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Glaciers and Glaciation in Glacier National Park, Montana

by

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INTRODUCTION

Glacier National Park presently contains only about 50 small glaciers. Many of these glaciers are in remote and inaccessible areas rarely visited by anyone. However, the park is applicably named as the spectacular scenery that surrounds the visitor everywhere is due to the great glaciers that occupied the park and surrounding region until quite recently (geologically speaking, of course). These great glaciers scoured the high areas of the park forming the jagged peaks and sheer walls that we find so breath-taking. In the lower areas of the park these glaciers deposited their great loads of debris damming many of the valleys and forming the beautiful large lakes that the park is noted for. This pamphlet will provide you with information about the glacial history of Glacier National Park, features of glacial erosion and deposition in the park that you can see first hand, and some general information on glaciers and ice ages.

THE GLACIAL HISTORY OF THE GLACIER NATIONAL PARK REGION FROM THE TIME OF THE LAST MAJOR GLACIATION TO THE PRESENT

During the maximum extent of the last major glaciation (the Wisconsin glaciation) about 20,000 years ago, much of northwestern Montana, including the Glacier National Park region, was covered by glaciers (fig. 1). To the west, the Cordilleran ice sheet advanced into this region from Canada. The easternmost lobe of that ice sheet, the Flathead lobe, flowed south into the present-day Flathead Lake area. To the east, the Shelby lobe of the Laurentide ice sheet advanced from Canada across the Montana plains almost as far south as the present-day city of Great Falls. Between these two large ice sheets, valley glaciers and ice fields flourished in the mountains along the Continental Divide. West of the divide, some of these glaciers merged with the Flathead lobe of the Cordilleran ice sheet. East of the divide, glaciers advanced beyond the mountain front onto the plains where they spread out laterally to form large piedmont glaciers.

Deglaciation of the Glacier National Park region is thought to have been completed more than 10,000 years ago. A volcanic ash that erupted about 11,200 years ago from Glacier Peak volcano, about 350 miles to the west in Washington State, has been identified at nine sites in the Glacier National Park region (fig. 2), where it rests on glacial deposits. Therefore, this ash indicates that the underlying glacial deposits are at least 11,200 years old. The locations at which this ash was found indicate that deglaciation of the Glacier National Park region was at least 90 percent complete by that time. Remaining glaciers, if any, were confined to valleys within the Livingston and Lewis Ranges. By 10,000 years ago, remaining glaciers probably were confined to those cirques and well-shaded niches where present-day glaciers and snowfields lie.

During the next several thousand years, temperatures in the Glacier National Park region were several degrees warmer than they are now and there were fewer glaciers. Some of the larger glaciers may have survived this warm period, but many of the park's smaller glaciers probably did not exist at this time. This warm period ended sometime between 5,000 and 3,000 years ago. After it ended existing glaciers probably increased in size, others may have been formed.

