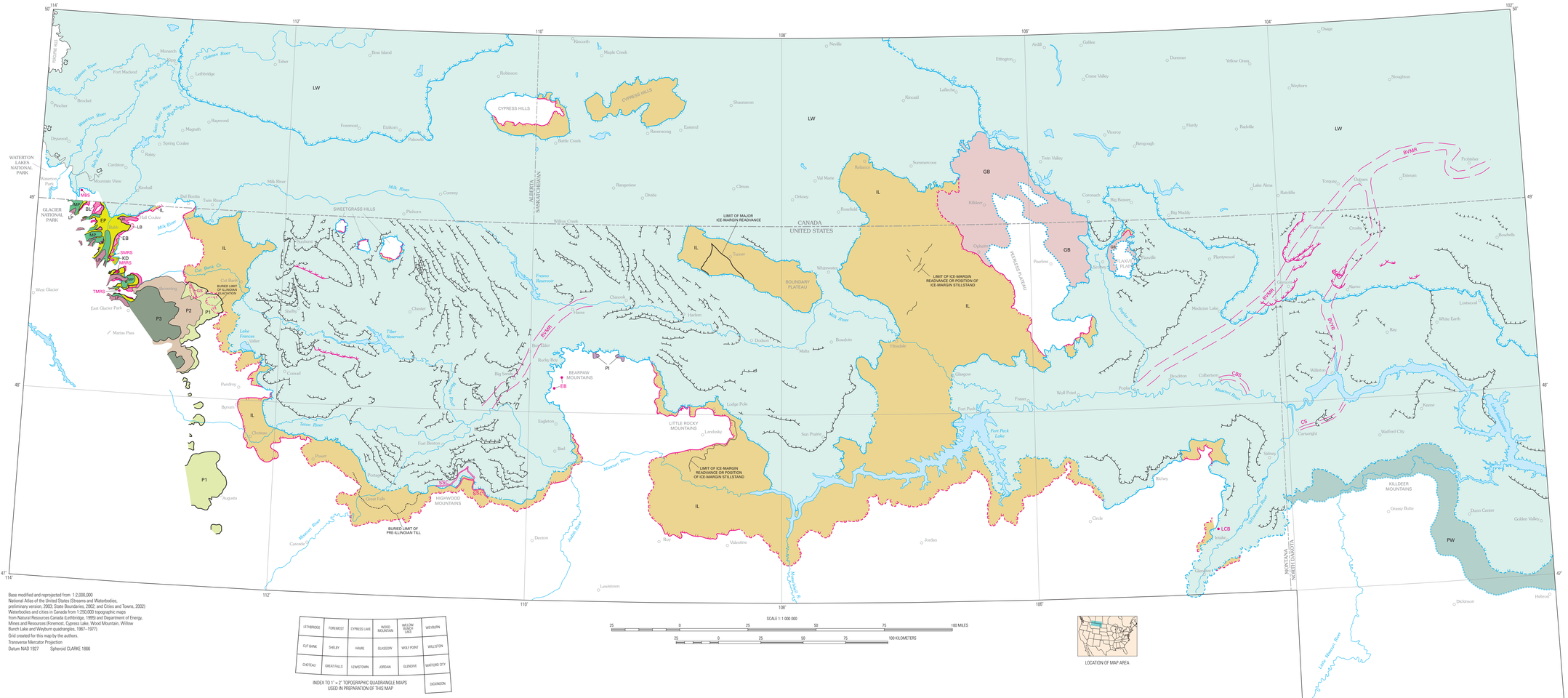
U.S. DEPARTMENT OF THE INTERIOR
U.S. GEOLOGICAL SURVEY

SCIENTIFIC INVESTIGATIONS MAP 2843
Pamphlet accompanies map



Base modified and reprojected from 1:2,000,000
National Atlas of the United States (Streams and Waterbodies,
preliminary version, 2003; State Boundaries, 2002; and Cities and Towns, 2002)
Waterbodies and cities in Canada from 1:250,000 topographic maps
from Natural Resources Canada (Lethbridge, 1995) and Department of Energy,
Mines and Resources (Foremost, Cypress Lake, Wood Mountain, Willow
Bunch Lake and Weyburn quadrangles, 1967–1977)
Grid created for this map by the authors.
Transverse Mercator Projection
Datum NAD 1927 Spheroid CLARKE 1866

