

Glaciers and Glaciation in Glacier National Park

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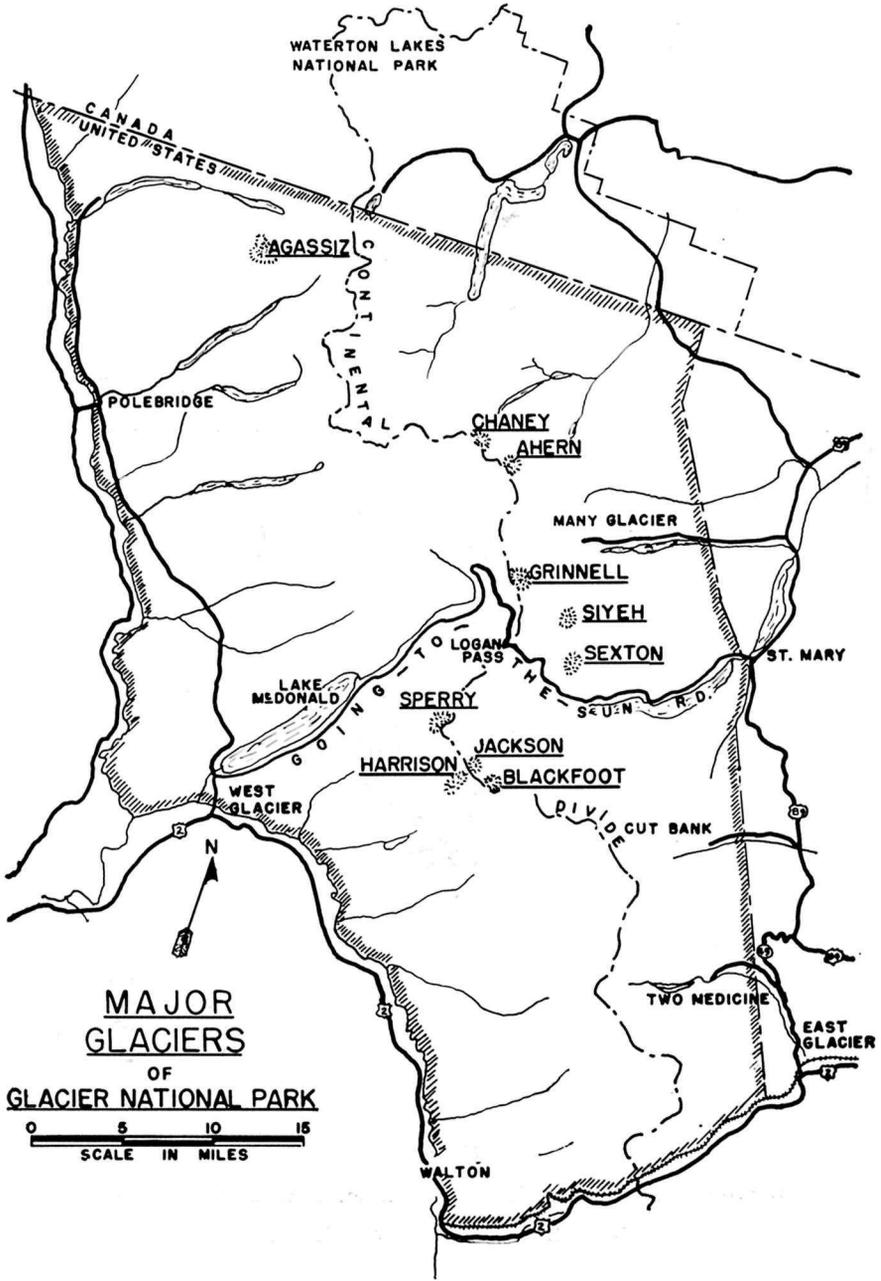
Cover

Surveying Sperry Glacier — Arthur Johnson of U. S. G. S.
N. P. S. Photo by J. W. Corson

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**MAJOR
GLACIERS
OF
GLACIER NATIONAL PARK**

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SCALE IN MILES

GLACIERS AND GLACIATION

In

GLACIER NATIONAL PARK

By James L. Dyson



MT. OBERLIN CIRQUE AND BIRD WOMAN FALLS

SPECIAL BULLETIN NO. 2

GLACIER NATURAL HISTORY ASSOCIATION, INC.

GLACIERS AND GLACIATION IN GLACIER NATIONAL PARK

By

James L. Dyson

Head, Department of Geology and Geography
Lafayette College

Member, Research Committee on Glaciers
American Geophysical Union*

The glaciers of Glacier National Park are only a few of many thousands which occur in mountain ranges scattered throughout the world. Glaciers occur in all latitudes and on every continent except Australia. They are present along the Equator on high volcanic peaks of Africa and in the rugged Andes of South America. Even in New Guinea, which many think of as a steaming, tropical jungle island, a few small glaciers occur on the highest mountains.

Almost everyone who has made a trip to a high mountain range has heard the term, "snowline," and many persons have used the word without knowing its real meaning. The true snowline, or "regional snowline" as the geologists call it, is the level above which more snow falls in winter than can be melted or evaporated during the summer. On mountains which rise above the snowline glaciers usually occur. The snowline is an elusive feature and can be seen only in late summer. For example, during the latter part of the month of June snow extends from the summits of most Glacier National Park mountains down their slopes to timberline, and some snowbanks extend even lower. At that time snowline appears to be down near timberline. But as the summer progresses and higher temperatures melt the lower-lying snowbanks this apparent snowline retreats higher and higher up the slopes, until late August or early September, when most of the park mountains are devoid of snow. Then we know that here the regional snowline actually lies above the summits of most peaks, at a height of more than 10,000 feet. The only parts of the United States which project above the regional snowline are the highest summits in the Cascade Range in California, Oregon and Washington, and in the Olympic Mountains in the latter State.

The Olympic area is unique, for here the regional snowline descends to about 6,000 feet, lower than anywhere within the boundaries of the Continental United States. Extrordinarily heavy annual snowfall and the high percentage of cloudy weather, which retards the melting of snow, combine to depress the snowline to such a low level.

* Dr. Dyson worked as a ranger naturalist in Glacier National Park for eight different summers starting in 1935. During that time he undertook special research on park glaciers in addition to his regular assignments.

