Pleistocene geology of Lincoln County, Wisconsin. Bulletin 93 1997

Ham, Nelson R.; Attig, John W.
Madison, Wis.: University of Wisconsin-Extension, Wisconsin Geological and Natural History Survey, 1997

https://digital.library.wisc.edu/1711.dl/7VRS3XJ2NAY5J9A

Pleistocene Geology of Lincoln County, Wisconsin

Nelson R. Ham and John W. Attig

Wisconsin Geological and Natural History Survey
Bulletin 93 ◆ 1997

Wisconsin Geological and Natural History Survey

James M. Robertson, *Director and State Geologist*
Ronald G. Hennings, *Assistant Director*

Lyle J. Anderson, *office manager*
John W. Attig, *geologist*
Kathryn Barrett, *geographic information specialist*
William G. Batten, *geotechnician*
Kenneth R. Bradbury, *hydrogeologist*
W.A. Broughton, *geologist*
Bruce A. Brown, *geologist*
Kim J. Cates, *soil scientist*
Lee Clayton, *geologist*
Brian L. Coulter, *information manager*
Michael L. Czechanski, *cartographer*
Kim M. Dawson, *Map Sales assistant*
Timothy T. Eaton, *hydrogeologist*
Thomas J. Evans, *geologist*
Rilla M. Hinkes, *office manager*
Susan L. Hunt, *graphic designer*
Mindy C. James, *publications manager*
Marcia J. Jesperson, *word processing operator*
Rochelle V. Juedes, *Map Sales manager*
Kathy A. Kane, *computer specialist*
Pamela Naber Knox, *State Climatologist*
Irene D. Lippelt, *water resources specialist*
Kristine L. Lund, *soil and water analyst*
Frederick W. Madison, *soil scientist*
Kathleen M. Massie-Ferch, *subsurface geologist*
Matthew Menne, *assistant State Climatologist*
M.G. Mudrey, Jr., *geologist*
Maureen A. Muldoon, *hydrogeologist*
Stanley A. Nichols, *biologist*
Deborah L. Patterson, *cartographer*
Roger M. Peters, *subsurface geologist*
Kathy Campbell Roushar, *cartographer*
Alexander Zaporozec, *hydrogeologist*
Kathie M. Zwettler, *administrative manager*

plus approximately 10 graduate and undergraduate student workers.

Research Associates

Gregory J. Allord, *USGS*
Mary P. Anderson, *UW–Madison*
Larry K. Binning, *UW–Madison*
Michael F. Bohn, *Wis. Dept. of Nat. Res.*
Stephen M. Born, *UW–Madison*
William F. Cannon, *USGS*
Kevin Connors, *Dane Co. Land Conserv. Dept.*
Albert B. Dickas, *UW–Superior*
C. Patrick Ervin, *Northern Ill. Univ.*
J.K. Greenberg, *Wheaton Coll.*
Robert F. Gurda, *Wis. State Cartographer's Office*
Nelson R. Ham, *St. Norbert Coll.*
William J. Hinze, *Purdue Univ.*
Randy J. Hunt, *USGS*
Peter Jacobs, *Valdosta State Coll.*
Mark D. Johnson, *Gustavus Adolphus Coll.*
John Klasner, *Western Ill. Univ.*
James C. Knox, *UW–Madison*
George J. Kraft, *Central Wis. Groundwater Center*
James T. Krohelski, *USGS*
Gene L. LaBerge, *UW–Oshkosh*
Lyle D. McGinnis, *Argonne Natl. Lab.*
Kevin McSweeney, *UW–Madison*
Christine Mechenich, *Central Wis. Groundwater Center*
David M. Mickelson, *UW–Madison*
Donald G. Mikulic, *Ill. Geol. Survey*
Robert Patenaude, *Wis. Dept. of Transportation*
James O. Peterson, *UW–Madison*
Jeffrey K. Postle, *Wis. Dept. Ag., Trade & Consumer Protection*
Kenneth W. Potter, *UW–Madison*
Todd W. Rayne, *Hamilton Coll.*
Allan F. Schneider, *UW–Parkside*
Byron H. Shaw, *UW–Stevens Point*
J. Antonio Simo, *UW–Madison*
George L. Smith, *Lawrence Univ.*
Kent M. Syverson, *UW–Eau Claire*
Conrad Weiffenbach, *Wis. Dept. of Health & Soc. Serv.*
Jeffrey A. Wyman, *UW–Madison*

The Wisconsin Geological and Natural History Survey also maintains collaborative relationships with a number of local, state, regional, and federal agencies and organizations regarding educational outreach and a broad range of natural resource issues.

