is they cling to the north and east sides of the high ridges and peaks where the winter snows find a lodging place and

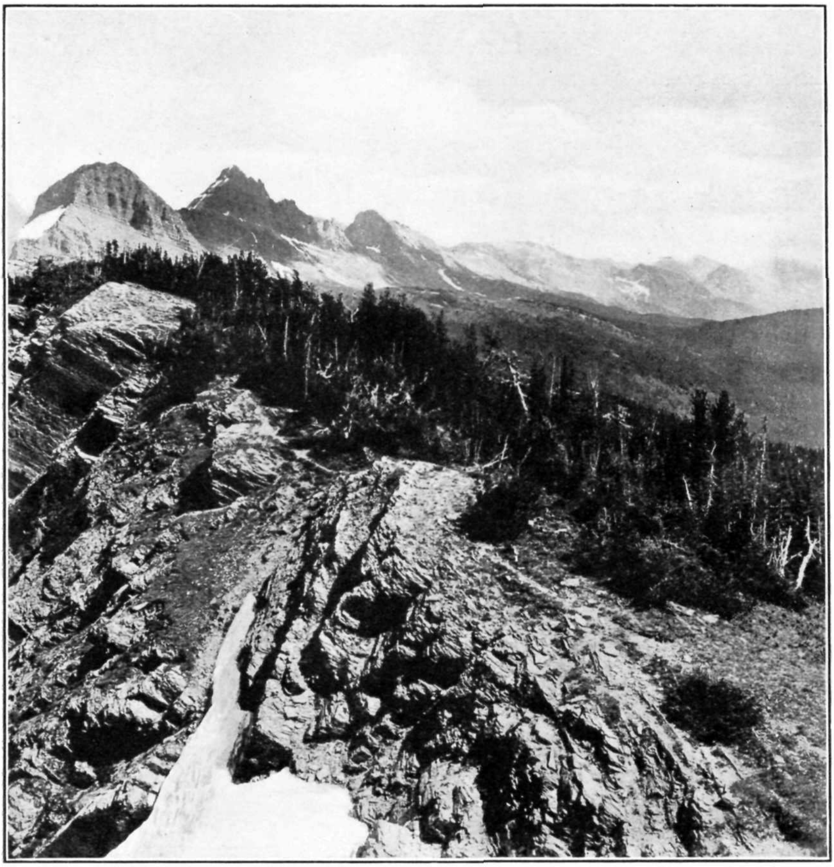


Fig. 19.—Part of the north rim of the basin of Flattop Mountain, as seen from Kootenai Ridge.
Photograph by Bailey Willis.

where the summer sun has little effect upon them. There are no longer any rivers of ice, but the work they accomplished is still visible and lends beauty to the mountain scenery, for the rugged mountain tops are accentuated by the rounded graceful forms of the valley walls.

The glaciers have had an even more marked effect upon the topography than that of smoothing the valleys in which they lay. They