Glaciers of Glacier National Park

Within the boundaries of Glacier National Park there are 50 to 60 glaciers, of which only two have surface areas of about one-half square mile, and not more than seven others exceed one-fourth square mile in area.

All these bodies of ice lie in shaded locations on the east- or north-facing slopes at elevations between 6,000 and 9,000 feet, in all cases well below the regional snowline. Consequently, they owe their origin and existence almost entirely to wind-drifted snow.

Ice within these glaciers moves slowly. The average rate in the smallest ones may be as low as 6 to 8 feet a year, and in the largest probably 25 to 30 feet a year. There is no period of the year when a glacier is motionless, although movement is somewhat slower in winter than in summer. Despite the slowness of its motion the ice, over a period of years, transports large quantities of rock material ultimately to the glacier's end where it is piled up in the form of a moraine.

Sperry is the largest glacier in the park. Its surface in 1950 was somewhat more than 300 acres. A striking feature of this glacier is the precipitous character of its front, which at one point consists of a sheer cliff from 80 to 100 feet high. Blocks of ice occasionally



THE ICE FRONT ON SPERRY GLACIER IS ABOUT 100 FEET HIGH (BEATTY PHOTO)

break from this cliff and go crashing down into a little unnamed lake where they float as bergs throughout the summer months.

The second largest glacier in the park is Grinnell with a surface area of 280 acres. Both Sperry and Grinnell have probable maximum thicknesses of 400 to 500 feet.



JACKSON GLACIER IS VISIBLE FROM GOING-TO-THE-SUN ROAD (BEATTY PHOTO)

Other important park glaciers, although much smaller than the first two mentioned, are Harrison, Chaney, Sexton, Jackson, Blackfoot, Siyeh, and Ahern. Several others approach some of these in size, but because of isolated locations they are seldom seen. As a matter of fact, there are persons who visit Glacier National Park without seeing a single glacier, while others, although they actually see glaciers, leave the park without realizing they have seen them. This is because the highways afford only distant views of the glaciers, which from a distance appear much like mere accumulations of snow. A notable example is Grinnell as seen from the highway along the shore of Sherburne Lake and from the vicinity of the Many Glacier Entrance Station. The glacier, despite its length of almost a mile, appears merely as a conspicuous white patch high up on the Garden Wall at the head of the valley.

Several of the glaciers, however, are accessible by trail and are annually visited by many hundreds of people, either on foot or by horse. Most accessible of all park glaciers is Grinnell. It can be reached by a six-mile trip over an excellent trail from Many Glacier Hotel or Swiftcurrent Camp. Sperry, likewise, can be reached by trail, although the distance is several miles greater than in the case of Grinnell. The trip,

however, can be broken and possibly made more interesting by an overnight stop at Sperry Chalet, which is located about three miles from the glacier. Siyeh is the only other regularly visited park glacier. It lies about half a mile beyond the end of the Cracker Lake trail, and can be reached from that point by an easy walk through grassy meadows and a short climb over a moraine. Siyeh, however, is less spectacular than either Grinnell or Sperry, being much smaller and lacking crevasses, so common on the other two. Few people make the spectacular trail trip over Siyeh Pass but those who do may visit Sexton Glacier by making a short detour of less than half a mile where the trail crosses the bench on which the glacier lies. Sexton is a small glacier, but late in the summer after its snow cover has melted off it exhibits many of the features seen on much larger bodies of ice.

Interesting surface features which can be seen on any of these glaciers include crevasses, moulins (glacier wells), debris cones, and glacier tables. Crevasses are cracks which occur in the ice of all glaciers. They are especially numerous on Sperry and Grinnell. Moulins, or glacier wells, are deep vertical holes which have been formed by a stream of water which originally plunged into a narrow crevasse. Continual flow of the stream enlarges that part of the crevasse, creating a well. Several such features on Sperry Glacier have penetrated to depths of more than 200 feet, and are 20 or more feet wide at the top.

No one can walk over the surface of Grinnell Glacier without noticing a number of conical mounds of fine rock debris. Actually these are cones of ice covered with a veneer, seldom more than two inches thick, of rock debris, so their name, debris cone is somewhat misleading.



CREVASSE IN GRINNELL GLACIER (WALKER PHOTO)

The rock material is deposited on the glacier by a stream. After the stream changes its course the debris protects the ice underneath from the sun's rays. As the surface of the glacier, except that insulated by the debris, is lowered by melting, the mounds form and grow grad-

ually higher until the debris slides from them, after which they are speedily reduced to the level of the rest of the surface. They are seldom higher than 3 or 4 feet.

A glacier table is a mound of ice capped, and therefore protected from melting, by a large boulder. Its history is similar to that of the debris cone. After a time the boulder slides off its perch, and then the mound of ice melts away.

Snow which fills crevasses and wells during the winter often melts out from below, leaving thin snowbridges in the early part of the summer. These constitute real hazards to travel on a glacier because the thinner ones are incapable of supporting a person's weight. This is one very good reason why the inexperienced should never venture onto the surface of a glacier without a guide.

It is probable that the park glaciers are not remnants of the large glaciers present during the Ice Age which terminated approximately 10,000 years ago, because it is known that several thousand years after that time the climate of the Glacier National Park region was somewhat drier and warmer than now. Under such conditions glaciers could not have existed.

Shrinkage of Park Glaciers

Prior to the beginning of the present century all glaciers in the park, and practically all others throughout the Temperate Zone of the Earth, began to shrink in response to a slight change in climate, probably involving both a temperature rise and a decrease in annual snowfall. From about 1900 until 1945 shrinkage of park glaciers was very rapid. In other words these glaciers were not in equilibrium with the climate, for less ice was added to them each winter than disappeared by melting and evaporation during the remainder of the year.

Over a period of several years such shrinkage is apparent to the eye of an observer and is manifest by a lowering of the glacier's surface, and more particularly by a "retreat" of the lower edge of the glacier. This part of the ice is generally referred to as the **ice front**. When sufficient snow is added to the upper part of the glacier to cause the ice at the front to move forward equal to the rate at which it melts away, the glacier is in equilibrium with the climate. When the yearly added snow decreases in amount the ice front seems to retreat or move back, whereas the mass of the glacier is merely decreasing by melting on top and along the edges, just as a cube of ice left in the kitchen sink decreases in size.