Pleistocene Geology of Lincoln County, Wisconsin

Nelson R. Ham and John W. Attig

A discussion of the Pleistocene materials and landforms deposited along the southern part of the Wisconsin Valley Lobe of the Laurentide Ice Sheet during the last part of the Wisconsin Glaciation

Wisconsin Geological and Natural History Survey
Bulletin 93 ◆ 1997

Published by and available from
Wisconsin Geological and Natural History Survey
3817 Mineral Point Road • Madison, WI 53705-5100
James M. Robertson, Director and State Geologist

ISSN: 0375-8265

This report and accompanying map are interpretations of the data available at the time of preparation. Every reasonable effort has been made to ensure that these interpretations conform to sound scientific and cartographic principles; however, these publications should *not* be used to guide site-specific decisions without verification. Proper use of these publications is the sole responsibility of the user.

Issued in furtherance of Cooperative Extension work, Acts of May 8 and June 30, 1914, in cooperation with the U.S. Department of Agriculture, University of Wisconsin–Extension, Cooperative Extension. University of Wisconsin–Extension provides equal opportunities in employment and programming, including Title IX and ADA requirements. If you need this information in an alternative format, contact the Office of Equal Opportunity and Diversity Programs or the Wisconsin Geological and Natural History Survey (☎ 608/262.1705).

Mission of the Wisconsin Geological and Natural History Survey

The Survey conducts earth-science surveys, field studies, and research. We provide objective scientific information about the geology, mineral resources, water resources, soil, climate, and biology of Wisconsin. We collect, interpret, disseminate, and archive natural resource information. We communicate the results of our activities through publications, technical talks, and responses to inquiries from the public. These activities support informed decision-making by government, industry, business, and individual citizens of Wisconsin.

PLATE (inside back pocket)

FIGURES

Pleistocene Geology of Lincoln County, Wisconsin

Nelson R. Ham and John W. Attig

ABSTRACT

The Wisconsin Valley and Langlade Lobes of the Laurentide Ice Sheet covered the northern and central parts of Lincoln County, Wisconsin, during the last part of the Wisconsin Glaciation. Most of this area was covered by the Wisconsin Valley Lobe, which advanced toward the south and southeast. The Langlade Lobe advanced toward the southwest and covered only the far northeastern part of the county. The Laurentide Ice Sheet began to waste back from its maximum extent in north-central Wisconsin between about 18,000 and 15,000 years ago. Till and other Pleistocene sediment deposited by the Wisconsin Valley and Langlade Lobes are included in the Copper Falls Formation.

The maximum extent of the Wisconsin Valley Lobe is marked by a broad band of hilly glacial topography that includes many ice-walled-lake plains. Two areas of high-relief (up to 70 m) hills and ice-walled-lake plains, known as the Harrison Hills and the Underdown, mark the former southeastern ice margin. These ice-disintegration landforms indicate that a broad zone of stagnant, debris-covered, debris-rich ice separated from the margin of the Wisconsin Valley Lobe as it wasted back from its maximum extent. The presence of ice-walled-lake plains in an area of high-relief hills indicates two phases in landscape evolution. During an early stable phase, buried ice was insulated and supraglacial lakes developed. Some of the supraglacial lakes melted their way to solid ground, forming ice-walled lakes. During a later unstable phase, the buried ice began to melt, slopes became unstable, supraglacial and ice-walled lakes drained, and hills formed. Permafrost conditions during the last part of the Wisconsin Glaciation likely delayed the melting of the debris-covered ice until after about 13,000 years ago.

In the southern part of Lincoln County, till sheets deposited before the last part of the Wisconsin Glaciation are at the surface and in the subsurface. Till of the Merrill Member of the Lincoln Formation is the surface sediment throughout much of the area. Glacial landforms are generally poorly preserved on this till surface. The orientations of subdued moraines and pebbles in the till indicate that ice flowed toward the southeast in the southern and southeastern parts of Lincoln County and toward the south and southwest in the southwestern part. Merrill till was deposited prior to the last part of the Wisconsin Glaciation.

INTRODUCTION

Setting

The landscape of Lincoln County, Wisconsin, is the direct result of Pleistocene glaciation. During the last part of the Wisconsin Glaciation, the northern and central parts of the county were covered by the Wisconsin Valley and Langlade Lobes of the Laurentide Ice Sheet (fig. 1). The Wisconsin Valley Lobe advanced toward the south and southeast and covered most of this area. The far northeastern part of the county was covered by the Langlade Lobe, which advanced toward the southwest (Nelson, 1973). The Laurentide Ice Sheet began to waste back from its maximum extent in northern Wisconsin between about 18,000 and 15,000 years ago (Clayton and Moran, 1982; Mickelson and others, 1983; Attig and others, 1985).