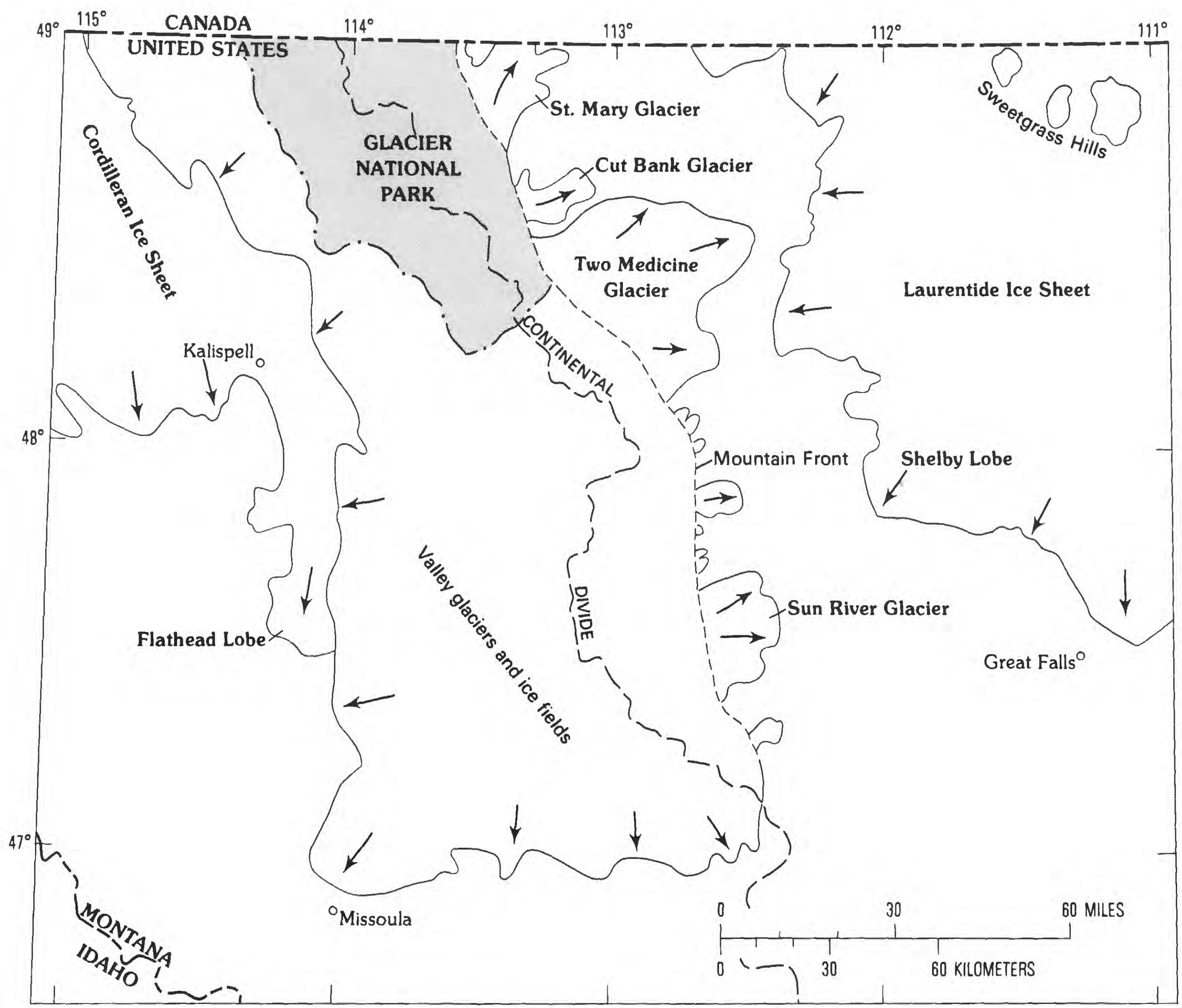

Figure 1. The Glacier National Park region showing the extent of glacial ice about 20,000 years ago. Arrows indicate ice flow directions.

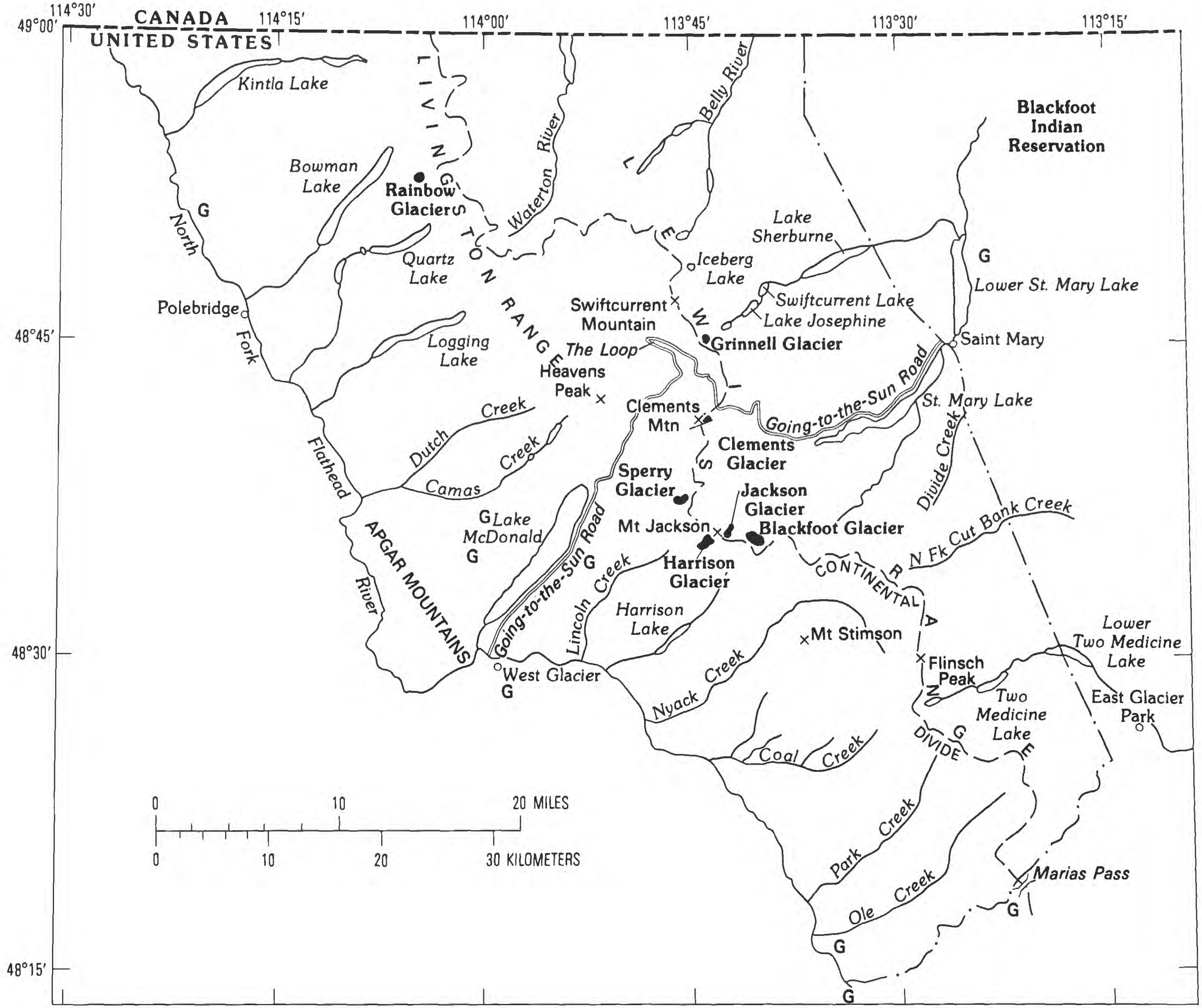

Figure 2. Index map of the Glacier National Park region. "G" denotes those sites where a Glacier Peak ash has been found.