The National Park Service initiated observations on glacier variations in 1931. At first the work consisted only of the determination of the year by year changes in the ice front of each of several glaciers. In 1937, 8, and 9 the program was expanded to include the detailed mapping of Grinnell, Sperry, and Jackson Glaciers, respectively, to serve as a basis for comparisons in future years. Aerial photographs were obtained of all the known Park glaciers in 1950 and 1952 and again in 1960. Since 1945, the glacier observations have been carried on in cooperation with the U.S. Geological Survey. The work has included the periodic measurement of profiles to determine changes occurring in the surface of Grinnell and Sperry Glaciers and also the determination of the rate of annual movement. Some of the more important data yielded by surveys on Grinnell and Sperry, the two largest glaciers in the Park, are summarized in the following tabulations:*

GRINNELL GLACIER
(Change in area in acres) ^A

Year	Area	Remarks
1901	525	From Chief Mountain topographic quadrangle map.
1937	385	From map by Dyson of lower portion of glacier plus area of upper glacier (57 acres) as shown on 1950 U.S.G.S. map.
1946	337	Same as above.

* This information by Mr. Dyson which appears on pp. 97-102 in Vol. 38 of the GEOGRAPHICAL REVIEW, has been revised by Mr. Arthur Johnson of the U.S.G.S.

^A Grinnell Glacier originally consisted of an upper and lower portion connected by a narrow ice tongue. This tongue disappeared in 1926 and since then the two portions have been separate.

Year	Area	Remarks
1950	314	From 1950 U. S. G. S. map including upper portion.
1960	300(approx.)	Very little decrease in area since 1950. Surface area in 1960 estimated to be not more than 10 or 15 acres less than in 1950. (Including upper portion.)

Recession of front, in feet, of half-mile section of front southeast from lake at north end of glacier.

Period	Recession During Period	Total Recession Since 1937	Average Annual Recession
1937-45	270	270	34
1945-50	75	345	15
1950-60	44 ^B	389	4

The above data indicates that there has been no significant change in the area of Grinnell Glacier during the past decade. The surface elevation varies somewhat from year to year. The average elevation of the ice surface at the end of the melting season in 1960 was approximately 10 feet less than in 1950.

The movement of Grinnell Glacier, based on observations since 1947, has been about 35 to 40 feet per year.

SPERRY GLACIER (Change in area in acres)

Year	Area	Remarks
1901	810	From Chief Mountain topographic quadrangle map.
1938	390	From map by Dyson.
1950	298	From 1950 U.S.G.S. map of the glacier.
1961	275	From 1950 U.S.G.S. map of the glacier with front corrected to 1961.

^B Much of this apparent change is due to the change in the lakeshore which varies considerably from year to year and is not a true indication of recession.

Recession of front, in feet, of central half-mile section

Period	Recession	Total Recession Since 1938	Average Annual Recession
1938-45	351	351	50
1945-50	177	528	35
1950-56	85	613	14
1956-61	196	809	39

Sperry Glacier, in contrast with Grinnell Glacier, has shown a continuing recession and consequent shrinkage in area. The shrinkage has been most pronounced in the portion of the glacier below an altitude of 7,500 feet.

The forward movement of Sperry Glacier, based on observations since 1949, has averaged 13 feet per year.

It is of interest to note from the above data that the changes in Sperry Glacier are more pronounced than those in Grinnell Glacier al-

though the straight-line distance between them is only 9 miles. One possible reason—Grinnell Glacier is on the eastern slope of the Continental Divide whereas Sperry Glacier is on the western slope.

Sperry Glacier in 1900 had a surface area of 1.31 square miles (840 acres.) By 1938 the area had shrunk to 390 acres, and in 1946 to about 330 acres.

Even more significant is the lowering of the glacier's surface, from which volume shrinkage may be obtained. In 1938 Sperry Glacier had a thickness of 108 feet at the site of the 1946 ice margin. At this same place in 1913 the thickness was nearly 500 feet, and the average thickness of the glacier over the area from which it has since disappeared was at least 300 feet.

The average thickness of **Grinnell Glacier** in 1937 at the site of the 1946 ice front was 73 feet. The surface of the entire glacier was lowered 56 feet during that nine-year period. This means that each year the glacier was reduced in volume by an amount of ice equivalent to a cube 450 feet high.



GRINNELL GLACIER AS IT LOOKED PRIOR TO 1926 WHEN THE LOWER AND UPPER SEGMENTS WERE STILL CONNECTED.

At the northern terminus of Grinnell Glacier, which is bordered by a small marginal lake, a large section of the ice front fell into the water on or about August 14, 1946, completely filling it with icebergs. This event, although witnessed by no one, must have been comparable to many of the icefalls which occur at the fronts of the large glaciers along the southeast coast of Alaska.

The volume of Grinnell Glacier was reduced by about one-third from September 1937 to September 1946. Several other glaciers have exhibited a more phenomenal shrinkage than Sperry or Grinnell. The topographic map of Glacier National Park, prepared in 1900-1902, shows several comparatively large glaciers such as Agassiz, Blackfoot and Harrison. Their shrinkage has been so pronounced that today Agassiz has virtually disappeared and the other two are pitifully small remnants, probably less than one-fifth the size they had been when originally mapped.

Since 1945, because of above-normal snowfall and subnormal temperatures, glacier shrinkage has slowed down appreciably, coming virtually to a standstill in 1950; and in 1951, for the first time since glacier changes have been recorded in the park, Grinnell Glacier increased slightly in volume. This was also reflected by a readvance of the front. Although no measurements were made in 1951 on other park glaciers some of them certainly made similar readvances. Thus the climatic conditions which caused glaciers to shrink for fifty or more years seem to have been replaced by conditions more favorable to the glaciers. Time alone will tell whether the new conditions are temporary or mark the beginning of a long cycle of wetter and cooler climate.

Former Extent of Park Glaciation

During the Pleistocene Period or Ice Age when most of Canada and a large portion of the United States were covered by an extensive ice sheet or continental glacier, all the valleys of Glacier National Park were filled with valley glaciers. These originated in the higher parts of the Lewis and Livingstone Ranges. On the east side of the Lewis Range they moved out onto the plains. From the Livingstone Range and the west side of the Lewis Range they moved into the wide Flathead Valley. During the maximum extent of these glaciers all of the area of the park except the summits of the highest peaks were covered with ice.