INDEX TO 1° × 2° TOPOGRAPHIC QUADRANGLE MAPS
USED IN PREPARATION OF THIS MAP

EXPLANATION

VALLEY GLACIAL DEPOSITS

- LP — Late Pinedale till
- MP — Middle Pinedale till
- EP — Early Pinedale till
- LB — Late Bull Lake till
- EB — Early Bull Lake till
- BL — Bull Lake till, undivided
- KD — Kennedy drift

PIEDMONT GLACIATION GLACIAL DEPOSITS (OUTLET DEPOSITS OF GLACIERS FROM THE NORTHERN MONTANA ICE FIELD)

- P3 — Pinedale 3 till
- P2 — Pinedale 2 till
- P1 — Pinedale 1 till

CONTINENTAL GLACIAL DEPOSITS

- LW — Late Wisconsin till
- IL — Illinoian till
- PW — Pre-Wisconsin till and glacial erratic boulders
- PI — Pre-Illinoian till (Pleistocene)
- GB — Pre-Illinoian glacial erratic boulders on eroded bedrock (Pleistocene)—Contains no till

VALLEY GLACIATION

- Limit of late or middle Pinedale glacial advance (limit of unit LP or MP)
- Limit of early Pinedale glacial advance or glaciation (limit of unit EP)
- Limit of late Bull Lake glacial advance or glaciation (limit of unit LB)
- Limit of early Bull Lake glacial advance or glaciation (limit of unit EB), or limit of Bull Lake till, undivided (unit BL)
- Mapped limit of pre-Bull Lake Kennedy drift (limit of unit KD)

PIEDMONT GLACIATION

- Limit of Pinedale 3 or Pinedale 2 glacial advance (limit of unit P3 or P2)
- Limit of Pinedale 1 glacial advance or limit of Pinedale glaciation (limit of unit P1)

CONTINENTAL GLACIATION
[Line decorations on up-glacier side of limit]

Late Wisconsin

- **Limit of glaciation (limit of unit LW)**—Defined by stratigraphy and (or) surface morphology. Dashed where inferred
- C2 — **Limit of C2 regional glacial readvance in southwestern Alberta**
- **Limit of regional glacial readvance (see fig. 1C) caused by reorganization of glacial dispersal centers**—Defined by stratigraphy and surface morphology. Dashed where inferred
- **Limit of an ice-margin readvance or position of an ice-margin stillstand**—Defined by stratigraphy and (or) surface morphology. Dashed where inferred
- **Limit of major glacitectonic deposit or structure**—Defined by stratigraphy and (or) surface morphology

Illinoian

- **Limit of glaciation (limit of unit IL)**—Defined by stratigraphy and (or) surface morphology. Dashed where inferred; dotted where buried by Pinedale 1 till
- **Limit of a major ice-margin readvance**—Defined by surface morphology
- **Limit of an ice-margin readvance or position of an ice-margin stillstand**—Defined by surface morphology

Pre-Wisconsin

- **Limit of till and glacial erratic boulders (unit PW)**—Till is not present as far south as the limit of boulders

Pre-Illinoian (Pleistocene)

- **Southern limit of known surface exposure of till (unit PI) on north flank of Bearpaw Mountains**
- **Buried limit of till (unit PI), overlapped by Illinoian till (unit IL)**—Mapped from distribution of exposures of till
- **Limit of glacial erratic boulders on eroded bedrock (unit GB)**
- **Stream or shoreline**
- MBS — **Locality for stratigraphic section**—See pamphlet for details. MRRS, Milk River Ridge; MBS, Mokowan Butte; TMRS, Two Medicine Ridge; SMRS, St. Mary Ridge
- EB — **Location of erratic blocks from Canadian Shield**
- LCB — **Lava Creek B volcanic ash site**
- SSC — **Sag or spillway**—CS, Charbonneau Sag; CBS, Culbertson Sag; GS, Guardpee Lake Spillway; SSC, Shonkin Sag channels
- BVMR / BVYR — **Buried valley**—BVMR, buried valley of ancestral Missouri River; BVYR, buried valley of ancestral Yellowstone River

