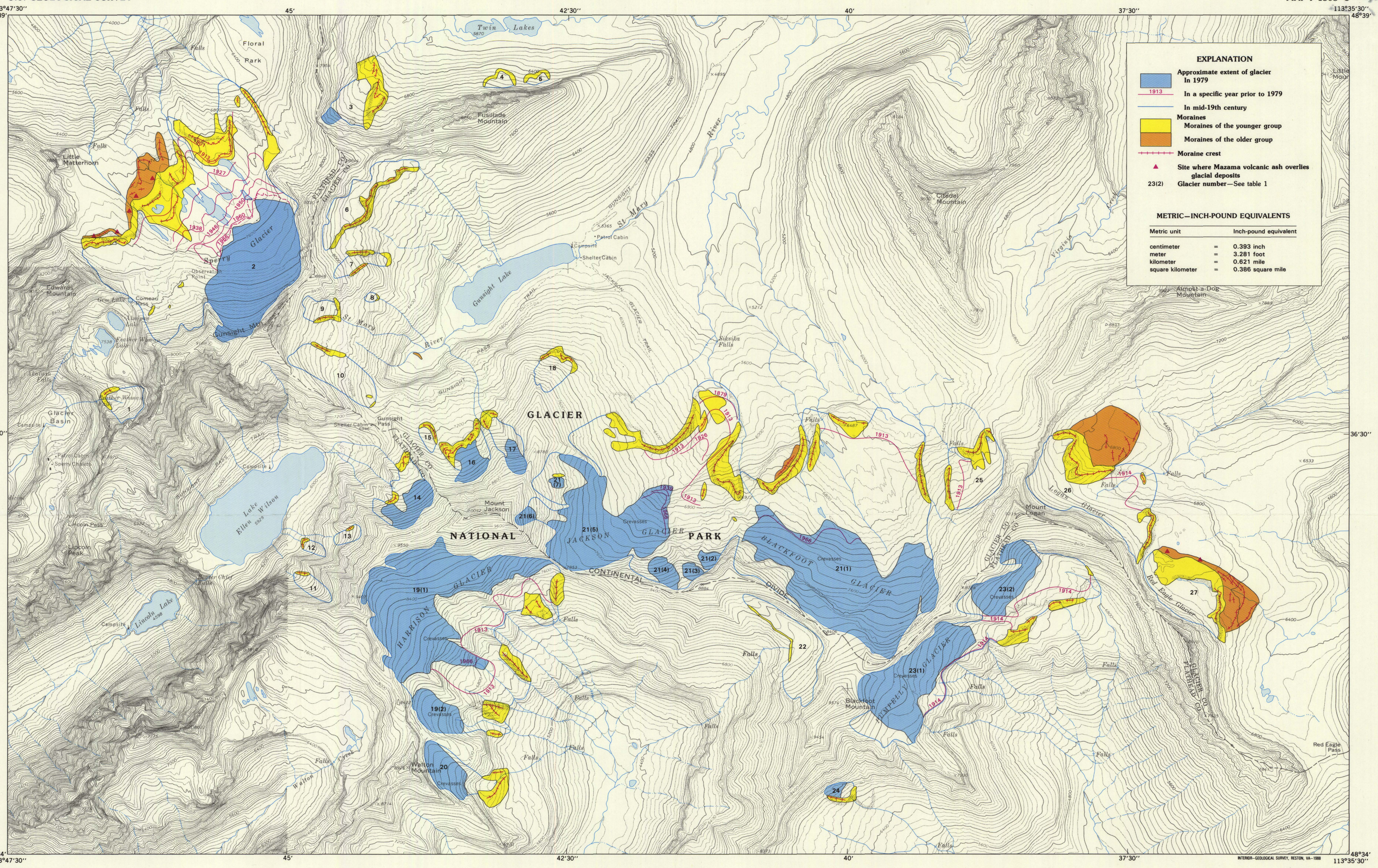

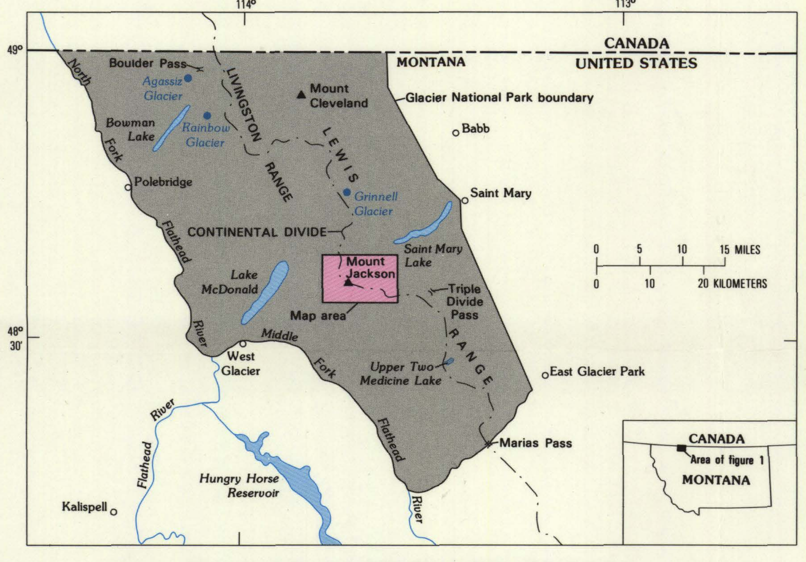

Figure 1.—Index map of the Glacier National Park region.

Figure 2.—The Blackfoot Glacier, the largest glacier in Glacier National Park. Note the crevasses and bluish-white glacial ice exposed at the lower margins of the glacier.

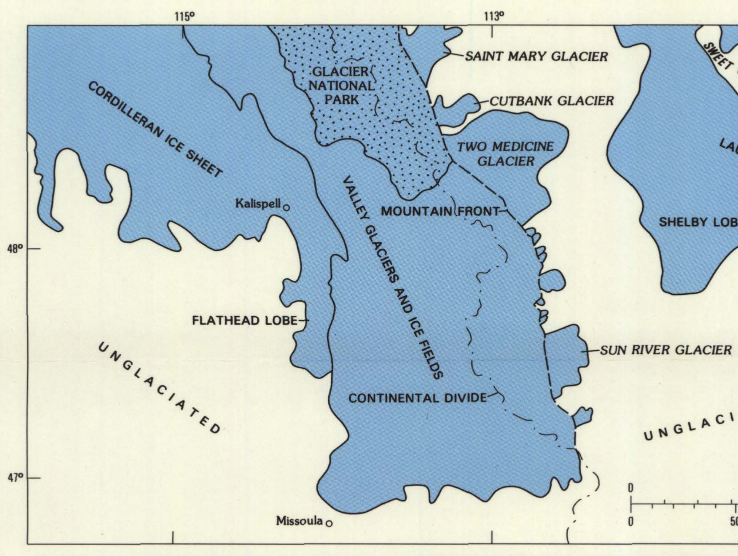

Figure 3.—Generalized paleogeographic map of northwestern Montana showing late-Wisconsin glaciers. (Modified from Alden, 1932, 1953; Calhoun, 1906; Colton and others, 1961; and Waitt and Thorson, 1983.)

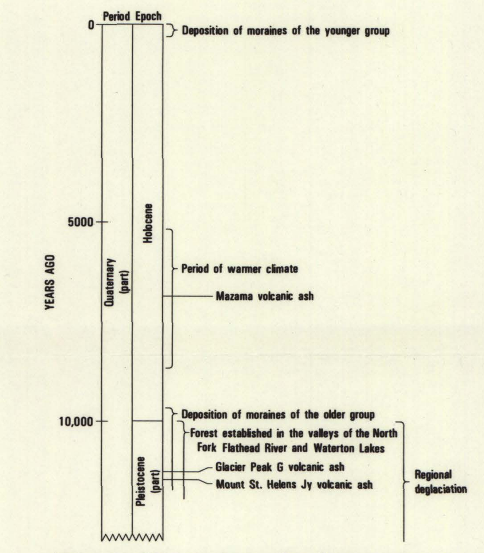

Figure 4.—Diagram showing late Quaternary events in the Glacier National Park region.