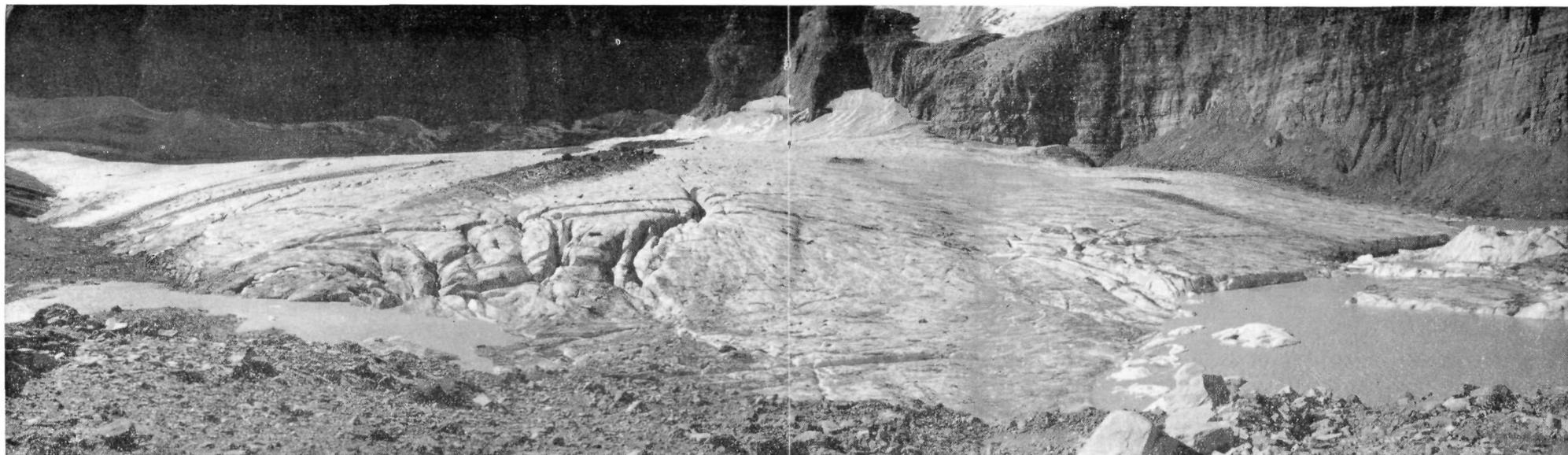
The great Two Medicine Glacier, with its source in the head of the Two Medicine and tributary valleys, after reaching the plains spread out into a big lobe (piedmont glacier) eventually attaining a distance of about 40 miles from the eastern front of the mountains. The stream of ice emerging onto the plains from St. Mary Valley also extended

many miles out from the mountain front. In the major valleys these glaciers attained thicknesses of 2,000 or more feet. Although man probably never viewed this magnificent spectacle, the park at that time must have been similar in aspect to some of the present day ice filled ranges along the Alaska-Yukon border.

At least twice these glaciers advanced down the park valleys, and at least twice they melted away and disappeared.

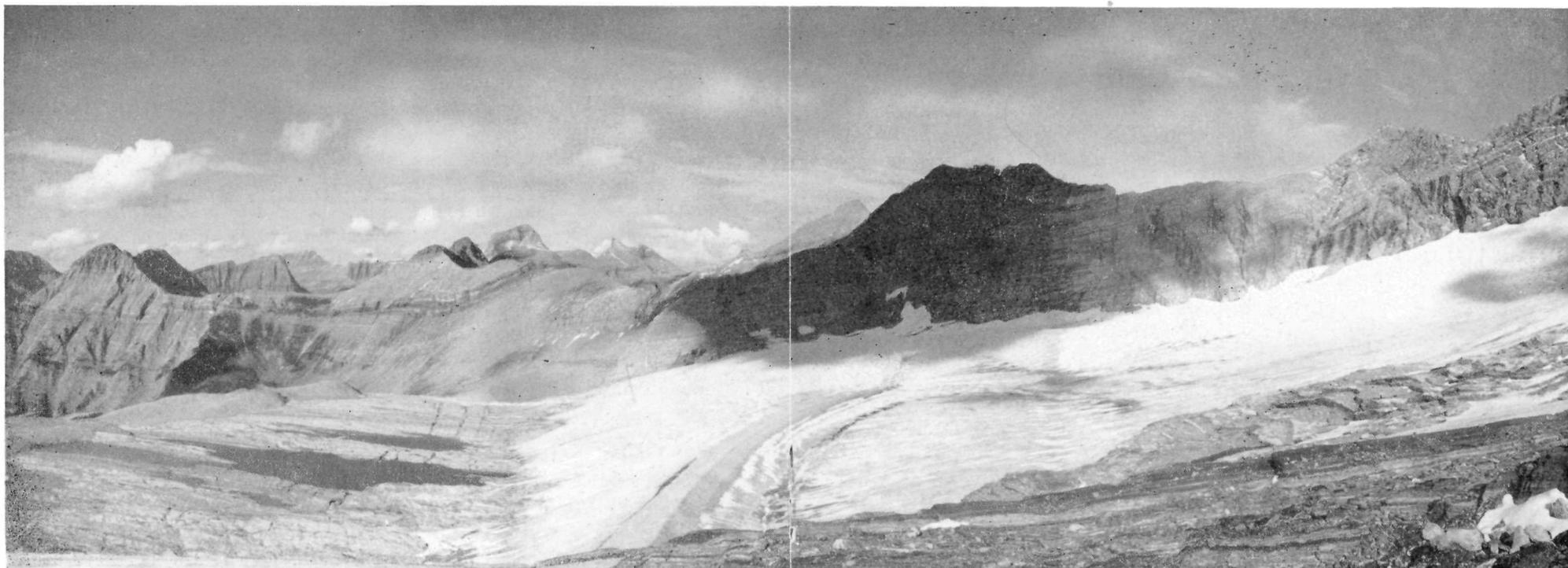
Evidence of these two distinct glacial advances is yielded by the deposits left by the ice. On the east side of the park the lower courses of the major valleys and the adjoining ridges are covered with moraines. The material in them ranges in size from clay to large boulders, and was deposited by glaciers after being transported down the valleys. The debris deposited by the latest stage of glaciation, known as the Wisconsin, is fresh in appearance and contains fragments of all park rocks. Moraines of the earlier stage, because of much greater age, are more weathered. They contain many fragments of diorite, from the layer of rock which appears as a conspicuous black band on many of the mountains, and almost no fragments of limestone, so common in the newest moraine. The diorite is resistant to weathering; the limestone slowly dissolves, thus during the interval between the first and second stages of glaciation most of the limestone boulders disappeared and the resistant diorite remained. The only localities where this older moraine occurs are the crests of the ridges which run eastward from the mountains out onto the plains. On top of Two Medicine Ridge along and just above the highway, fragments of this material have been cemented together into a comparatively hard tillite. Lower down on the slopes the older moraine cannot be found as it is covered by that of the Wisconsin glacier which was less extensive and did not override the ridge crests as did the earlier glaciers. The older debris is also found on top of Milk River Ridge, as the glacier (Wisconsin Stage) from the Cut Bank Valley did not attain the crest, although it did spill northward through the gap in the ridge (the highway now goes through this low place) for a distance of three miles into the Milk River Valley. Swifteurent and Boulder Ridges, north and south of Sherburne Lake, respectively, are also capped with this old moraine.

