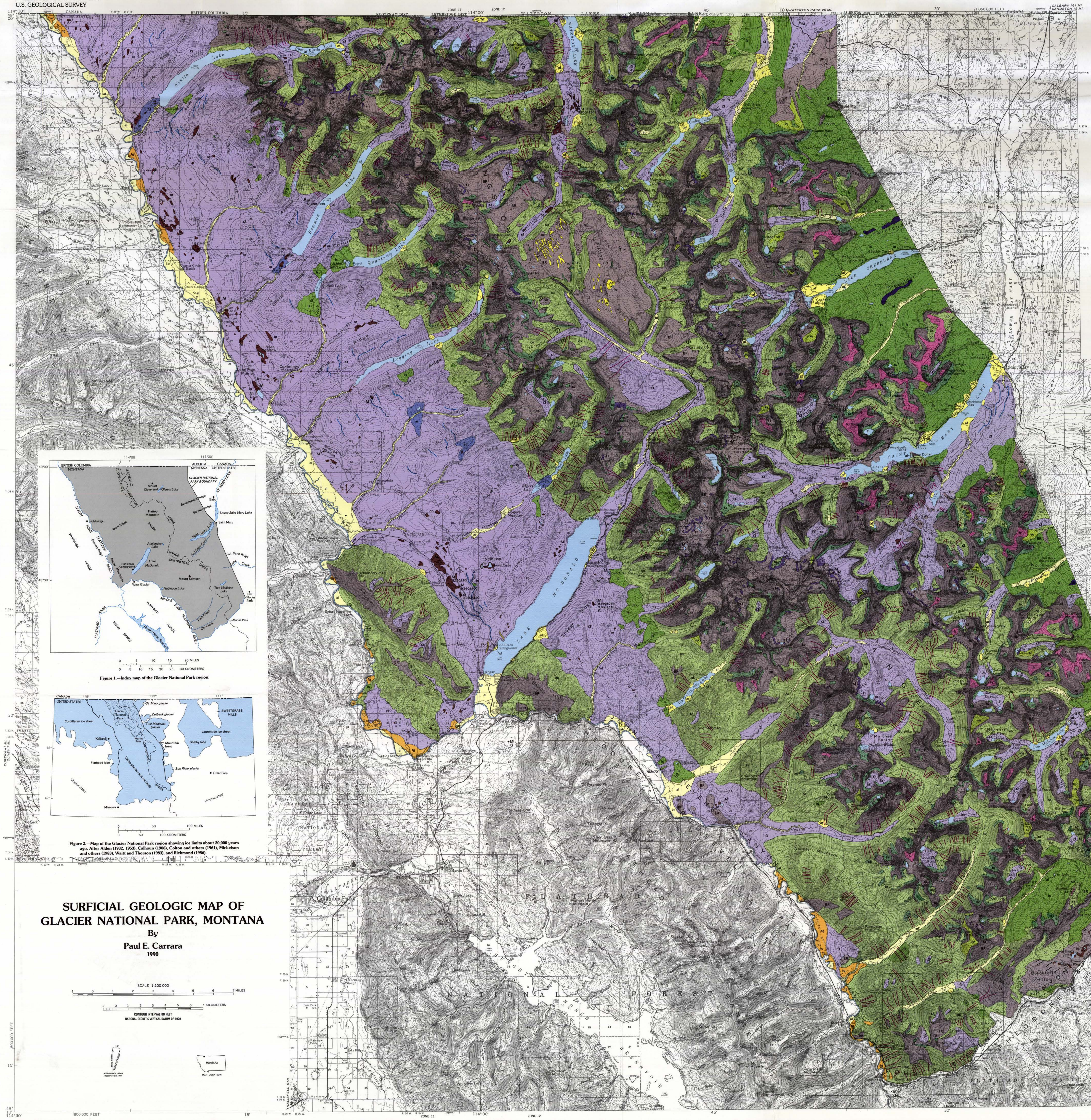


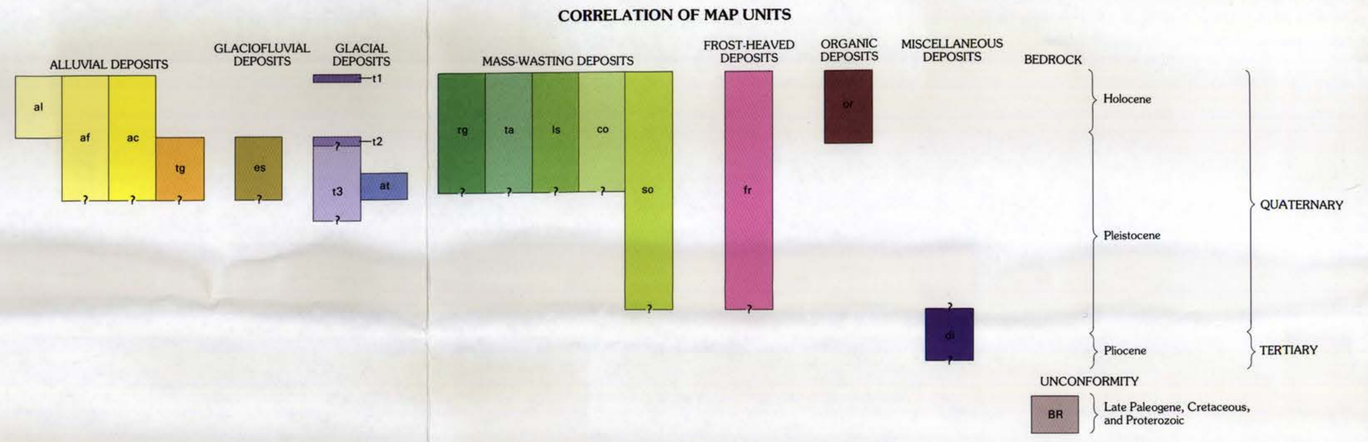
Figure 1.—Index map of the Glacier National Park region.

Figure 2.—Map of the Glacier National Park region showing ice limits about 20,000 years ago. After Alden (1932, 1953), Calhoun (1906), Colton and others (1961), Mickelson and others (1983), and Waitt and Thorson (1983), and Richmond (1986).

SURFICIAL GEOLOGIC MAP OF GLACIER NATIONAL PARK, MONTANA

By
Paul E. Carrara
1990

CORRELATION OF MAP UNITS



DESCRIPTION OF MAP UNITS

ALLUVIAL DEPOSITS

al **Alluvium (Holocene)**—Sand and gravel deposits and minor amounts of silt; in places silt forms thin lenses. Includes channel and overbank deposits in modern floodplain. In narrow mountain valleys locally includes small areas of colluvium. Unit consists mainly of rounded and subrounded clasts of Belt Supergroup rocks; other rock types, chiefly coarse-grained granites, are also present in minor amounts along the North Fork Flathead River. Thickness 1–5 m

af **Alluvial-fan deposit (Holocene and late Pleistocene)**—Fan-shaped deposits of fluvial sand and gravel. In places unit contains thin lenses of silt. Unit consists chiefly of rounded and subrounded clasts of Belt Supergroup rocks. Locally includes debris-flow deposits. Thickness 2–50 m

ac **Alluvial and colluvial deposit (Holocene and late Pleistocene)**—Locally derived deposits of silt and sand on Flattop Mountain. Unit locally includes sandy and silty sheetwash deposits. Thickness 0.5–2 m