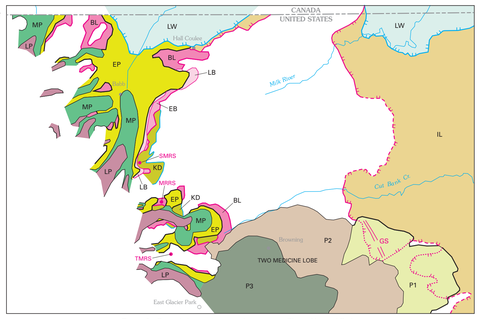


Figure 1. Expanded view of rectangular area near Glacier National Park.

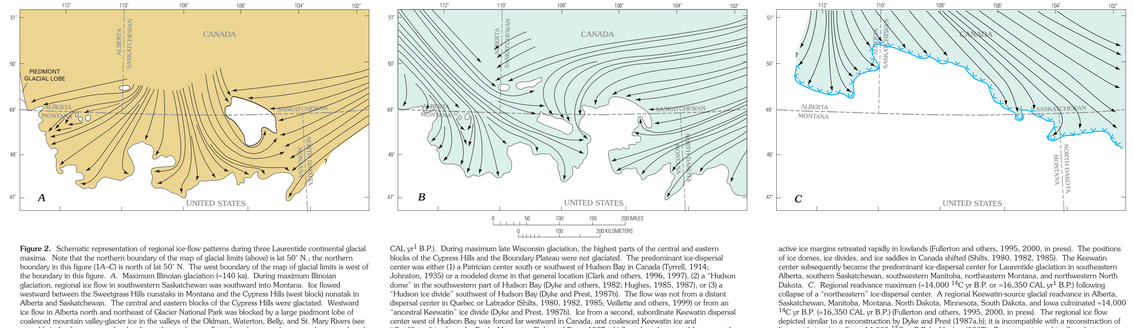


Figure 2. Schematic representation of regional ice-flow patterns during three Laurentide continental glacial maxima. Note that the northern boundary of the map of glacial limits (above) is lat 50° N.; the northern boundary in this figure (*A*–*C*) is north of lat 50° N. The west boundary of the map of glacial limits is west of the boundary in this figure. *A*. Maximum Illinoian glaciation (~140 ka). During maximum Illinoian glaciation, regional ice flow in southwestern Saskatchewan was southward into Montana. Ice flowed westward between the Sweetgrass Hills nunataks in Montana and the Cypress Hills (west block) nunatak in Alberta and Saskatchewan. The central and eastern blocks of the Cypress Hills were glaciated. Westward ice flow in Alberta north and northeast of Glacier National Park was blocked by a large piedmont lobe of coalesced mountain valley-glacier ice in the valleys of the Oldman, Waterton, Belly, and St. Mary Rivers (see pamphlet). Ice from a second, subordinate dispersal center flowed southwestward, west-southwestward, and westward through southwestern Manitoba (east of this map area), southeastern Saskatchewan, and northwestern North Dakota into Montana. The areal distributions and the clast lithologies of the subsurface deposits of the two documented pre-Illinoian Pleistocene continental glaciations in Montana (not mapped) indicate that the regional pattern of ice flow during the maxima of both of those glaciations was similar to that during Illinoian glaciation, and it was very different from the regional flow pattern during maximum late Wisconsin glaciation (fig. 1*B*). *B*. Maximum late Wisconsin glaciation (~20,000 ^{14}C yr B.P. or ~23,360 CAL yr[1] B.P.). During maximum late Wisconsin glaciation, the highest parts of the central and eastern blocks of the Cypress Hills and the Boundary Plateau were not glaciated. The predominant ice-dispersal center was either (1) a Patrician center south or southwest of Hudson Bay in Canada (Tyrrell, 1914; Johnston, 1935) or a modeled dome in that general location (Clark and others, 1996, 1997), (2) a "Hudson dome" in the southwestern part of Hudson Bay (Dyke and others, 1982; Hughes, 1985, 1987), or (3) a "Hudson ice-dispersal center" southwest of Hudson Bay (Dyke and Prest, 1987*b*). The flow was not from a distant dispersal center in Quebec or Labrador (Shilts, 1980, 1982, 1985; Veillette and others, 1999) or from an "ancestral Keewatin" ice divide (Dyke and Prest, 1987*b*). Ice from a second, subordinate Keewatin dispersal center west of Hudson Bay was forced far westward in Canada, and coalesced Keewatin ice and "Cordilleran" ice from the Rocky Mountains (Dyke and Prest, 