Following the maximum advance of the Wisconsin glaciers they slowly shrank until about 8,000 years ago when all glacial ice probably disappeared from the mountains. After this there was a warm, dry period during which no glaciers were present. Then about 4,000 years ago the present small glaciers were born. During the period of their existence they have fluctuated in size, probably attaining maximum



PANORAMIC VIEW OF GRINNELL GLACIER AS IT APPEARED IN 1945.

THE CREVASSES IN GLACIER MAY BE OVER 50 FEET DEEP. (BEATTY PHOTO)



PANORAMIC VIEW OF SPERRY GLACIER AS IT APPEARED IN 1946.

NOTE MELT-WATER LAKES TERMINATING AGAINST MORAINES AT EXTREME LEFT (DYSON PHOTO)

dimensions around the middle of the last century. Since then they have been getting smaller.

Park Features Resulting From Glaciation

A glacier is an extremely powerful agent of erosion, capable of profoundly altering the landscape over which it passes.

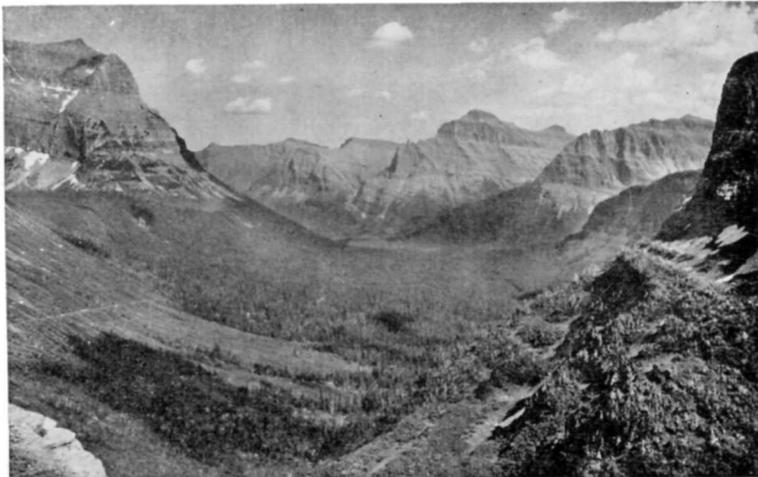
Glaciers erode mainly by two processes, **plucking** and **abrasion**. The first is more active near the head of the glacier, but may take place anywhere throughout its course; abrasion or scouring is effective underneath most sections of the glacier, particularly where the ice moves in a well-defined channel.

In plucking, the glacier actually quarries out masses of rock, incorporates them within itself, and carries them along. At the head of the glacier this is accomplished mainly by water which trickles into crevices and freezes around blocks of rock, causing them to be pulled out by the glacier, and also by the weight of the glacier, squeezing ice into the cracks in the rock. As the glacier moves forward these blocks of rock are dragged or carried along with it. Usually a large crevasse, the **bergschrund**, develops in the ice at the head of a glacier. The bergschrund of most glaciers in the park consists of an opening, usually 10 to 20 feet wide at the top and as much as 50 feet deep, between the head of the glacier and the mountain wall. On Sperry Glacier, however, it is more typical of that found on larger valley glaciers and consists of several conspicuous



ICEBERG LAKE AND CIRQUE. THE SMALL GLACIER SHOWN HERE WHICH PRODUCED THE BERGS NO LONGER EXISTS. (HILEMAN PHOTO)

crevasses separating the firn area (where the snow is compacted into ice) on top of Gunsight Mountain from the glacier proper below. It is at this site that plucking is most dominant because water enters by day and freezes in the rock crevices at night. This quarrying headward and downward finally results in the formation of a steep-sided basin called a **cirque** or **glacial amphitheatre**. Because the cirque is the first place that ice forms and the place from which it disappears last, it is subjected to glacial erosion longer than any other part of the valley. Thus its floor is frequently plucked and scraped out to a comparatively great depth so that a body of water known as a **cirque lake** forms after the glacier disappears. Iceberg Lake lies in one of the most magnificent cirques in the park. The lowest point on the crest of the wall encircling three sides of the lake is more than 1500 feet above the water. Prior to 1940 this cirque contained a small glacier. It had been shrinking rapidly for about two decades, and in the last two or three years of its existence was hardly recognizable as a glacier. Its disappearance is made more remarkable by the knowledge that in 1920 the front of the glacier rose in a sheer wall of ice nearly 100 feet above the surface of the lake. All that remains of this glacier which once kept the lake filled with icebergs each summer is a large bank of snow at the base of the cirque wall at the head of the lake. Other good examples of cirques are those which hold Hidden, Avalanche and Cracker Lakes. The tremendous cliff on the south side of the latter rises 4,100 feet from the lake to the summit of Mount Siyeh. Other notable cirque lakes are Ellen Wilson, Gunsight, Ptarmigan and Upper Two Medicine.