INTRODUCTION

Glacier National Park, in northwestern Montana adjacent to the Canadian border (fig. 1), is dominated by two rugged mountain ranges trending northwest to southeast. The Livingston Range, on the west, extends for about 35 kilometers from the border south through the park to the Lake McDonald region. The Lewis Range, on the east, extends for about 100 kilometers from the border south through the park to Marias Pass. Large areas of these two mountain ranges lie above timberline (about 2,000 meters) and many peaks in these two ranges exceed 2,800 meters in elevation. Mount Cleveland (3,191 meters), in the Lewis Range, is the highest peak in the park. The Continental Divide transects the park, following the crest of the Lewis Range northward to about 16 kilometers south of the border, then swinging westward and following the crest of the Livingston Range to Canada.

The Livingston and Lewis Ranges presently contain many small glaciers and snowfields, most of which lie in the high regions above timberline. Most of the ice bodies lie in cirques that were carved by large glaciers during the last ice age. Others lie in well-shaded niches, where they are partly nourished by wind-drifted snow or avalanches. These ice bodies range in size from small snowfields (less than 0.1 square kilometer) to the Blackfoot Glacier (fig. 2), the largest glacier in the park, which was about 1.74 square kilometers in 1979. These ice bodies have shrunken drastically since the mid-19th century, when they attained their largest size in the last 10,000 years (Carrara and McGimsey, 1981). At that time there were more than 150 glaciers in the region of the present-day Glacier National Park; more than half of these glaciers no longer exist (Carrara, 1987).

A concentration of these glaciers and snowfields is situated in the Mount Jackson area in the south-central part of Glacier National Park. This map shows the distribution of moraines and extent of glaciers from the mid-19th century to 1979 in the Mount Jackson area. The margins of some of these glaciers between these times are also shown. In the following text, we first present an overview of the regional glacial history, including a summary of late Quaternary events in the Glacier National Park region during the last 20,000 years and a discussion of the moraines of two different ages found in the high regions of the park. We then describe how this map was prepared and discuss the glaciers in the Mount Jackson area from the mid-19th century to 1979. In addition, a glossary has been provided.

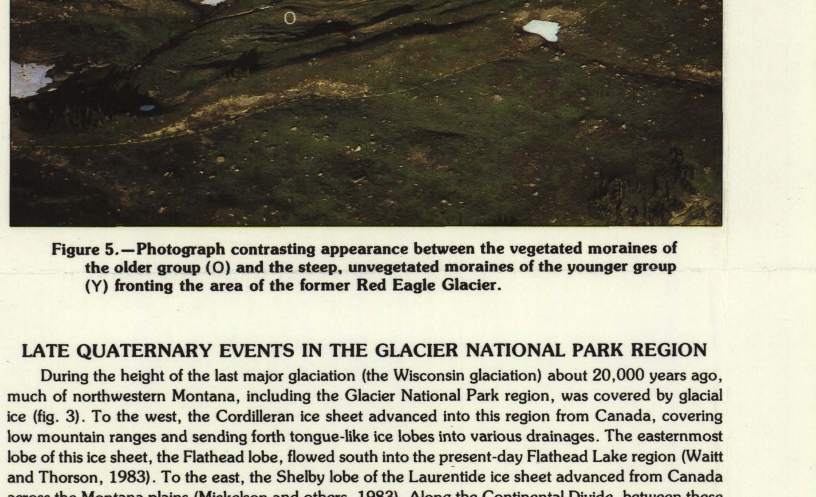

Figure 5.—Photograph contrasting appearance between the vegetated moraines of the older group (O) and the steep, unvegetated moraines of the younger group (Y) fronting the area of the former Red Eagle Glacier.

LATE QUATERNARY EVENTS IN THE GLACIER NATIONAL PARK REGION

During the height 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 glacial ice (fig. 3). To the west, the Cordilleran Ice Sheet advanced into this region from Canada, covering low mountain ranges and sending forth tongue-like ice lobes into various drainages. The easternmost lobe of this ice sheet, the Flathead lobe, flowed south into the present-day Flathead Lake region (Waitt and Thorson, 1983). To the east, the Shelby lobe of the Laurentide Ice Sheet advanced from Canada across the Montana plains (Mickelson and others, 1983). Along the Continental Divide, between these two large ice sheets, valley glaciers and ice fields flourished in the mountains. West of the Continental Divide some of these glaciers merged with the Flathead lobe of the Cordilleran Ice Sheet. East of the divide, these glaciers, some of which were also fed by ice flowing east across the divide, advanced beyond the mountain front onto the plains to form large piedmont glaciers (Carrara and others, 1986).