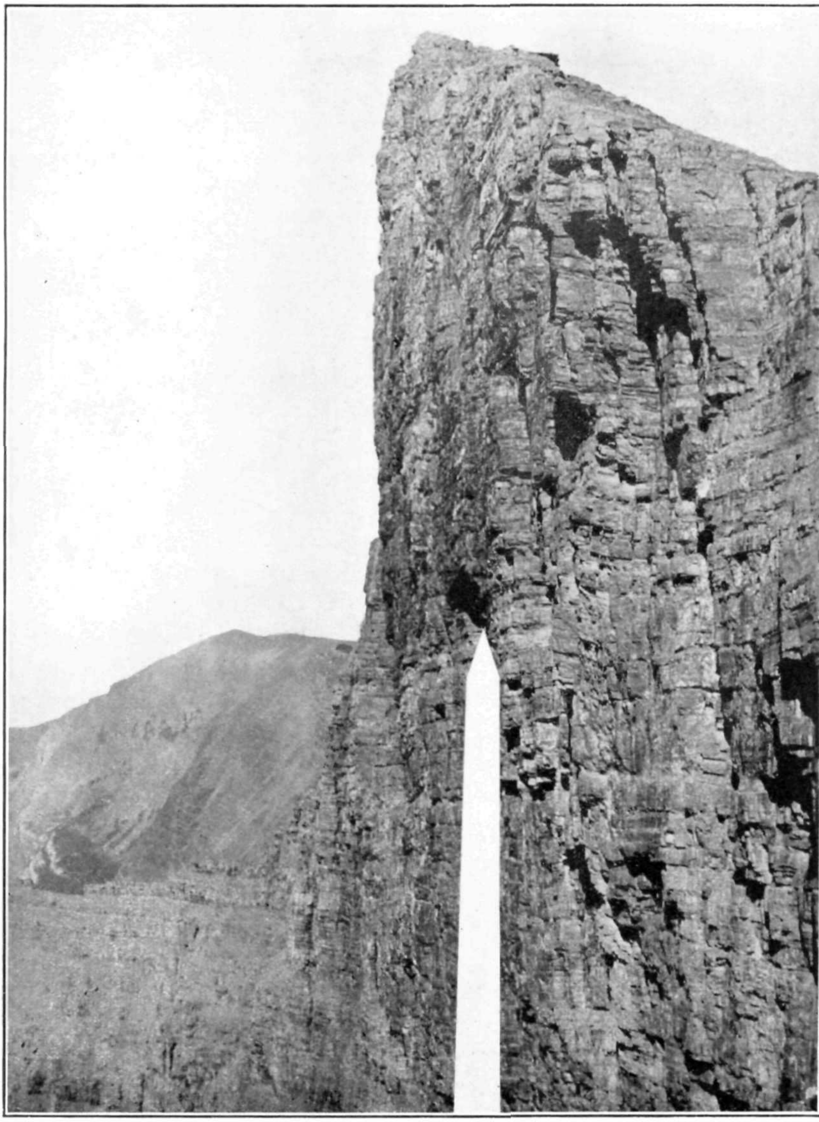


FIG. 20.—GREAT VERTICAL CIRQUE WALL ON THE NORTH FACE OF GOATHAUNT MOUNTAIN.

Part shown in picture fully 1,200 feet high, and the wall extends below at least an equal distance. To appreciate this great height, compare it with the white outline representing the Washington Monument (555 feet high) on the same scale.

Photograph by Bailey Willis.

have the power to cut into the mountain slopes at their heads, forming cirques that add greatly to the ruggedness and variety of the topographic forms to be found here. The process of cutting out these cirques is not well understood, but at or near the point where the névé or snow field changes into the moving ice of the glacier the cirque is formed. Blocks of rock are evidently plucked out by the moving ice even back to the névé and this tends to give to the cirque a nearly level floor. The plucking extends constantly backward, undermining the bounding walls, and these break down in more or less vertical cliffs, giving to the excavation a circular or semicircular form with nearly vertical walls from a few hundred to more than 3,000 feet in height, as shown in figure 20.

All of the present glaciers lie in such cirques, but some are much better developed than others. One of the best examples is Grinnell Glacier, which lies on the east side of the Continental Divide on Cataract Creek, one of the tributaries of Swiftcurrent. This glacier has eaten back into the mountains so far that the crest is nearly cut through and the cirque wall is jagged in the extreme. It is known as the Garden Wall, and, as shown in figure 9, it stands in rugged grandeur, a veritable wall a thousand feet in height.

One of the most striking cirque walls is that surrounding Iceberg Lake, a little sapphire gem at the head of North Fork of Swiftcurrent Creek, shown in figure 21. The lake and glacier lie in a beautiful amphitheater about one-half mile in diameter surrounded on three-fourths of its circumference by nearly vertical walls from 2,500 to 3,000 feet high. Four Woolworth buildings, New York's greatest skyscraper, 750 feet high, could be placed one above another in this cirque, and the spire of the uppermost one would just reach the highest point of the bounding wall.

Probably the deepest cirques are on Cleveland Mountain, the highest summit in the park. Cirques on either side have walls approximately 4,000 feet high. The one on the west side shown in figure 22 looks as though some immense prehistoric animal had taken a huge bite out of the side of the mountain which previously had sloped regularly from the margin of the valley to the summit of the peak. The "bite" has a fairly level floor and is bounded on the back by a cliff so steep that on it vegetation can not find a foothold and across it only the most hardy of the mountain goats can make their way.

The glaciers have not only produced the cirques which add so much to the picturesqueness of the topography and to the ruggedness of the range, but to them are due directly most of the beautiful lakes, large and small, which are without doubt one of the most attractive features of the region. Some of the lakes, such as McDermott, Red Eagle, Ellen Wilson, Two Medicine, and many smaller ones, occupy rock basins which the old glaciers scoured out in places where the rocks were slightly softer than they were lower down the valley. These may be distinguished by the rocky barrier that crosses at the outlet. The limestone ledge which holds Lake McDermott in place is partly shown in figure 23. Similar ledges cross the outlets of Red Eagle and Two Medicine Lakes. Some may suppose that these ledges were thrust