ST. MARY VALLEY FROM LOGAN PASS SHOWING GLACIAL PROFILE. (HILEMAN PHOTO)

Rock fragments of various sizes frozen into the bottom and sides of the ice form a huge file or rasp which abrades or wears away the

bottom and sides of the valley down which the glacier flows. The valley thus attains a characteristic U-shaped cross section, with steep sides (not necessarily vertical) and a broad bottom. A mountain valley cut entirely by a stream does not have such shape because the stream cuts only into the bottom of the valley, whereas a glacier, filling its valley to a great depth, abrades along the sides as well as on the floor. Practically all valleys of the park, especially the major ones, possess the U-shaped cross section. This feature can best be seen by looking down from the head of the valley rather than from the valley floor. Splendid examples are the Swiftcurrent Valley viewed from Swiftcurrent Pass or Lookout; St. Mary Valley from east of Logan Pass; the Belly River Valley from Ptarmigan Tunnel; and Cataract Creek Valley from Grinnell Glacier.

The floors of many of the park's major **U-shaped valleys** instead of having a more or less uniform slope, steeper near the head than farther down, as is usually the case in a normal stream valley, are marked by several steep drops or "steps," between which the valley floor has a comparatively gentle slope. Such a valley floor, throughout its entire course, is sometimes termed the **glacial stairway**. Most of the steps, particularly those in the lower courses of the valleys, are due to differences in resistance of the rocks over which the former ice flowed. On the east side of the Lewis Range, where the steps are especially pronounced, the rock strata of which the mountains are composed dip toward the southwest, directly opposite to the direction of the slope of the valley floors (Figure 1). Thus, as glaciers flowed from the center of

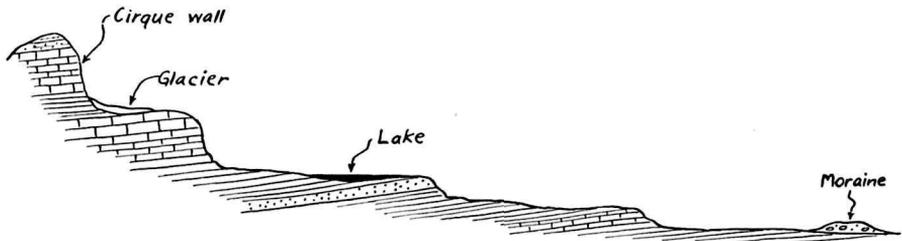


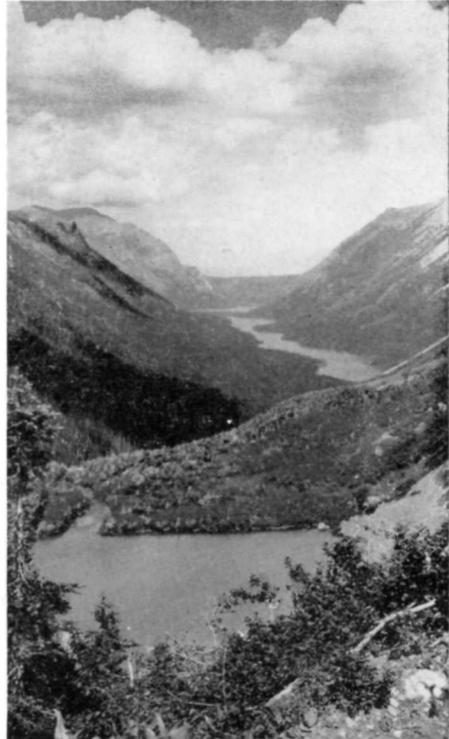
Figure 1. Idealized sketch of a glacial stairway from the arete at the center of the range to the Ice Age moraine at the mouth of the valley.

the range down toward the plains, they cut across the edges of these tilted rock layers; where the ice flowed over weaker beds it was able to scour out the valley floor more deeply creating a "tread" of the glacial stairway. The more resistant rock formations were less easily removed, and the ice stream, in moving away from the edges of these resistant strata, employed its powers of plucking and quarrying to give rise to cliffs or "risers." Lakes dammed partly by the resistant rock

strata now fill depressions scoured out of the weaker rock on the treads (Figure 1). These are **rock-basin lakes**, and where several of them are strung out along the course of the valley they are referred to as **pater noster** lakes because their arrangements resembles that of beads on a string. Well-known examples of such bodies of water are Swiftcurrent and Bullhead Lakes, two of the long series which stretches for seven miles between Many Glacier Hotel and Swiftcurrent Pass. Resistant layers in the lower portion of the Altyn formation, the upper part of the Appekunny, and the upper part of the Grinnell* normally create risers.

The tributaries of glacial valleys are also peculiar in that they usually enter the main valley high above its floor and for this reason are known as **hanging valleys**. The thicker a stream of ice, the more erosion it is capable of performing; consequently, the main valley becomes greatly deepened, whereas the smaller glacier in the tributary valley does not cut down so rapidly, leaving its valley hanging high above the floor of the major valley. The valleys of Virginia and Florence Creeks, tributary to the St. Mary Valley are excellent examples of hanging valleys. A splendid view of Virginia Creek valley may be had from Going-to-the-Sun Road near the head of St. Mary Lake. The valley above Bird Woman Falls as seen from Going-to-the-Sun Road just west of Logan Pass is a spectacular illustration of hanging valley. In addition there are many others, such as Preston Park, on the trail from St. Mary Valley to Piegan Pass; and the Hanging Gardens near Logan Pass.