Deglaciation of the Glacier National Park region is thought to have been completed before 10,000 years ago. The presence of well-dated beds of volcanic ash, erupted from Glacier Peak (G ash) and Mount St. Helens (Jy ash) in Washington State, in post-glacial deposits at nine sites in this region indicate that by 11,200 years ago extensive deglaciation had occurred. In addition, a radiocarbon date from a bog near the lower end of Bowman Lake also indicates that before 11,000 years ago deglaciation was at least 90 percent complete and remaining glaciers, if any, were confined to local mountain valleys (Carrara, 1986). Radiocarbon-dated deposits near existing glaciers in Banff and Jasper National Parks, Alberta, indicate that by 10,000 years ago late Wisconsin glaciers had shrunk back to positions similar to those of present-day glaciers (Luckman and Osborn, 1979). A similar amount of deglaciation by that time is inferred for the Glacier National Park region; hence, by 10,000 years ago remaining glaciers were probably confined to those cirques and well-shaded niches where present-day glaciers and snowfields lie.

This regional deglaciation was followed by the establishment of forest in the Glacier National Park region. At Marias Pass (fig. 1), a section of post-glacial lake sediments has been found that contains both the Glacier Peak and Mount St. Helens ashes (Carrara and others, 1986). In these lake sediments a conifer needle and an alder (Alnus) fragment were found beneath the Glacier Peak ash and several small fragments of willow (Salix) were found immediately below the Mount St. Helens ash. This information plus pollen data and macrofossils at this same site indicate that when these ashes were deposited, vegetation at Marias Pass consisted of shrubs, herbs, and scattered conifers (Carrara and others, 1986). Radiocarbon dates from spruce (Picea) or larch (Larix) wood fragments and from lodgepole pine (Pinus contorta) wood fragments and cones indicate that the valley of the North Fork Flathead River was reforested by 10,000 years ago (Carrara, 1986). A radiocarbon date, on a piece of Douglas fir wood fragments from the upper Waterton Lakes Valley, just west of Mount Cleveland, indicates that this area was also reforested by about 10,000 years ago. These events are shown on figure 4.

MORAINES IN THE HIGH REGIONS OF GLACIER NATIONAL PARK

Moraines of two different age groups have been identified in the high regions of Glacier National Park including the Mount Jackson area (fig. 5). Most of these moraines lie at elevations between 1,900 and 2,400 meters, and they are generally found within a kilometer or two of their respective headwall. Both groups of moraines are found fronting present-day glaciers and snowfields, indicating that glacial fluctuations during the last 10,000 years have been small.

MORAINES OF THE OLDER GROUP

Moraines of the older group are seldom more than 10 meters high (fig. 5) and commonly support a dense cover of alpine tundra and dwarfed wind-swept trees of subalpine fir (Abies lasiocarpa) and Engelmann spruce (Picea engelmannii). These moraines have been identified at 25 sites in Glacier National Park. Many of these sites are in the central part of the Lewis Range, from the Sperry Glacier area east to the Triple Divide Pass area. In the Livingston Range, moraines of this group have been identified at only two sites; one near the site of the former Agassiz Glacier, the other in the Boulder Pass area. Where present, these moraines generally extend only slight distances downvalley from moraines of the younger group. However, in the Upper Two Medicine Lake area several snowfields are fronted only by moraines of the older group; moraines of the younger group are not present.

Volcanic ash, erupted from Mount Mazama (present site of Crater Lake, Oregon) about 6,850 years ago (Bacon, 1983), has been found in the soil of some of the moraines of the older group. In the Mount Jackson area, the ash has been found on moraines of the older group fronting the Sperry Glacier and the site of the former Agassiz Glacier (Carrara, 1987). The ash occurs in small depressions as a yellowish-brown sandy silt layer, 5 to 10 centimeters thick, 10 to 20 centimeters beneath the surface. Because the ash overlies these moraines, they are known to be older than the Mazama ash. However, the actual age of these moraines has not been determined by radiocarbon dating.