A significant advance of glaciers around the world, referred to as the "Little Ice Age", occurred between about AD 1500 and 1900. In Glacier National Park, glaciers reached their maximum extent during the mid-19th century. Although glaciers produced during this advance were small compared to those of full-glacial conditions, this advance was the most extensive since the end of the Wisconsin glaciation. During the Little Ice Age, there were about 150 glaciers in the park. These glaciers ranged in size from small ice bodies of only a few acres to the Blackfoot Glacier, which covered about 1875 acres and encompassed the area of the present-day Blackfoot and Jackson Glaciers. The Mt. Jackson area of the park contained 27 glaciers that totaled about 5330 acres at that time.

Since the mid-19th century, glaciers in Glacier National Park have shrunk drastically. Retreat rates were slow from the mid-19th century until about 1920. However, from 1920 to the mid-1940's, above-average summer temperatures and below-average annual precipitation in the Glacier National Park region caused the glaciers to retreat rapidily; many disappearred altogether. After the mid-1940's, the overall retreat rates slowed. A study by the U.S. Geological Survey in 1979 determined that 17 of the 27 glaciers formerly present in the Mt. Jackson area during the mid-19th century no longer existed. The remaining glaciers covered only about 1830 acres.

Today, only about 50 small glaciers remain in Glacier National Park. These glaciers range in size from just a few acres to the Blackfoot Glacier (fig. 3), the largest in the park with an area of about 430 acres in 1979. Other sizeable glaciers in the park include the Harrison (370 acres), Rainbow (260 acres), Sperry (250 acres), Jackson (250 acres), and Grinnell (225 acres).

GLACIERS

A **glacier** is a perennial mass of moving ice. It forms by the compaction and recrystallization of snow into ice, which then moves slowly downslope. Glaciers form in areas where more snow falls over a number of years than melts. These conditions presently exist at high latitudes, such as in Antarctica, Greenland, and the Candian Arctic, or at high altitudes, such as in the Himalayas, the Andes, and the Alps. As snow accumulates and thickens, it is compressed under its own weight and changes into dense, solid, glacial ice. Although we think of ice as being hard and brittle, under enormous weight it behaves like a viscous fluid, such as cold tar, and flows downslope. Some of this flow is internal in which ice crystals are deformed under the tremendous weight of the overlying snow and ice. In addition, a glacier also moves downslope by slippage along its base. A glacier flows from an area of snow accumulation to an area of net ice loss, where yearly melting exceeds accumulation. Large glaciers, such as many in Alaska, commonly move several feet per day. Small glaciers, such as those in Glacier National Park, move about 10 to 20 feet per year.

An **ice sheet** is a very large glacier that covers a broad land surface and spreads outward in all directions. For instance, the Antarctic ice sheet is thousands of feet thick and covers almost the entire continent of Antarctica. **Valley glaciers** are tongue-like masses confined within mountain valleys. **Ice fields** are large glaciers consisting of many interconnected valley glaciers covering all but the highest peaks and ridges of a mountainous region. Good examples of valley glaciers and ice fields can be see today

Figure 3. Blackfoot Glacier, the largest glacier in Glacier National Park.

in Banff and Jasper National Parks in Canada. **Piedmont glaciers** form when valley glaciers flow out beyond a mountain front and spread out laterally into broad lobes. The Malaspina Glacier in Alaska is a classic example of this kind of glacier. A **cirque glacier** is a small valley glacier that is confined to the high basin (cirque) at the upper end of a mountain valley. A **snowfield** is a perennial mass of ice and snow too small to move like a glacier. A visitor to Glacier National Park can see many cirque glaciers and snowfields in the higher regions of the park.

ICE AGES

Ice ages have occurred throughout the history of the earth. Geological evidence suggests that the first ice age may have occurred more than 2 billion years ago. These past ice ages may have lasted 20 to 50 million years. The most recent ice age (which really hasn't ended) began several million years ago, and as many as 17 major glaciations have occurred during the last 2 million years. These major glaciations were separated by periods of warmer climatic conditions and reduced ice cover. During the maximum extent of the last major glaciation, about 20,000 years ago, large ice sheets covered much of North America, Europe, and Siberia. In addition, the Greenland and Antarctic ice sheets were thicker and more extensive than today. Altogether, glaciers covered about 30 percent of the world's land surface at that time compared to the 10 percent they cover today.