Even more conspicuous than the large U-shaped valleys and their hanging tributaries are the long, sharp-crested, jagged ridges which form most of the backbone of the Lewis Range. These features of which the Garden Wall is one of the most noticeable, are known as **aretes** and owe their



TYPICAL GLACIAL VALLEY WITH CHAIN OF ROCK-BASIN LAKES. GLENN AND CROSSLEY LAKES IN DISTANCE; UN-NAMED LAKE IN FOREGROUND RESTS IN A HANGING VALLEY AND ITS OUTLET DROPS SEVERAL HUNDRED FEET TO THE MAIN VALLEY. (HILEMAN PHOTO)

* For a brief description of these rock formations see Special Bulletin No. 3 (Geologic Story) of the Glacier Natural History Association.

origin to glaciers. As the former long valley glaciers enlarged their cirques by cutting farther in toward the center of the range, the latter finally was reduced to a very narrow steep-sided ridge, the arete. The imposing height of the Garden Wall can readily be determined by using the layer of diorite as a scale. The conspicuous black band formed by the edge of this layer has an average width of 75 feet. So, from the porch of the Many Glacier Hotel a park visitor can readily see that the Garden Wall, even though five miles distant, is about 4,200 feet high. The height of other aretes can be just as readily obtained, for the band of diorite appears on the faces of most of them. In certain places glaciers on opposite sides of an arete nearly cut through creating a low place known as a **col**, usually called a **pass**. Gunsight, Logan, Red Eagle, Stony Indian and Piegan are only a few of many such passes in the park. At places three or more glaciers plucked their way back toward a common point leaving at their heads a conspicuous, sharp-pointed peak



REYNOLDS MOUNTAIN AT LOGAN PASS—A TYPICAL HORN. (HILEMAN PHOTO)

known as a **horn**. Innumerable such horn peaks occur throughout both the Lewis and Livingstone Ranges. Excellent examples near Logan Pass are Reynolds, Bearhat, and Clements Mountains. Other imposing horns are Split Mountain at the head of Red Eagle Valley, Kinnerly Peak in the Kintla Valley, and Mount Wilbur in Swiftcurrent Valley. The horn peak, because of its precipitous sides, is especially attractive to mountain climbers. The comparatively recent dates of first ascents on many park peaks attest to the difficulties they offer the mountaineer. Mount Wilbur, despite proximity to Many Glacier Hotel and camp, was unclimbed until 1923; Mount St. Nicholas succumbed in 1926, and the only ascent of Kinnerly Peak was made by several members of the Sierra Club in 1937.

Another feature of the park which must be attributed partly to glaciation is the waterfall. There are two principal types, one which occurs in the bottom of the main valleys and one at the mouth of the hanging tributary valleys. The former, exemplified by Swiftcurrent, Red Rock, Dawn Mist, Trick, Morning Eagle and others, is located where streams drop over the risers of the glacial stairway. In other words, resistant layers of rock which the former glaciers were unable to entirely wear away give rise to this type of fall.

Examples of the hanging tributary type of fall which is due directly to the activity of the glaciers are Florence, Bird Woman, Virginia, Grinnell, Lincoln, and many others.

No less conspicuous than the mountains themselves are the lakes. In most instances glaciers have been either directly or indirectly responsible for the origin of the several hundred in the Park. In general, these lakes may be divided into five main types, depending upon their origin.

(1) **Cirque lakes.** This type of lake frequently is circular in outline and fills the depression plucked out of solid rock by a glacier at its source. Some of the most typical examples are listed in the foregoing discussion of cirques.



TRICK FALLS IN THE TWO MEDICINE RIVER
(GRANT PHOTO)

(2) **Other rock-basin lakes.** This type, referred to above, fills basins created where glaciers moved over areas of comparatively weak rock. In all cases the lake is held in by a bedrock dam. A typical example is Swiftcurrent, which lies behind a dam of massive Altyn Limestone layers. The highway, just before it reaches Many Glacier Hotel, crosses this riser of the glacier stairway.

(3) **Lakes held in by outwash.** Most of the large lakes on the west side of the park fall in this category. The dams holding in these lakes are composed of stratified gravel which was washed out from former glaciers when they extended down into the lower parts of the valleys. Lake McDonald, largest in the park, is of this type.



ST. MARY LAKE LOOKING WEST. (HILEMAN PHOTO)

(4) **Lakes held by alluvial fans.** St. Mary, Lower St. Mary, and Lower Two Medicine Lakes belong in this group. These bodies of water may have been rock basin lakes, but at a recent date in their history streams entering the lake valley have completely blocked the valley with deposits of gravel; thus either creating a lake or raising the level of one already present. St. Mary and Lower St. Mary Lakes probably were joined originally to make a lake 17 miles long. More recently Divide Creek, entering this long lake from the south, built an alluvial fan of gravel where it entered the lake. This fan was large enough to cut the lake into the two present bodies of water. The St. Mary Entrance Station at the eastern end of Going-to-the-Sun Highway is located on this alluvial fan, the form of which can readily be distinguished from a point along the road at the north side of the upper lake near its outlet.

(5) **Moraine lakes.** Most lakes with moraines at their outlets are partly dammed by outwash or rock ridges. The most spectacular example is Josephine Lake. The moraine which is partly responsible for the lake appears as a prominent hill, particularly when viewed from Many Glacier Hotel.

Another type of moraine lake, which occurs only at Sperry and Grinnell Glaciers, has already been mentioned. It differs from all other park lakes in having a glacier for part of its shoreline. There are two of these lakes at Sperry and one at Grinnell. Despite their small size, they are tremendously interesting, not only because of their relation to the glacier, but also because they are ordinarily filled with icebergs throughout the summer. Their surfaces often remain frozen until mid-summer.

There are several types of minor importance, the principal one of which is that formed by a landslide damming a valley.

One cannot remain long in Glacier National Park without noticing the varying colors of its lake waters. In fact this feature is so striking that ranger-naturalists probably are questioned more about it than about any other feature or phenomenon. To find the answer we must go again, as in so many instances, to the glaciers. As the ice moves it continually breaks rock fragments loose. Some of these are ground into powder as they move against each other and against the bedrock under the glacier. Most types of rock, especially the limestones and shales on which the park glaciers rest, when ground fine enough yield a gray powder. All melt-water streams issuing from glaciers are cloudy or milky from their load of this finely ground "rock flour."

Water from Grinnell Glacier is so laden with rock flour that the small lake along the edge of the ice into which the water pours is nearly white. Much of the silt is deposited in this lake, but enough is carried downstream to give Grinnell Lake a beautiful turquoise hue. Some of the very finest sediment which fails to settle in Grinnell Lake is carried a mile farther to Josephine Lake to give it a blue-green color. Even Swiftcurrent Lake, still farther downstream, does not contain clear water.

The rock flour which colors these as well as other park lakes can also be seen in the streams. Baring Creek at Sunrift Gorge (See p. 19 in Motorist's Guide) is milky with powdered rock from Sexton Glacier. Cataract Creek along the trail between Josephine and Grinnell Lakes is noticeably milky, extraordinarily so in mid-afternoon on very warm days. At such times melting of the glaciers is accelerated and more silt is then supplied to the streams.