Evidence from other areas of the Rocky Mountains suggests that moraines of the older group may be appreciably older than the Mazama ash. In the Jasper National Park region, a period of higher timberline and warmer climate from 5,200 to 8,700 years ago suggests that older cirque moraines (Crowfoot moraines) in that region, which are also overlain by Mazama ash, are older than 8,700 years (Kearney and Luckman, 1983). In the San Juan Mountains of southwestern Colorado, Yankee Boy moraines, correlative to moraines of the older group in Glacier National Park, are thought to predate a period of higher timberline and warmer climate that began 9,600 years ago (Carrara and others, 1984). Hence, moraines of the older group in Glacier National Park are probably 10,000 years old or older.

MORAINES OF THE YOUNGER GROUP

Moraines of the younger group, typified by sharp-crested, steep-sided, unstable moraines (fig. 5), are as much as 50 meters high, and may be ice cored. They are not covered by soil or volcanic ashes and generally lack vegetation, although pioneering plants, including scattered dwarf conifers, have gained a foothold. These moraines have been identified at more than 150 sites throughout Glacier National Park and are commonly the only moraines fronting the many present-day glaciers and snowfields in the park (Carrara, 1987).

Many of the terminal moraines of the younger group in Glacier National Park are thought to date from the mid-19th century. Tree-ring studies within the forest trimlines fronting the Jackson Glacier and the site of the former Agassiz Glacier indicate that moraines of the younger group were formed by glacial advance that culminated in the mid-19th century (Carrara and McGimsey, 1981). In addition, several trees cored just beyond the outermost moraine of the younger group fronting the Sperry Glacier contained very narrow tree rings between 1840 and 1850, suggesting that this glacier was also near its maximum extent during the mid-19th century.

At some sites there are several moraines of the younger group, indicating that there was more than one advance within the last couple of centuries. However, because these moraines lie above timberline their ages could not be determined by tree-ring dating. Studies in the Canadian Rockies indicate that moraines correlative to moraines of the younger group in Glacier National Park date from between the 16th and early-20th centuries (Luckman and Osborn, 1979).

At most sites (about 80 percent) in Glacier National Park, only a single moraine of the younger group fronts the present-day glaciers and snowfields; moraines of the older group are usually not present. Apparently, in most cases the climatic cooling of the mid-19th century produced glaciers that overran and destroyed moraines of the older group. Hence, the climatic cooling of the mid-19th century, although mild compared to full-glacial conditions, was the most severe cooling in the park since the end of the Wisconsin glaciation, about 10,000 or 12,000 years ago.

PREPARATION OF THE MAP

Moraines shown on the map were plotted directly from air photos using a photogrammetric plotter after field investigations. The low, vegetated moraines of the older group are easily distinguished from the high, steep-sided, bouldery, unvegetated moraines of the younger group both in the field and on air photos (fig. 5).

The ice-front positions of mid-19th century glaciers were inferred to have coincided with (1) the crest of moraines of the younger group, or (2) the distal extent of hummocky ground moraines, or (3) a forest trimline, as in the case of the Jackson Glacier.

The ice-front positions of several glaciers at various times between the mid-19th century and 1966 were compiled from various sources, including Dyson (1948), Johnson (1980), U.S. Geological Survey (1902 and 1964), and the unpublished maps, photographs, and field notes of various U.S. Geological Survey personnel, including W. C. Alden, H. R. Bennett, R. B. Dole, F. E. Matthes, and E. C. Stebinger. The positions of the Jackson Glacier from 1879 to 1926 were determined by tree-ring dating (Carrara and McGimsey, 1981). Because of (1) often-conflicting historical data, (2) problems of accurately transferring glacier boundaries from old photographs to the map, and (3) the limitations of tree-ring dating, glacier boundaries shown on the map between the mid-19th century and 1966 should be regarded as approximate.

Glacier boundaries in 1966 and 1979 were plotted directly from U.S. Geological Survey air photos (scales of 1:30,000 and 1:80,000, respectively) taken in those years. Whether an ice body was a glacier or a snowfield was determined by the presence or absence of crevasses, debris bands, and bluish-white glacial ice (fig. 2) observed either on the air photos or in the field. The absence of these features on an ice body having a concave surface profile suggests that this ice body is only a snowfield; hence, it is not shown on this map. Table 1 compares the mid-19th century glacier boundaries to those of 1979.