Many processes have been proposed to explain the cause of ice ages. These processes include continental drift, mountain building, volcanic activity, changes in the sun's output, and changes in oceanic or atmospheric circulation. Currently, many scientists favor the Milankovitch theory, named for a Yugoslavian mathematician. This theory proposes that climate change is caused by changes in the geometrical relationship between the Earth and the Sun, including variations in the tilt of the Earth's axis and ellipticity of the Earth's orbit.

GLACIAL FEATURES IN GLACIER NATIONAL PARK

Glacier National Park takes its name from the spectacular scenery formed by the large glaciers that covered the park in the past. Among the most distinctive features are the glacially eroded **U-shaped valleys** (fig. 4). The cross-profiles of these valleys contrast with the sinuous V-shaped valley profiles cut by streams. As a glacier moves downslope, some of the rock debris from the underlying bedrock is incorporated into the base of the glacier. This rock debris acts as a giant rasp and grinds the valley floor and sides producing the characteristic U-shape typical of glaciated valleys. An excellent example of an U-shaped valley is the McDonald Valley (fig. 5) as seen from Going-to-the-Sun Road two miles or so above "the Loop" (fig. 2).

Hanging tributary valleys (fig. 4) are formed on the sides of major glaciated valleys. During glaciation, erosion of the valley floor by the smaller tributary glaciers cannot keep pace with the greater erosive power of the larger glacier in the main valley. Upon deglaciation, the tributary valleys are left hanging high up on the sides of the main valley. Fine examples of hanging valleys can also be seen from Going-to-the-Sun Road, especially along St. Mary Lake.

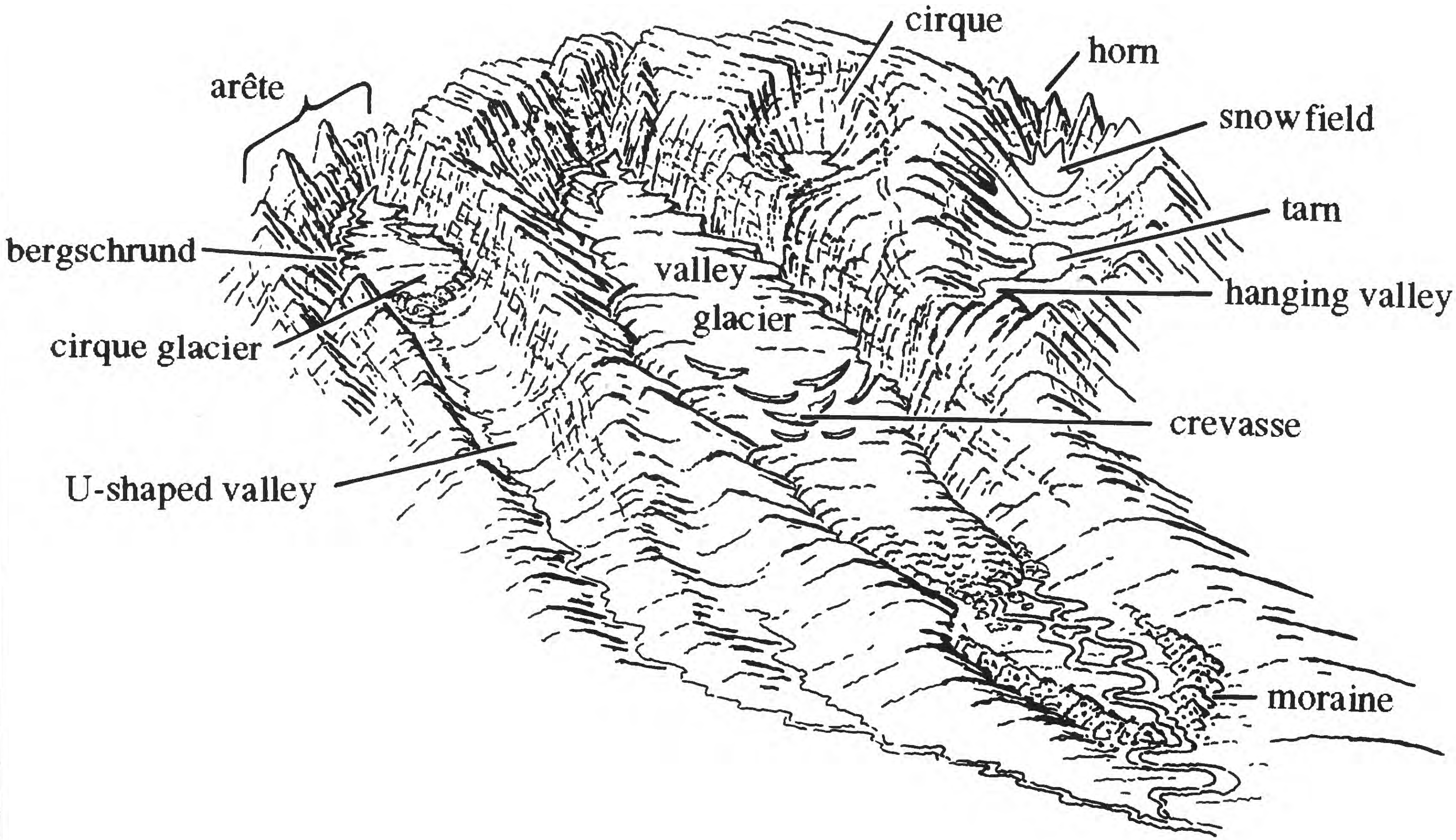

Figure 4. diagram showing various glacial features, sketch by T.R. Alpha, U.S. Geological Survey.