tg **Terrace deposit (late Pleistocene)**—Sand and gravel deposits underlying terraces along the North and Middle Forks Flathead River and the mouths of Ole and Park Creeks. Unit consists mainly of rounded and subrounded clasts of Belt Supergroup rocks. Locally contains thin lenses of silt. Terraces range from 3 to 20 m above present stream levels. Thickness 2–10 m

GLACIOFLUVIAL DEPOSITS

es **Esker deposit (late Pleistocene)**—Identified in two areas: (1) along north side of Lake McDonald in the Fish Creek campground area, where deposit consists of well-sorted silty sand and gravel composed of Belt Supergroup rocks; (2) in the Railroad Creek area in southeastern corner of park, where deposit consists of sand, silt, and clay derived from the local bedrock. In both areas these deposits form sinuous ridges 0.5–1 km long and about 10–20 m high

GLACIAL DEPOSITS

t1 **Till (late Holocene)**—Unsorted subrounded to subangular bouldery rubble, consisting of Belt Supergroup rocks, and minor amounts of sand, silt, and clay. Striated rocks are common. Unit forms steep, rubbly moraines 10–50 m high in front of many of the glaciers and snowfields in the park. Unit [illegible]

t2 **Till** [illegible]

at **Ablation till** [illegible]

t3 **Till** [illegible]

MASS-WASTING DEPOSITS

rg **Rock-glacier deposit** [illegible]

ta **Talus deposit** [illegible]

ls **Landslide deposit** [illegible]

Colluvial deposit [illegible]

Solifluction and related deposits [illegible]

FROST-HEAVED DEPOSITS

Frost rubble [illegible]

ORGANIC DEPOSITS

Organic deposit [illegible]