Ice bodies shown on 1:24,000 scale topographic maps include snowfields as well as glaciers; this map shows only those ice bodies thought to be glaciers. Hence, ice bodies shown on topographic maps covering parts of this map do not correspond to those shown on this map.

DISCUSSION OF GLACIERS IN THE MOUNT JACKSON AREA

During the mid-19th century, 27 glaciers, having a total surface area of about 21.6 square kilometers, existed in the Mount Jackson area (map and table 1). These glaciers ranged in size from small ice bodies (less than 0.1 square kilometer) to the Blackfoot Glacier, which was then about 7.6 square kilometers in size. More than 16 square kilometers of this ice was in the four largest glaciers: Blackfoot, Harrison, Pumpelly, and Sperry. Between 1900 and 1914, observations and photographs indicate that although many of these glaciers had experienced downwasting, most still extended to or near to their terminal moraines.

A period of rapid glacier retreat began just before 1920 and continued until about the mid-1940's. From tree-ring studies and historical records, Carrara and McGimsey (1981) concluded that the retreat rates of both the Agassiz and Jackson Glaciers were modest before 1920, but after that time both glaciers began to retreat rapidly. This conclusion is supported by climatic records from Kalispell, Montana, which indicate that this region of northwestern Montana experienced above-average summer temperatures and below-average annual precipitation from about 1918 to 1943 (Carrara and McGimsey, 1981). Glacier retreat rates slowed markedly after this period (Dyson, 1952).

By 1979, only about 7.4 square kilometers of glacial ice remained in the Mount Jackson area, and of the 27 glaciers present during the mid-19th century, 17 no longer existed. Not surprisingly, most of these 17 glaciers were either small or unfavorably oriented with respect to sun angle. The Logan and Red Eagle Glaciers, the largest of these 17 former glaciers, faced due east and were 0.93 and 0.50 square kilometers in size, respectively, during the mid-19th century. These two glaciers probably disappeared by 1950 (Dyson, 1952). In August 1983, the site of the former Red Eagle Glacier was occupied by freshly striated bedrock covered by a thin veneer of bouldery rubble. A small snowfield lay against the headwall, and in several places bedrock projected through the snow surface.

Some of the remaining glaciers have divided into a number of smaller ice bodies. For instance, the Blackfoot Glacier, which covered about 7.6 square kilometers during the mid-19th century, has divided into seven smaller glaciers having a total area of about 3.0 square kilometers. Tree-ring studies fronting the present-day Jackson Glacier the western half of the mid-19th century Blackfoot Glacier) indicate that retreat from the maximum mid-19th century position began about 1860 (Carrara and McGimsey, 1981). However, most of the shrinkage and breakup of the Blackfoot Glacier occurred during the warm, dry period between 1920 and the mid 1940's. A description of the Blackfoot Glacier in 1913 by W. C. Alden (1914) and photographs taken by E. C. Stebinger in 1914 indicate that at that time, although reduced in size from its mid-19th century extent, the glacier was probably still one continuous ice body. By 1939, the western remnant of this glacier (the present-day Jackson Glacier) was separated from the eastern remnant (the present-day Blackfoot Glacier) by about 0.8 kilometers (Dyson, 1940).

Other glaciers, such as the Sperry, have retreated markedly since the mid-19th century. Because this glacier has been the most studied glacier in the Mount Jackson area, information about its size at various times since the mid-19th century is more abundant than for any other glacier in this area. The map and table 2 show the shrinkage of the Sperry Glacier since the mid-19th century.

Several of the larger glaciers in the Mount Jackson area advanced slightly between 1966 and 1979. A comparison of 1966 and 1979 air photos revealed that the ice tongue of the Harrison and Jackson Glaciers both advanced about 100 meters during this period. The Blackfoot Glacier advanced as much as 100 meters along its western margin while its eastern margin appears to have remained stationary during this period. However, the Sperry Glacier continued a pattern of overall retreat.