A prominent east–west trending zone of hilly glacial topography, with many ice-walled-lake plains, crosses the central part of Lincoln County and marks the maximum extent of the Wisconsin Valley Lobe. Drumlins, outwash fans and terraces, eskers, and recessional moraines lie north of this broad area of ice-disintegration landforms. The origin and distribution of these landforms provide evidence of the glacier-bed conditions and dynamics of this part of the Laurentide Ice Sheet as well as the nature of ice wastage and landscape evolution during deglaciation. Glacial sediment deposited by the Wisconsin Valley and Langlade Lobes is included in the Wildcat Lake and Nashville Members of the Copper Falls Formation, respectively (Mickelson and others, 1984; Attig and others, 1988).

In the southern part of Lincoln County, south of the area covered by the Laurentide Ice Sheet, till sheets deposited before the last part of the Wisconsin Glaciation are at the surface or in the subsurface (fig. 1) (Stewart, 1973; Stewart and Mickelson, 1974, 1976; Mickelson and others, 1984; Attig and Muldoon, 1989). Till of the Merrill Member of the Lincoln Formation is the surface sediment in this area. Glacial landforms are generally poorly preserved on this till surface, although a few areas of subdued hilly topography can be identified in places.

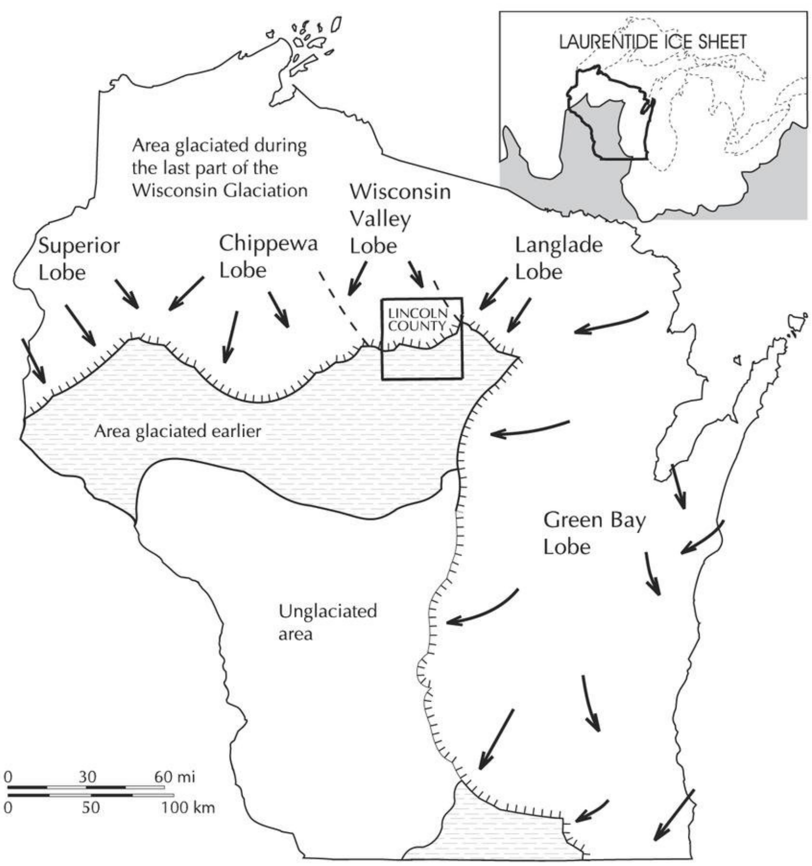


__Figure 1.__ Location of Lincoln County, Wisconsin, and the maximum extent of the Laurentide Ice Sheet (hachured line) during the last part of the Wisconsin Glaciation. Arrows show the direction of ice flow.

Study methods, map compilation, and terminology

This report is based on field and laboratory research completed from 1992 to 1994. In the field, we described and interpreted landforms and surface exposures as well as sediment samples obtained by exploratory drilling with a truck-mounted, solid-stem auger or hollow-stem auger with split-spoon sampler. Laboratory studies included interpretation of aerial-photograph stereopairs (black and white, scale 1:20,000, and color-infrared, scale 1:58,000) and topographic maps (U.S. Geological Survey, scales 1:24,000 and 1:100,000).