Part of Sperry Glacier, in contrast to Grinnell, rests on a bright red shaly rock (known to the geologists as argillite) which yields a red-gray powder when finely ground. Hence the water in several small lakes adjacent to the glacier has a pinkish tint.

Although a large number of park streams are fed by glaciers there are many others, particularly in the south and west sections, which have no ice as their source. On a trail trip from Sunrift Gorge to Virginia Falls, one is certain to be impressed by the extreme clarity of the water in Virginia Creek. For half a mile below the falls the trail follows this cascading torrent from one crystal pool to another. So clear is the water that we are apt to mistake for wading pools places where the water may be five or more feet deep. Snyder Creek near Lake McDonald Hotel nearly rivals Virginia Creek in clarity. The sources of these two streams obviously are not melting glaciers.

From the foregoing discussion, it is evident that glaciers constitute one of the principal controlling factors in the color of the water in park streams and lakes. Where there are no ice masses streams are clear, and where glaciers occur the water possesses many shades varying from clear blue through turquoise to gray, and in rare cases even pink.

Although the former large glaciers of the Ice Age transported huge amounts of rock debris down the valleys of the park, the **moraines** which they deposited are, as a rule, not conspicuous features of the landscape. The Going-to-the-Sun Highway, however, crosses several accumulations of moraine in which road cuts have been made. The road traverses a

number of such places along the shore of Lake McDonald. Because of the large proportions of rock flour (clay) in these accumulations, the material continually slumps, sometimes sliding onto the road surface. One of these cuts has been partly stabilized by a lattice-like framework of logs. The largest excavation in moraine along the highway is located about three miles east of Logan Pass just below the big loop where the road crosses Siyeh Creek. The surfaces of many boulders in this moraine are marked by grooves and scratches, imparted to them as they were scraped along the side of the valley by the glacier.



MORAINE NEAR GRINNELL GLACIER IS 120 FEET HIGH. THE GLACIER EXTENDED NEARLY TO TOP OF MORAINE 50 YEARS AGO. (DYSON PHOTO)

A small moraine is exposed along the exit road from the parking lot at Many Glacier Hotel. It contains a number of small red boulders, the sources of which are the red rock ledges in the mountains several miles up the Swiftcurrent Valley, plainly visible from the hotel.

One of these ancient moraines which, unlike most of the others, is a prominent feature of the landscape, consists of a series of mounds (25 to 100 feet high) extending from Swiftcurrent Cabin Camp down the valley on the north side of the road to a point near the entrance to Many Glacier Ranger Station. Some of the cabins are actually situated in a space between two of the highest mounds.

Surrounding all existing park glaciers are **recent moraines** varying in height from a few feet to more than two hundred. So recently have they accumulated that little or no vegetation is growing on them. They are particularly striking at Grinnell, Sperry, Blackfoot, Agassiz and Sexton Glaciers. On the last



LOOKING SOUTH ALONG THE GRINNELL GLACIER ICE FRONT. NOTE CREVASSES ALONG WHICH BERGS ARE BREAKING OFF. (DYSON PHOTO)

few yards of the spectacular Grinnell Glacier trail all persons who make the trip to the glacier must climb over the moraine before setting foot on the ice. From this vantage point on the highest part of this moraine the visitor can look down upon a huge crevassed mass of ice lying in a stupendous rock-walled amphitheatre, then merely by facing the opposite direction, he will see unfolded before his view one of the most colorful vistas in the Park. More than a thousand feet below in the head of a splendid U-shaped valley lies the turquoise gem of Grinnell Lake. A mile farther away the blue surface of Lake Josephine stands out in sharp contrast to the dark green of the spruce which lines its shores. High above he can see the red summit of Mount Allen carrying its white snowbanks into the deep blue of a Montana sky. Despite this magnificence the visitor must soon turn his attention to the tremendous accumulation upon which he stands, for it is no less interesting than the mountains and lakes. Among the many boulders which lie along the path are two prominent limestone blocks each 10 to 15 feet in diameter. The underside of one was grooved and polished as the ice pushed it across the rock surface underlying the glacier. The other, partially embedded in the moraine, has a polished

upper surface because the glacier flowed over it for a time. Both these boulders, although now nearly 300 yards from the ice front, were covered by the glacier until about 20 years ago.

Because of shrinkage many of the glaciers are no longer in contact with these newer moraines. In some cases a quarter of a mile of bare rock surface intervenes between the moraine and the glacier which made it.

A few glaciers have disappeared within recent years, but their moraines remain as evidence of former glacier activity. One of the most notable examples is afforded by Clements Glacier, a small body of ice which existed until about 1938 in the shadow of Clements Mountain at Logan Pass. Its edge was bordered by a ridge-like moraine nearly a hundred feet high. Today, the trail from Logan Pass to Hidden Lake skirts the outside edge of the moraine. Should the hiker leave the trail and climb the few yards to the top of this moraine he could see it stretched out before him as a giant necklace encircling the base of Clements Mountain, but between mountain and moraine, where a few years ago the glacier lay, he will see only bare rock or drifted snow.

Despite recent rapid shrinkage of glaciers and the disappearance of some, Glacier National Park still is a land of ice, yet when the visitor views its present day glaciers and its sublimely beautiful mountain



CLEMENTS MOUNTAIN AND GLACIER. THE GLACIER HAS SINCE DISAPPEARED. (HILEMAN PHOTO)

scenery he should not be unmindful of the powerful forces which, working during many thousands of years, have brought it all about. Then, and only then, can he properly appreciate the magnificence which Nature has so generously bestowed upon us.

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The Superintendent
Glacier National Park
West Glacier, Montana

GLACIER NATURAL HISTORY ASSOCIATION, Inc.

Glacier National Park

West Glacier, Montana

Organized for the purpose of cooperating with the National Park Service by assisting the Interpretive Division of Glacier National Park in the development of a broad public understanding of the geology, plant and animal life, history, Indians, and related subjects bearing on the park region. It aids in the development of the Glacier National Park library, museums, and wayside exhibits; offers books on natural history for sale to the public; assists in the acquisition of non-federally owned lands within the park in behalf of the United States Government; and cooperates with the Government in the interest of Glacier National Park.

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