GLOSSARY

cirque—A deep, steep-walled amphitheater at the head of a valley, produced by glacial erosion.
crevasse—A vertical crack in a glacier, caused by differential movement.
deglaciation—The uncovering of an area from beneath a retreating glacier.
downwasting—The decrease in thickness of a glacier due to melting.
forest trimline—A sharp boundary separating a mature forest from an area from which a glacier has recently receded. Small young trees may have started to colonize the deglaciated area.
glacier—A perennial mass of ice formed by the compaction and recrystallization of snow, moving slowly downslope by internal flowage and basal slippage caused by the stress of its own weight.
ice field—A glacier consisting of many interconnected valley glaciers covering all but the highest peaks and ridges of a mountainous region.
ice sheet—A glacier of great thickness and areal extent forming a continuous cover over a land surface and spreading from its center outward in all directions because it is not confined by the underlying topography.
moraine—A ridge, mound, or other accumulation of unsorted rock debris carried or deposited by a glacier.
piedmont glacier—A glacier at the base of a mountain range, formed by the spreading and coalescing of valley glaciers emerging from the mountains.
radiocarbon dating—A method of determining the age of organic material by measuring the amount of carbon-14 isotope remaining. Because of radioactive decay, the amount of this isotope decreases with age. The method is commonly used to determine ages in the range of 500 to 30,000 years.
snowfield—A perennial mass of ice and snow not large enough to induce downslope movement like a glacier.
terminal moraine—A ridgelike accumulation of rock debris formed at the terminus of a glacier, marking its farthest advance.
valley glacier—A glacier confined within a mountain valley.
volcanic ash—A fine unconsolidated rock material ejected during volcanic eruptions.

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Table 1.—*Comparison of glacial data for the mid-19th century and 1979 in the Mount Jackson area*

[Glacier numbers refer to those shown on map. Area in square kilometers, terminus elevation in meters. Leader (--), during mid-19th century glacier was one large ice body and had not broken up into present-day remnants. Asterisk (*), glacier no longer exists]

Glacier number (or name)	Mid-19th century		1979	
	Area	Terminus elevation	Area	Terminus elevation
1	0.15	2,225	*	*
2 (Sperry)	3.87	1,895	1.06	2,270
3	.29	1,980	.04	2,195
4	.05	1,985	*	*
5	.03	1,950	*	*
6	.31	2,220	*	*
7	.10	2,135	*	*
8	.01	2,135	*	*
9	.09	2,315	*	*
10	.37	1,980	*	*
11	.09	2,170	*	*
12	.04	1,950	*	*
13	.06	2,270	*	*
14	.29	2,285	.15	2,415
15	.04	2,165	*	*
16	.21	2,225	.12	2,285
17	.18	2,195	.06	2,365
18	.16	2,075	*	*
19 (1, Harrison)	3.18	1,800	1.49	2,035
(2)	--	--	.21	2,040
20	.28	1,830	.19	2,075
21 (1, Blackfoot)	7.59	1,680	1.74	2,120
(2)	--	--	.04	2,330
(3)	--	--	.04	2,440
(4)	--	--	.09	2,315
(5, Jackson)	--	--	1.02	1,945
(6)	--	--	.05	2,665
(7)	--	--	.02	2,450
22	.43	2,380	*	*
23 (1, Pumpelly)	1.88	2,090	.72	2,360
(2)	--	--	.34	2,340
24	.06	2,105	.03	2,145
25	.38	2,025	*	*
26 (Logan)	.93	1,985	*	*
27 (Red Eagle)	.50	2,105	*	*
Totals	21.57		7.41	

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

Year	Area (square kilometers)	Source
Mid-19th century	3.87	This study
1901	3.71	U.S. Geological Survey (1902)
1913	3.41	This study and Dyson (1948)
1927*	1.99	Dyson (1948)
1938	1.71	Dyson (1948)
1946	1.50	Dyson (1948)
1950	1.29	U.S. Geological Survey (1964)
1960	1.24	U.S. Geological Survey (1964)
1966	1.12	This study
1979	1.06	This study

*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 in the area southeast of Gem Lake. As there are no surveys or historical records with which to reconstruct the boundaries of these two small former glaciers, measurements from 1927 and later are for the main ice body (present-day Sperry Glacier) only.

MAP SHOWING DISTRIBUTION OF MORAINES AND EXTENT OF GLACIERS FROM THE MID-19TH CENTURY TO 1979 IN THE MOUNT JACKSON AREA, GLACIER NATIONAL PARK, MONTANA

By
Paul E. Carrara and Robert G. McGimsey

1988

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