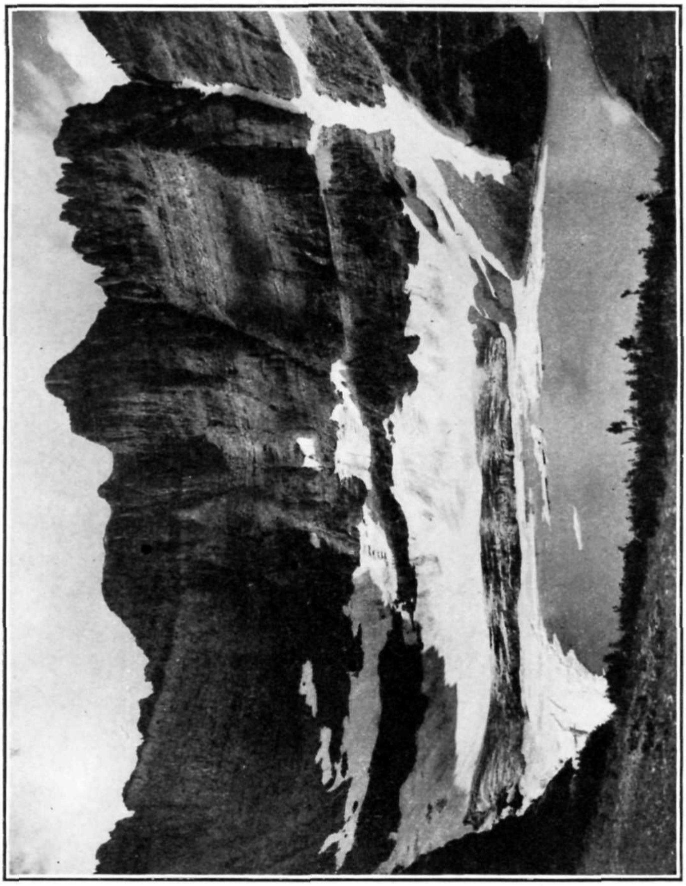


Fig. 21.—Iceberg Lake.

View shows lake and glacier about one-half mile in diameter, surrounded on three sides by rock wall 3,000 feet high at the highest point. Black band of lava shows on left. A great dike cuts the wall in notch on right.

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up like a dike, but such is not the case. They have remained in their original positions, but the softer rocks in the valley above them have been carried away, leaving a basin in which the waters of the lake accumulated. In Two Medicine Lake the water does not now, as formerly, flow over the top of this ledge but it has found a crack or subterranean channel and through this it flows and bursts from a hole in the bottom of the ledge. From this circumstance it is known as Trick Falls.

Other lakes, such as Bowman and Upper Quartz, are held in place by great glacial moraines which have been deposited across their valleys like huge dams. These may be known by the hummocky ridges that are plainly visible at the lower ends of both of these lakes.