MISCELLANEOUS DEPOSITS

di **Diamicton** [illegible]

BEDROCK

BR **Bedrock (late Paleogene, Cretaceous, and Proterozoic)**—Includes: (1) late Paleogene sedimentary rocks of the Kishenehn Formation, consisting of lacustrine and fluvial sediments in west side of park (Constenius, 1981); (2) Cretaceous sedimentary rocks, consisting predominantly of the Upper Cretaceous Marias River Shale, a dark-gray marine mudstone, in east side of park (Mudge and Earhart, 1983); and (3) Proterozoic rocks of the Belt Supergroup, consisting mainly of siltites and argillites and subordinate amounts of igneous rocks that occur as sills, dikes, and flows in central mountainous region of park (McGimsey, 1985; Ross, 1959; Raup and others, 1983; Whipple and others, 1984). In places, unit is mantled by small, thin patches of surficial material

Contact

Glacial meltwater channel

Orientation of drumlinoid feature

Prominent snow avalanche track—Many have well-defined forest trimlines. Limits of avalanche tracks are approximate

M→ **Bog, exposure, or soil pit location containing Mazama ash**

G→ **Bog or exposure containing Glacier Peak G ash**

H→ **Exposure containing Mount St. Helens Jy ash**

8,730±80 **Locality of ¹⁴C age**—In years B.P. (see table 1)

DISCUSSION

GEOLOGY AND GEOGRAPHY

Glacier National Park, in northwestern Montana adjacent to the Canadian border, encompasses about 4,000 km² of Flathead and Glacier Counties (fig. 1). The park contains three physiographically distinct areas: (1) the valleys of the North and Middle Forks Flathead River on the west, (2) the central mountainous region, and (3) the plains on the east. Bedrock in the park ranges in age from late Paleogene to Proterozoic (Ross, 1959; Raup and others, 1983) and is in many places mantled by surficial deposits of Quaternary age.

On the west, the heavily forested valleys of the North and Middle Forks Flathead River trend northwest to southeast; valley floors range in altitude from about 975 to 1,280 m. These valleys have been downdropped on the east and are underlain by 5,000 m of upper Paleogene sedimentary rocks of the Kishenehn Formation, consisting of lacustrine and fluvial sediments (Constenius, 1981). In some places, these rocks have failed, resulting in large landslides, such as the one in the Halfmoon Lake area. In other areas, these rocks are covered by till of late Pleistocene age as much as 30 m thick. Depressions within this till contain numerous bogs filled with peats, organic muds, and volcanic ashes.

The central part of Glacier National Park is dominated by two rugged mountain ranges that trend northwest to southeast and contain numerous small glaciers and snowfields. The Livingston Range, on the west, extends for 40 km from the Canadian border south to the Lake McDonald region. The Lewis Range, on the east, extends for 85 km from the border south through the park to Marias Pass. Large areas of these ranges lie above timberline (about 2,000 m) and many of the peaks in these ranges exceed 2,800 m in altitude. Mount Cleveland (3,191 m), in the Lewis Range, is the highest peak in the park. Relief in these ranges is rugged and many of the valley floors are as much as 1,500 m below their surrounding summits. The Continental Divide follows the crest of the Lewis Range northward to a position about 16 km south of the border, then shifts westward and follows the crest of the Livingston Range north into Canada.

These mountain ranges are underlain by Proterozoic sedimentary rocks of the Belt Supergroup, ranging in age from about 800 Ma to 1,600 Ma (Raup and others, 1983). The rocks consist of a sequence of argillites, siltites, and carbonates that have a maximum stratigraphic thickness of 5,200 m (Whipple and others, 1984). Because these rocks have been affected only by low-grade metamorphism, many of their original sedimentary features (ripple marks, mud cracks, salt casts, and fossil algal stromatolites) are well preserved. In places these rocks have been intruded by diabasic and gabbroic sills and dikes. The upper part of the section contains mafic lava flows 10–60 m thick (McGimsey, 1985). This entire sequence of rocks was thrust eastward over Cretaceous sedimentary rocks along the Lewis thrust fault during the Paleocene (Raup and others, 1983), and today forms a broad syncline whose axis closely parallels the Continental Divide (Ross, 1959).

Numerous surficial deposits mantle these mountain ranges. A large rock block slide is present immediately west of Avalanche Lake and several are present in the area north of Glenns Lake. Steep valley sides, whose forest is scarred in places by snow avalanche tracks, are mantled by colluvium. Talus cones and sheets are common at the base of steep slopes and cliffs. Till mantles the floors of many of the mountain valleys. In the higher regions of these two ranges, two sets of moraines can be found in front of the present-day glaciers and snowfields (Osborn, 1985; Carrara, 1987; Carrara and McGimsey, 1988). High, unglaciated upland surfaces locally have a thin cover of stone stripes, sorted polygons, and solifluction deposits.