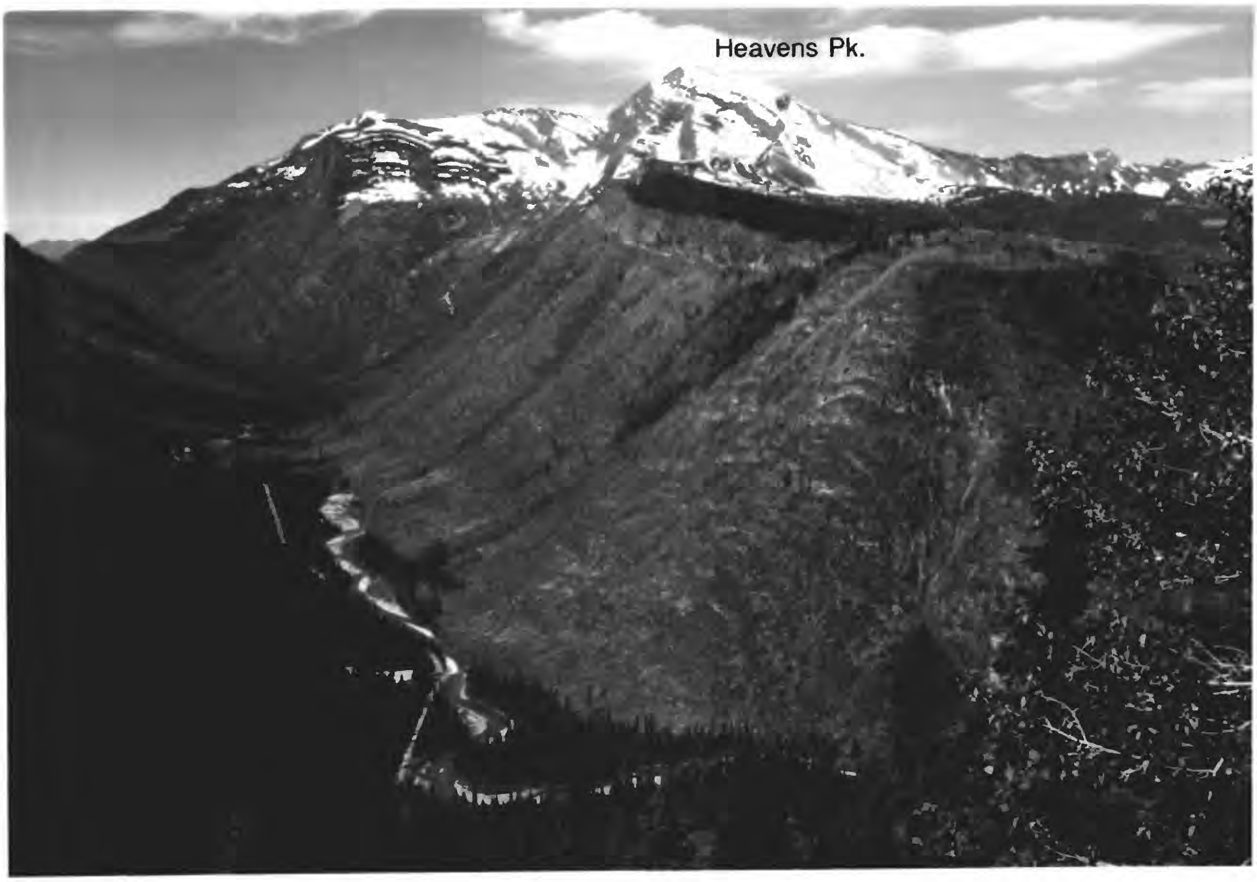

Figure 5. MacDonald Valley, a U-shaped glacial valley, as seen from Going-to-the-Sun road. Photo by O.B. Raup, U.S. Geological Survey.

An **arête** is a narrow, jagged, sharp-edged ridge formed by glaciers sapping away at a ridge from opposite sides. The Garden Wall is an excellent example of such a feature (fig. 6). A **horn** is a steep-sided pyramidal-shaped mountain peak formed by the headward erosion of glaciers back-cutting into the mountain from three or more sides. Clements and Swiftcurrent Mountains, Mount Stimson, and Flinsch Peak (fig.7) are some examples of horns in the park. A **cirque** is a steep-walled amphitheater produced by glacial erosion at the head of a valley. A **tarn** is a lake, commonly set in the floor of a cirque (fig. 7). Iceberg Lake is a tarn set in the floor of a spectacular cirque.

