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

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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Scientific Investigations Map 2843

ABSTRACT

This report is an overview of glacial limits and glacial history on the plains in northern Montana and northeastern North Dakota (long 102°-114°W.) and also in adjacent southern Alberta and Saskatchewan, Canada. In the Rocky Mountains and on the plains adjacent to the mountains in Montana, the map also depicts spatial relations of valley glaciers and piedmont ice lobes to continental ice sheets. Glacial limits east of 102°, in the United States and also in adjacent Canada, are depicted on published maps of the U.S. Geological Survey Quaternary Geologic Atlas of the United States (I-1420) map series. The limits shown here are from data compiled for the Lethbridge, Regina, Yellowstone, and Big Horn Mountains 4° x 6° quadrangles in the Quaternary Geologic Atlas series.

This geospatial database has been prepared with a degree of detail appropriate for viewing at a scale of 1:1,000,000. Because of the degree of generalization required, the map is intended for regional analysis, rather than for detailed analysis in specific areas. It depicts the geographic positions of the limits of mountain and continental glaciations and the limits of selected glacial readvances. That information provides a foundation for reconstruction of geologic history and for reconstruction.

The base map is simplified. Selected hydrographic features, selected towns and cities, selected physiographic features, and a grid of 1° x 2° topographic quadrangles are included to aid the reader in location of the glacial limits and other features that are depicted here on other maps at different scales. Most of the geologic data were compiled at 1:250,000 scale. The nominal reading scale of the digitized map data is 1:1,000,000. Enlargement will not restore resolution that was lost by simplification or generalization of data. Accompanying illustrations show regional directions of ice movement from Canada into the United States during maximum Illinoian glaciation, during maximum late Wisconsin glaciation, and during a later regional glacial readvance maximum

ILLUSTRATIONS

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 (1A–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 (about 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. 1B). B. Maximum late Wisconsin glaciation (about 20,000 14C yr B.P. or about 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 divide" southwest of Hudson Bay (Dyke and Prest, 1987b). 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, 1987b). 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, 1987a, 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 1B 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 (1987a,b), and Hughes (1987). Later than about 17,000 14C yr B.P. (about 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 (about 14,000 14C yr B.P. or »16,350 CAL yr1 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 about 14,000 14C 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 (1987a,b); it is incompatible with a reconstruction of Laurentide ice sheet flow about 14,000 14C 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 about 14,000 14C yr B.P., not regional ice flow during maximum glaciation about 20,000 14C yr B.P. (about 23,360 CAL yr B.P.).

Footnote for figure 2 explanation: The CAL ages are 14C ages calculated by calibration of the 14C time scale to sidereal years by comparison of 14C ages and 230Th/238U 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.

LIST OF SYMBOLS ON MAP

VALLEY GLACIAL DEPOSITS

Late Pinedale till

Middle Pinedale till

Early Pinedale till

Late Bull Lake till

Early Bull Lake till

Bull Lake till, undivided

Kennedy drift

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

Pinedale 3 till

Pinedale 2 till

Pinedale 1 till

CONTINENTAL GLACIAL DEPOSITS

Late Wisconsin till

Illinoian till

Pre-Wisconsin till and glacial erratic boulders

Pre-Illinoian till (Pleistocene)

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

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 glaciotectonic 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

Locality for stratigraphic section—See pamphlet for details. MRRS, Milk River Ridge; MBS, Mokowan Butte; TMRS, Two Medicine Ridge; SMRS, St. Mary Ridge

Location of erratic blocks from Canadian Shield

Lava Creek B volcanic ash site

Sag or spillway—CS, Charbonneau Sag; CBS, Culbertson Sag; GS, Guardipee Lake Spillway; SSC, Shonkin Sag channels

Buried valley—BVMR, buried valley of ancestral Missouri River; BVYR, buried valley of ancestral Yellowstone River

OTHER INFORMATION ABOUT THIS 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

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