Physical properties of selected sediment samples collected in the field were analyzed in the Quaternary Laboratory of the Department of Geology and Geophysics, University of Wisconsin–Madison. A detailed report of the sediment properties is given by Ham (1994). All sand:silt:clay ratios discussed in this report are for the less-than-2-mm fraction of the samples. A particle diameter of 0.0625 mm was used as the break between sand and silt; 0.002 mm, between silt and clay. We used the Munsell scale to describe sediment colors.

Unpublished maps from the Natural Resources Conservation Service were used to aid in interpretations of parent material in some areas. We used geologic information from well constructor's reports and geologic logs on file at the Wisconsin Geological and Natural History Survey (WGNHS) to interpret subsurface relationships and to construct a generalized map showing the thickness of Pleistocene material in Lincoln County.

Mapping was compiled on U.S. Geological Survey topographic quadrangles (scale 1:24,000). Contacts from these maps were digitized and compiled to create the final map at the scale of 1:100,000 (plate 1).

For clarity in discussion, throughout this report we use the term Laurentide Ice Sheet to refer only to the ice sheet as it existed during the last part of the Wisconsin Glaciation. Also, place names, such as rivers and lakes, that are referred to in the text are shown on plate 1.

Map reliability

The reliability of the information shown in plate 1 varies from place to place. Many areas of Lincoln County are densely forested and have few roads. Surface exposures are rare. Subsurface information is generally limited to populated areas in the southern, eastern, and north-central parts of the county. Information shown on the map (plate 1) is probably least reliable for areas west of the Wisconsin River in the west-central and northwestern parts of Lincoln County. We judge the map to be most accurate for the southern and eastern parts of the county. The estimated reliability of contacts between map units is indicated in the explanation for plate 1.

Acknowledgments

We thank Ole Hanson, Forester of Lincoln County (retired); Tom Geiger, University of Wisconsin–Extension agent; and Diane Hanson, Lincoln County Land Conservationist, for their cooperation and support throughout the course of this project. We are grateful to the Lincoln County Board for providing funds to purchase color-infrared aerial photographs. Mike Mitchell, Natural Resources Conservation Service, kindly provided us with preliminary soil maps of Lincoln County. We especially thank Ole and Barb Hanson, who allowed us to rent a trailer on their property during the summers of 1992 and 1993 while we conducted field work for this project. Lee Clayton, William Mode, and Carrie Patterson gave helpful critical reviews of the manuscript. Kathy Campbell Roushar designed and produced the final report. We thank Kate Barrett, Michael Czechanski, Matthew Menne, Deborah Patterson, Nils Richardson, and Kathy Campbell Roushar for production of the geologic map. This project was supported in part by a grant from the U.S. Geological Survey Statemap Program (Grant Number 1434-93-1178).

PRE-PLEISTOCENE GEOLOGY

Precambrian rock

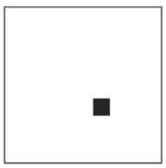
Lincoln County is underlain primarily by Early Proterozoic metavolcanic rock; however, the central part of the county is underlain by gneiss (Greenberg and Brown, 1984). This rock is considered part of a volcanic belt that formed during the Penokean Orogeny (Greenberg and Brown, 1984; Sims and others, 1989). The structural trend of the rock and associated faults is generally northeast to southwest (Greenberg and Brown, 1984).
Areas of rock outcrop in Lincoln County are shown on plate 1. The largest exposures of Precambrian rock are along the Wisconsin River near Grandfather Falls and Grandfather Dam (secs. 30 and 31, T33N, R6E; see plate 1) and along the Prairie River at the site of the former Prairie Dell Dam (sec. 13, T32N, R7E).

Paleozoic rock

One outlier of Paleozoic rock is on Irma Hill, about 0.7 km east of Irma, in central Lincoln County (fig. 2) (Mudrey and others, 1982; Greenberg and Brown, 1984). The upper part of Irma Hill is underlain by nearly flat-lying, well cemented, quartz sandstone that crops out near the hilltop on the north side of County Highway J (SE1/4 SW1/4 SE1/4 sec. 7, T33N, R7E). Primary sedimentary structures, including graded bedding and cross-bedding, are evident in the sandstone. The age of the sandstone is likely Cambrian (Greenberg and Brown, 1984; Mudrey and others, 1982). However, the exact stratigraphic relationship between the sandstone on Irma Hill and lower Paleozoic rock elsewhere in Wisconsin is not clear.

Several prominent hills similar to Irma Hill are in the central part of Lincoln County. Some of these hills may also be capped by sandstone; however, this cannot be confirmed because of the lack of surface exposures and subsurface information.