Till is the unsorted, rock debris carried and deposited by a glacier. The debris can range in size from very finely powered rock to great blocks of rock the size of a house. Much of the lower areas of Glacier National Park, such as McDonald Valley, are covered by a blanket of till as much as 100 feet thick in places. As a glacier moves, till may accumulate along its front and sides. After the glacier retreats, these ridge-like accumulations of till, which are called **moraines**, are left behind as evidence of former larger glaciers (fig. 8). Fresh, bouldery moraines formed during the Little Ice Age can be seen in front of the former Clements Glacier in the Logan Pass area and in front of the large snowfield on Heavens Peak, seen from Going-to-the-Sun Road, as well as in many other locations in the park. Also Bowman and Lower Kintla Lakes are dammed by large hummocky moraines, as much as a hundred feet thick, formed by glaciers in those valleys about 12,000 or 14,000 years ago. Today, these moraines are covered by forest and small ponds and not as obvious to an observer as those formed during the Little Ice Age.

Polish and **striations** are formed by the abrasive action of rock debris carried along the base of a glacier as it moves over its bed. Striations range from fine hairline scratches to large grooves. Good examples of polish and striations can be seen in front of many of the present-day glaciers (fig. 9) and snowfields in the park and in other areas where bedrock is exposed. Also, many of the rounded and smoothed boulders in till throughout the park are polished and striated.

SPERRY AND GRINNELL GLACIERS

Two well-known and frequently visited glaciers in Glacier National Park are the Sperry and Grinnell. Although small compared to many of the worlds glaciers, both of these glaciers exhibit features characteristic of glaciers around the world, such as crevasses, bergschrunds, firn, and moraines. A **crevasse** (fig. 10) is a vertical crack in a glacier resulting from the differential movement of the ice. Crevasses commonly occur where ice flows over a ledge on the valley floor. A **bergschrund** is the deep crevasse at the head of a glacier where the moving glacial ice pulls away from the cirque headwall. The surface of the glacier commonly consists of **firn**, an aggregate of small ice granules resembling what skiers call "corn snow". Snow gradually recrystalizes into firn through the summer; firn gradually changes to glacial ice through which water can no longer flow.

Figure 6. The Garden Wall, an arête as seen from the the east, Bishops Cap area.
Photo by O.B. Raup, U.S. Geological Survey.

Figure 7. Flinsch Peak, a glacial horn, with Oldman Lake, a tarn, in the foreground.

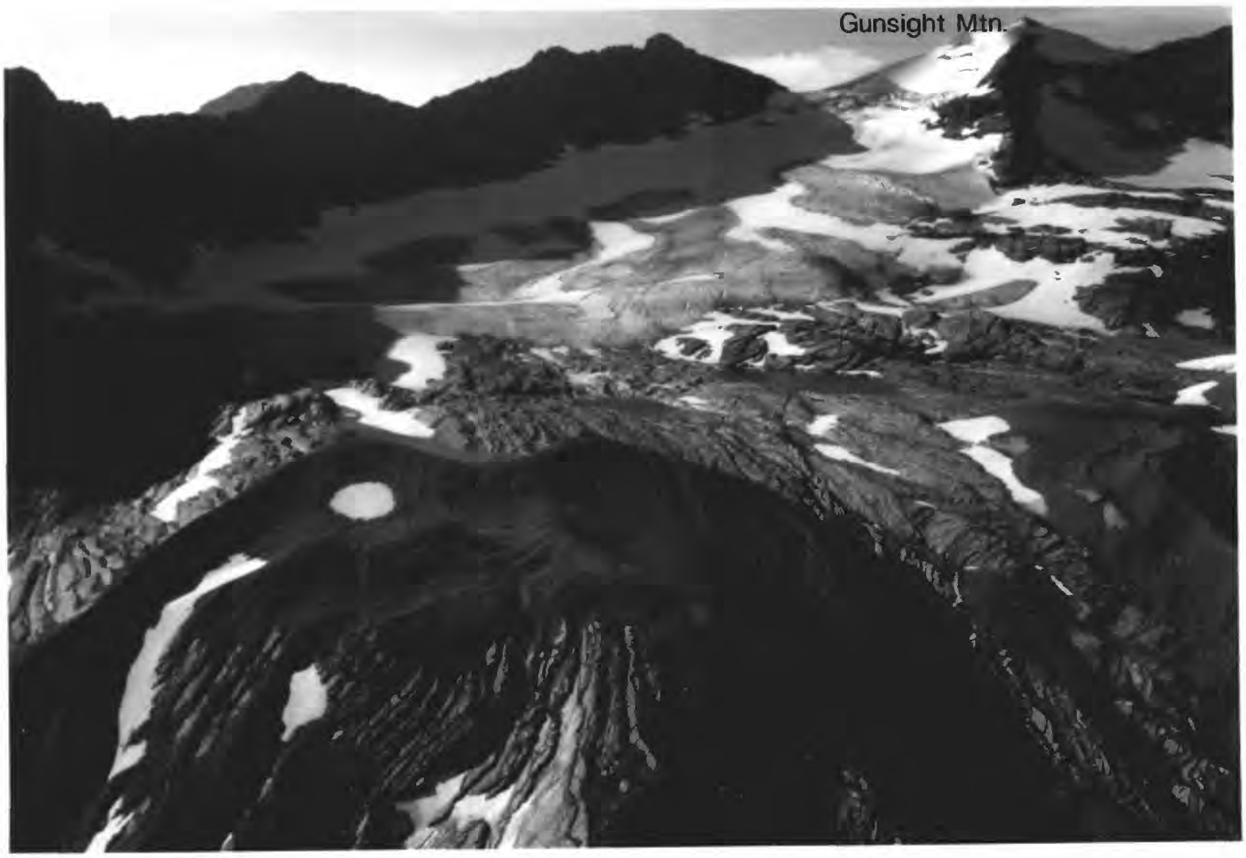

Figure 8. Little Ice Age moraines in front of the Sperry Glacier.