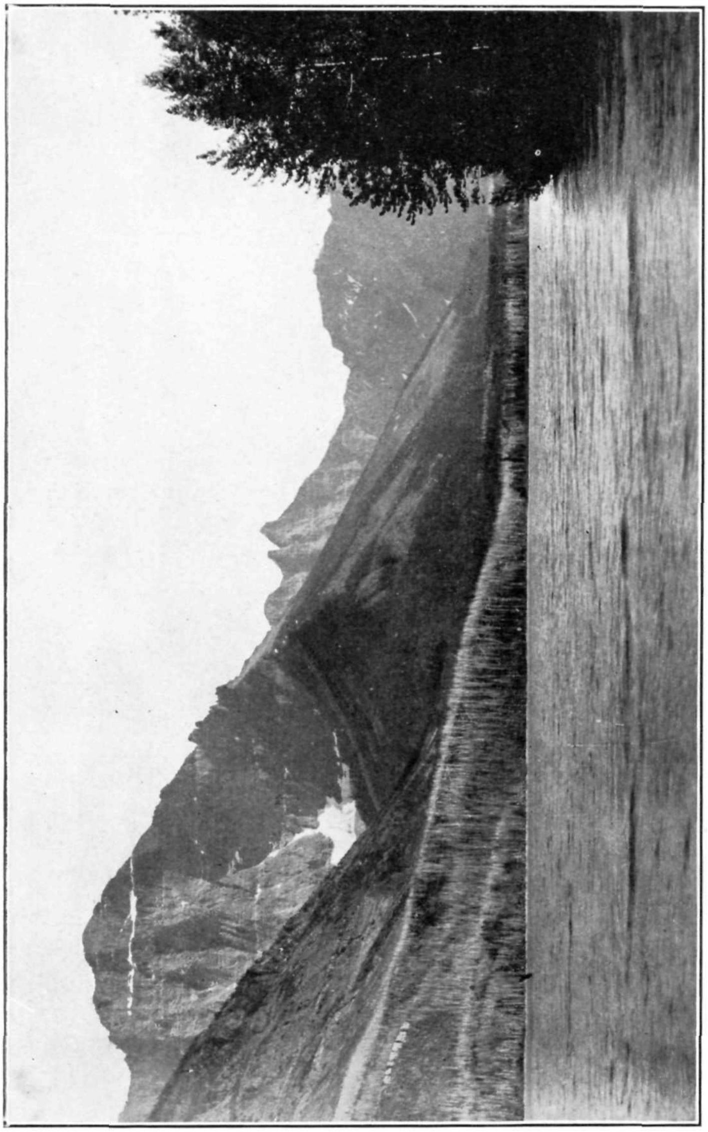

Fig. 22.—Great cirque on northwest side of Mount Cleveland, as seen from Waterton Lake.
Summit of mountain 6,200 feet above the lake. Cirque wall at least 4,000 feet high and nearly vertical.
Photograph by Bailey Willis.

Many other small lakes and ponds are rimmed about by moraines, but they are too numerous to mention.

A third class of lake basins has been formed by the glaciers, but in these the dam is not formed by a moraine, but by the outwash of sand

and gravel from the end of the ice. The basins of Logging, Lower Kintla, Lower Two Medicine, and McDonald Lakes are supposed to have been formed in this manner. At the extremities of these lakes there is no visible evidence of a barrier, but when the valley below the lake is examined it will be found to be deeply filled with coarse but well-rounded gravel which the stream flowing away from the ice doubtless carried and deposited, forming a dam just as effectively as though a moraine had been built around the ice front.

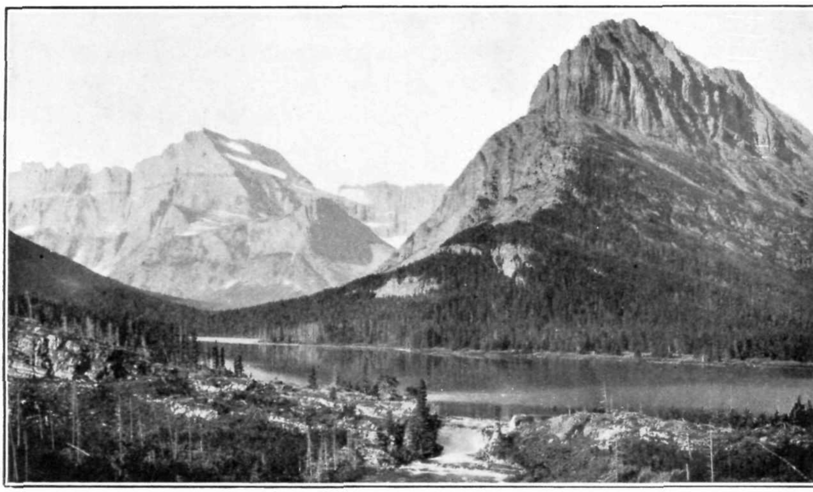

FIG. 23.—McDERMOTT LAKE, WITH GRINNELL AND GOULD MOUNTAINS IN THE BACKGROUND.

The lake lies in a rock basin, and the outlet forms a pretty fall over the massive ledges of limestone that hold the lake in place.

Photograph by T. W. Stanton.

SUMMARY.

The scenic features of the Glacier National Park are not due to any extraordinary or cataclysmic event in the geologic history of the region, but primarily to the uplift and overthrust of the mountain rocks upon the plains rocks and secondarily upon the erosion of this uplifted mass by the ordinary action of the weather, streams of water, and streams of ice. With most of these processes, especially those of erosion, the traveler is doubtless familiar, as they are going on to-day in much the same manner as they have been going on for countless ages in the past, not alone in the Glacier Park but all over the world wherever there is a land surface upon which they can operate. The movement of uplift and overthrust is less familiar, but even such movements in the crust of the earth are not altogether unkown at the present time. The San Franciscan earthquake was the result of a slip along an old line of fracture. In most places the movement was only a foot or two and at the maximum it only caused a displacement of 15 feet, but even such small movements might in time, if repeated often enough, produce such striking results as can be seen along the great overthrust fault in Glacier Park.

The wonderful results produced in the park are due simply to a peculiar combination of processes and conditions which in themselves are extremely commonplace to one who has been trained to observe them, but may appear wonderful to the observer who has not given them close study. It is to be hoped that the present paper has made it clear that the workings of nature are not concealed nor mysterious, but that they are simple in the extreme and open to the inspection of all who choose to look about them and study her work at first han

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