East of the mountain front is the western margin of the Montana plains. This area consists of low, rounded hills mantled in places by a veneer of glacial till. Altitudes range from about 1,370 to 2,000 m. This area is underlain by sedimentary rocks of mainly the Upper Cretaceous Marias River Shale, which is a dark-gray marine mudstone (Mudge and Earhart, 1983). In places immediately east of the mountain front, Pleistocene valley glaciers emerging from the Lewis Range gouged deep, steep-sided valley walls in these soft rocks. After deglaciation, many of these rocks failed and formed massive landslides.

GLACIER NATIONAL PARK DURING THE LATE WISCONSIN GLACIATION

During the height of the last major glaciation, about 20,000 years ago, much of northwestern Montana, including the Glacier National Park region, was covered by glacial ice (fig. 2). To the west, the southern margin of the Cordilleran ice sheet stretched from the Puget Sound area of Washington to western Montana. This large ice sheet was formed by the coalescence of valley glaciers in the mountains of British Columbia and flowed south overriding low mountain ranges in Washington, Idaho, and Montana. Lobes from this ice sheet flowed into various river valleys south of the main ice mass. The easternmost lobe of this ice sheet, the Flathead lobe, flowed south into the Flathead Lake region (Alden, 1953; Waitt and Thorson, 1983; Richmond, 1986).

On the plains of Montana east of Glacier National Park lay the southwestern lobe of the Laurentide ice sheet. This ice sheet covered most of Canada, and its southern margin stretched from Montana east to the Atlantic Ocean. The southwestern lobe of this ice sheet, the Shelby lobe, advanced south from [illegible] Canada across the Montana plains into this region (Alden, 1932; Mickelson and others, 1983).

Between these two large ice sheets, in the mountains along the Continental Divide, valley glaciers and icefields developed (Alden, 1953; Richmond, 1986). The present-day Glacier National Park region was covered by hundreds of meters of glacial ice so that only the higher peaks protruded as nunataks above this ice cover. On the western side of the Continental Divide, glaciers flowed from valleys along the western flank of the Livingston Range and the eastern flank of the Whitefish Range. Many of these glaciers were 10–20 km long and several hundreds of meters thick. These glaciers merged with a large trunk glacier flowing southeast down the valley of the North Fork Flathead River. This trunk glacier, which headed in the mountains of British Columbia, filled the valley of the North Fork with at least 1,000 m of ice. Evidence for such an ice thickness is given by striations and erratics along the crest of the Apgar Mountains and Demers Ridge (Alden, 1953), and by sinuous meltwater channels, which trend northwest-southeast, on the interfluves on the west flank of the Livingston Range, such as Adair Ridge. This ice drained to the southwest, overrode the Apgar Mountains, and merged with the Flathead lobe of the Cordilleran ice sheet.

From the Lake McDonald area south, the Lake McDonald glacier, which drained the Flattop Mountain area, and glaciers flowing from valleys along the western flank of the Lewis Range in the park and from valleys along the eastern flank of the Flathead Range merged with a large trunk glacier that occupied the valley of the Middle Fork Flathead River. This large trunk glacier, which headed in the Lewis and Clark Range about 100 km to the southeast in the present-day Great Bear Wilderness, formed a local ice field in the area west of Marias Pass. Some of this ice flowed to the northwest and joined the large trunk glacier flowing south in the valley of the North Fork Flathead River and eventually merged with the Flathead lobe of the Cordilleran ice sheet. Other ice from this glacier flowed east across the Continental Divide and was a major source of ice for the former Two Medicine glacier.

East of the Continental Divide in the Glacier National Park region, some glaciers advanced beyond the mountain front and formed large piedmont glaciers on the adjoining plains. The largest of these piedmont glaciers was the Two Medicine glacier. Mountain glaciers along a 60-km length of the mountain front merged to form this glacier, including glaciers from the Two Medicine Valley and ice from the icefield west of the Continental Divide in the Marias Pass area. This piedmont lobe had a maximum width of about 50 km, extended about 55 km east of the mountain front, and deposited a veneer of hummocky till over a 2,000-km² area (Calhoun, 1906; Alden, 1932).

To the north in Glacier National Park, glaciers occupied the valleys of Lake and Cut Bank Creeks. These glaciers flowed east and merged on the plains to form a small piedmont lobe that extended beyond the mountain front about 15 km (Calhoun, 1906; Alden, 1932).