Figure 9. A polished and striated surface in front of the Sperry Glacier.

Figure 10. A crevasse in the Grinnell Glacier. Photo by O.B. Raup, U.S. Geological Survey.

The Sperry Glacier is on the west side of the Continental Divide (fig. 2) and can be reached by a steep trail 10 miles long that begins near the upper end of Lake McDonald. Persons wanting to visit the glacier should plan to stay overnight at the Sperry campground, then hike the remaining 4 miles to the glacier early the next day.

Sperry Glacier was named for Dr. Lyman Sperry, a professor at Oberlin College who discovered the glacier in 1895. Since that time, the glacier has retreated drastically (fig. 11). During the mid-19th century, the Sperry Glacier was about 960 acres. By 1927, it had shrunk into one large and two smaller glaciers. The two smaller glaciers, which soon disappeared, lay against the northeast face of Edwards Mountain and the area southeast of Comeau Pass. By 1984, the Sperry Glacier had further shrunk into a single ice body of about 250 acres, lying against the northern flank of Gunsight Mountain.

Grinnell Glacier is on the eastern side of the Continental Divide (fig. 2), at the head of Grinnell Creek. The glacier can be reached by a 5-mile trail begining near Swiftcurrent Lake that follows the shores of Swiftcurrent and Josephine Lakes. From the head of Josephine Lake, the trail climbs 1,500 feet to the glacier. Grinnell Lake, which can be seen from above by hikers on the trail, has a milky-green color. This color is due to the presence of **glacial flour**, a very fine rock powder suspended in the water that forms when rocks embedded in the base of a glacier grind against the underlying bedrock. Meltwater then carries the glacial flour into the creek and downvalley into the lake.

Grinnell Glacier was named for George Grinnell, an editor of Forest and Stream, an outdoor magazine published in the late-19th century, who in 1887 was among a party that was the first to reach the glacier. At that time, the glacier consisted of two parts, a steep upper part (The Salamander) lying on a narrow bench and connected to the lower main ice mass (present-day Grinnell Glacier) by an icefall near its southern end. When this icefall disappeared in about 1927, the Grinnell Glacier was severed into two parts. Like Sperry Glacier, Grinnell Glacier has retreated drastically since the mid-19th century (fig. 12), when it covered about 500 acres (585 including the Salamander and the connecting ice fall). In 1984, the Grinnell Glacier consisted of a single ice body of about 225 acres lying against the northern flank of Mount Gould.

MAN AND THE FUTURE

At the present time, we live in a period of moderate climatic conditions, when large ice sheets cover only Antarctica and Greenland. Evidence suggests that these periods of moderate climatic conditions represent only about 10 percent of the last 2 million years. During this time, interglacial stages have lasted only about 10,000 years each. Our present interglacial stage started more than 10,000 years ago and, hence, could end soon. However, future climate changes may now also be affected by our pollution of the environment. Carbon dioxide in the atmosphere has increased about 25 percent from its preindustrial levels of the early 19th century, owing mainly to the increased use of fossil fuels and the destruction of tropical forests. Many climatologists believe that a "greenhouse effect" caused by this addition of carbon dioxide into the atmosphere will further warm the earth. How these two opposing forces --a natural climatic cooling versus a warming caused by society's reliance on fossil fuels-- will interact is not known at the present time.