1987*a*, *b*) flowed southeastward from central Alberta into Montana. Southeastward regional flow of ice from central Alberta into Montana occurred only during late Wisconsin glaciation. The regional ice flow pattern depicted in figure 1*B* is incompatible with reconstructions of Laurentide ice sheet flow during maximum late Wisconsin glaciation by Dyke and others (1982), Fisher and others (1985), Andrews and Fulton (1987), Dyke and Prest (1987*a*,*b*), and Hughes (1987). Later than ~17,000 ^{14}C yr B.P. (~19,850 CAL yr B.P.), the "northeastern" dispersal center collapsed and regional ice-flow patterns changed markedly. The ice thinned and stagnated on uplands, and active ice margins retreated rapidly in lowlands (Fullerton and others, 1995, 2000, in press). The positions of ice domes, ice divides, and ice saddles in Canada shifted (Shilts, 1980, 1982, 1985). The Keewatin center subsequently became the predominant ice-dispersal center for Laurentide glaciation in southeastern Alberta, southern Saskatchewan, southwestern Manitoba, northeastern Montana, and northwestern North Dakota. *C*. Regional readvance maximum (~14,000 ^{14}C yr B.P. or ~16,350 CAL yr[1] B.P.) following collapse of a "northeastern" ice-dispersal center. A regional Keewatin-source glacial readvance in Alberta, Saskatchewan, Manitoba, Montana, North Dakota, Minnesota, South Dakota, and Iowa culminated ~14,000 ^{14}C yr B.P. (~16,350 CAL yr B.P.) (Fullerton and others, 1995, 2000, in press). The regional ice flow depicted similar to a reconstruction by Dyke and Prest (1987*a*,*b*); it is incompatible with a reconstruction of Laurentide ice sheet flow ~14,000 ^{14}C yr B.P. by Hughes (1987). Reconstructions of ice flow during maximum late Wisconsin glaciation by Dyke and others (1982) and Andrews and Fulton (1987) depicted regional flow at ~14,000 ^{14}C yr B.P., not regional ice flow during maximum glaciation ~20,000 ^{14}C yr B.P. (~23,360 CAL yr B.P.).

[1]The CAL ages are ^{14}C ages calculated by calibration of the ^{14}C time scale to sidereal years by comparison of ^{14}C ages and ^{230}Th/^{234}U ages of coral samples (see "Introduction" in accompanying pamphlet).

Figure 3. Middle Pinedale and late Wisconsin Laurentide glacial limits in the Cut Bank 1° × 2° quadrangle. LW, late Wisconsin till; MP, middle Pinedale till; P2, Pinedale 2 till. Line decorations on up-glacier side of limit.

MAP SHOWING SPATIAL AND TEMPORAL RELATIONS OF MOUNTAIN AND CONTINENTAL GLACIATIONS ON THE NORTHERN PLAINS, PRIMARILY IN NORTHERN MONTANA AND NORTHWESTERN NORTH DAKOTA

By
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2004

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Digital cartography and graphics by Charles A. Bush, Arthur W. Straub, and Diane E. Lane. Edited by Diane E. Lane
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