Farther north, a large glacier flowed down Saint Mary Valley, beyond the mountain front and into Canada where its terminal deposits lie beneath till of a subsequent advance of the Laurentide ice sheet (Calhoun, 1906; Alden, 1932; Horberg, 1954). In the vicinity of Lower Saint Mary Lake this glacier was about 370 m thick (Alden, 1932). This large glacier was fed by other glaciers flowing from the valleys of Divide, Red Eagle, Boulder, Swiftcurrent, Kennedy, and Otatso Creeks in Glacier National Park. In the interior of the park, the valleys of the Belly and Waterton Rivers were filled with large glaciers, about 400 m thick, that flowed north into Canada.

CHRONOLOGY OF LATE PLEISTOCENE AND HOLOCENE EVENTS IN THE GLACIER NATIONAL PARK REGION

Volcanic ashes erupted from volcanos in the Cascade Range of the Pacific Northwest have been identified in postglacial deposits in the Glacier National Park region. Glacier Peak G ash, erupted from Glacier Peak in Washington State, has been identified in postglacial deposits at nine sites in the map area. This ash was erupted about 11,200 B.P. (Mehringer and others, 1984). At two of these sites, this ash is underlain by an ash erupted from Mount St. Helens (Jy) in Washington State. The Mount St. Helens Jy ash is thought to date from about 11,400 B.P. (Carrara and others, 1986).

Because the Glacier Peak G and Mount St. Helens Jy ashes were both erupted in the late Pleistocene, when the Glacier National Park region was undergoing extensive deglaciation, the presence of these ashes at a site provides information concerning the extent and timing of deglaciation. Also, at sites where these ashes were found with associated pollen and plant and insect macrofossils, information concerning revegetation and environmental conditions has also been obtained (Carrara and others, 1986).

The location of sites containing the Glacier Peak G and Mount St. Helens Jy ashes in the Glacier National Park region indicates that between 11,200 and 11,400 B.P. deglaciation was at least 90 percent complete. By this time remaining glaciers, if any, were confined to local mountain valleys (Carrara, 1986). In addition, data from Banff and Jasper National Parks, Alberta, indicate that by 10,000 B.P. late Wisconsin glaciers had receded to positions close to those of present-day glaciers (Luckman and Osborn, 1979). A similar amount of deglaciation at that time is inferred for the Glacier National Park region. Hence, by 10,000 B.P. any remaining glaciers were probably confined to those same cirques and well-shaded niches that contain present-day glaciers and snowfields.

The Mazama ash, which erupted from Mt. Mazama, the present site of Crater Lake, Oregon, about 6,845 B.P. (Bacon, 1983), was also deposited in the Glacier National Park region. This ash commonly occurs in bogs as well as in the soil overlying glacial and periglacial deposits in the higher regions of the park. The Mazama ash is a useful time-stratigraphic marker and provides a minimum date for many of the deposits in the higher regions of the park that could not be radiocarbon dated because of a lack of associated organic material (Osborn, 1985; Carrara, 1987; Carrara and McGimsey, 1988).

In addition, a number of radiocarbon ages have been obtained from organic material recovered from bogs and exposures along stream banks in the Glacier National Park region (table 1). Radiocarbon ages on the lowestmost organic material at these sites provide minimum dates for the beginning of organic sedimentation as well as minimum dates of deglaciation. Radiocarbon ages on wood fragments from some of these sites provide minimum dates of reforestation.

Because Glacier National Park was extensively covered by glacial ice about 20,000 years ago, most of the surficial deposits shown on this map were deposited during or after the late Pleistocene regional deglaciation. Only those deposits in areas not covered by glacial ice during the last glaciation may date from earlier periods.

Table 1.—*Radiocarbon ages in the Glacier National Park region*

¹⁴C age	Laboratory No.	Material dated
780±70	W-5169	Wood[1].
8,730±80	W-5041	Pine fragments[2].
9,510±350	W-5571	Pine fragments[2].
9,650±250	W-5575	Gyttja containing conifer fragments[2].
9,680±110	W-5182	Peat[3].
9,850±260	W-5577	Gyttja containing willow fragments[3].
9,910±100	W-5191	Pine fragments[2].
9,920±120	W-5187	Peat and pine fragments[2].
10,090±130	W-5185	Gyttja[3].
10,630±250	W-5348	Spruce or larch fragments[2].
11,150±90	W-5043	Organic material[3] (<0.125 mm).

[1]Material found at base of landslide.
[2]Minimum date of reforestation following deglaciation.
[3]Minimum date of organic sedimentation following deglaciation.

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