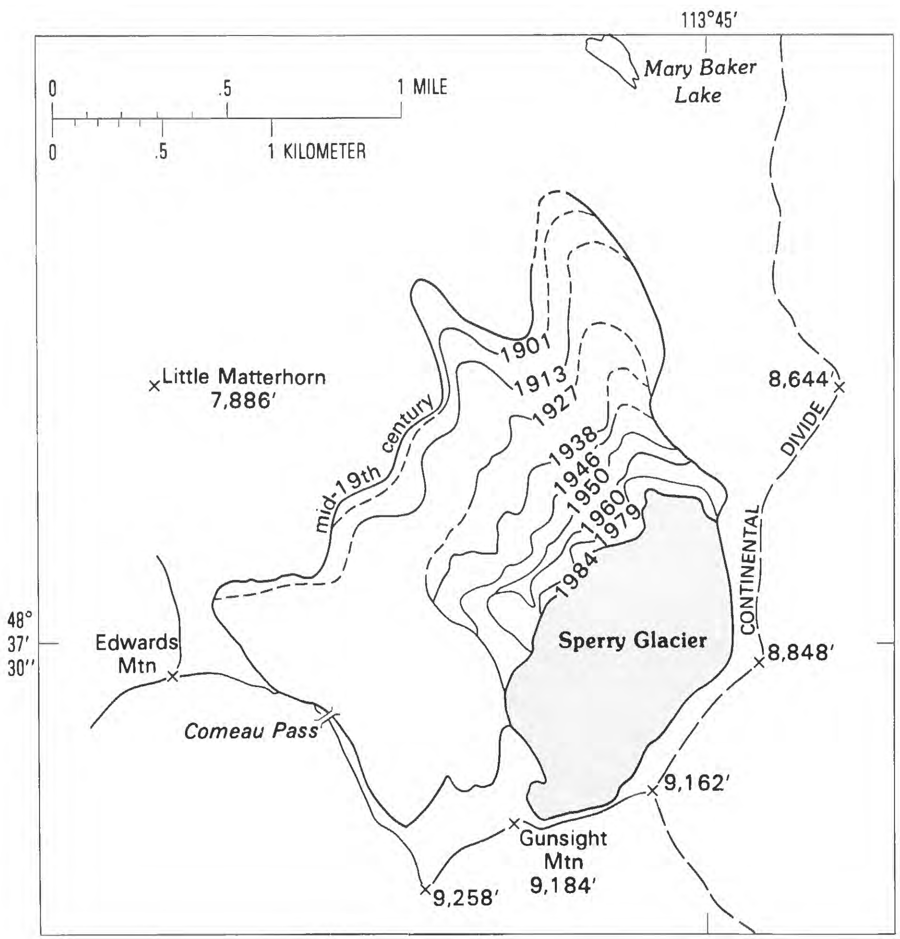

Figure 11. Sperry Glacier, showing shrinkage of this glacier from the mid-19th century to 1984.

Table 1. Area of Sperry Glacier at various times since the mid-19th century.

Year	Area (acres)
mid-19th century	960
1901	915
1913	830
1927*	480
1938	390
1946	330
1950	305
1960	285
1966	275
1979	260
1984	250

*By 1927, the Sperry Glacier had separated into one main and two smaller ice bodies. These smaller ice bodies lay along the northeast face of Edwards Mountain and the area southeast of Comeau Pass before they melted away. Measurements from 1927 and later are for the main ice body (present-day Sperry Glacier) only.

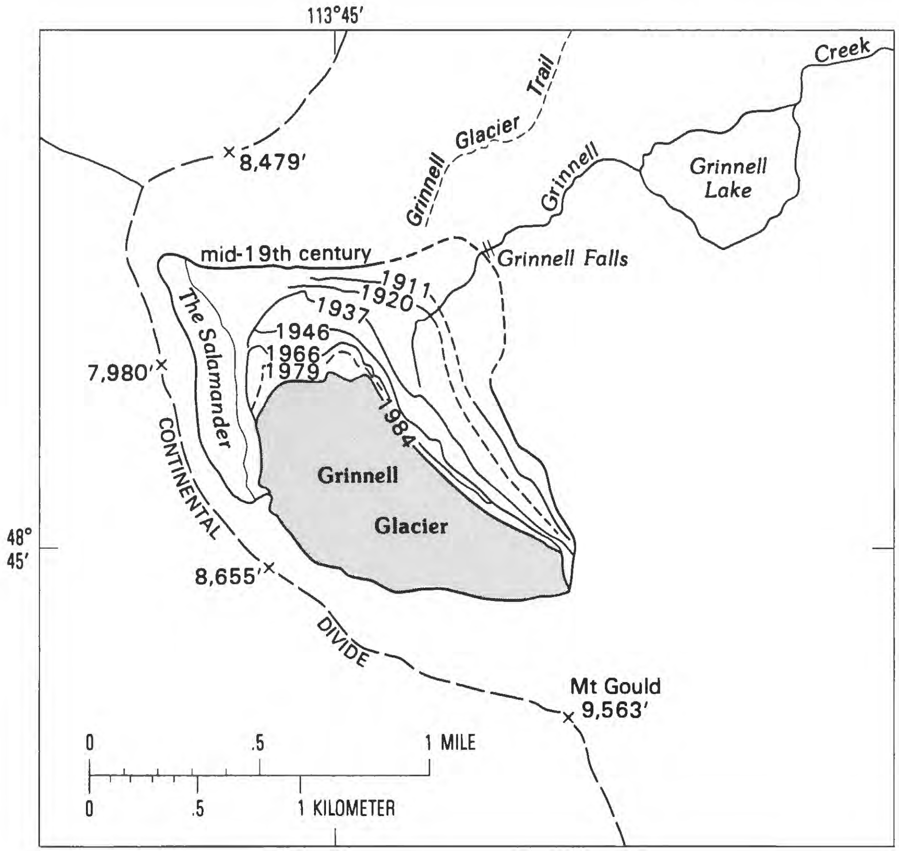

Table 2. Area of Grinnell Glacier at various times since the mid-19th century.

Year	*Area (acres)
mid-19th century	500
1900	470
1911	415
1920	380
1937	330
1946	280
1950	275
1960	260
1966	255
1979	245
1984	225

*Areas given are only for the present-day Grinnell Glacier and do not include the Salamander ice body.

Figure 12. Grinnell Glacier, showing shrinkage of this glacier from the mid-19th century to 1984.