Sub-Pleistocene surface



Very little is known about the surface of the rock beneath Pleistocene sediment in Lincoln County. Information from well constructor's reports and geologic logs on file at WGNHS suggests that the sub-Pleistocene surface generally slopes toward the south. The relief of this surface in the central and northern parts of the county is poorly known. Considerable relief (more than 50 m) exists in places in the southern part of the county.

PLEISTOCENE GEOLOGY

In the following sections, we describe the origin, distribution, and history of the Pleistocene deposits and landforms in Lincoln County. The discussion progresses from the oldest to youngest glacial deposits and landforms in the county, generally from the south to the north.

Thickness of Pleistocene sediment

Most of the sediment that overlies Precambrian and Paleozoic rock in Lincoln County is the direct result of glaciation. The thickness of Pleistocene sediment is known only in a general way. Subsurface information is scarce because large areas of the county are forested and sparsely populated; most of the available information is from the areas near Merrill and Tomahawk. In addition, few wells penetrate the entire thickness of unlithified sediment and reach bedrock. Figure 3 shows the general thickness of Pleistocene sediment in Lincoln County as indicated by well constructor's reports and test holes. In the areas where well information is sparse or absent, the map is based on interpretations of sediment thickness from the topography. A large contour interval is used because of the limited amount of subsurface information.

The Precambrian and Paleozoic rock in Lincoln County is covered nearly everywhere by Pleistocene sediment. Rock is close to the surface (within 5 to 10 m) on uplands in the southern part of the county (areas shown as map units **gm** and **gmh,** plate 1). This area was glaciated prior to the last part of the Wisconsin Glaciation. The thickest Pleistocene sediment is in a broad area of hilly topography and other ice-disintegration landforms that cross the central part of Lincoln County from east to

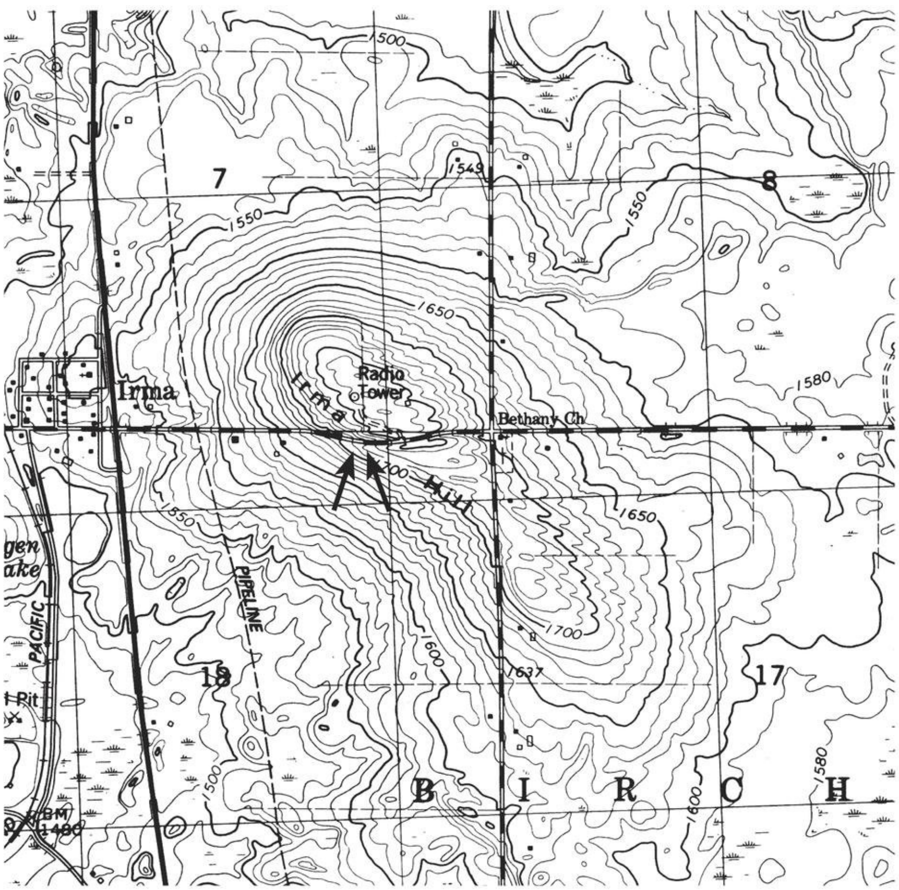


Figure 2. Part of the Irma Quadrangle, Wisconsin (U.S. Geological Survey, 7.5-minute series, topographic, 1982), showing Irma Hill, the upper part of which is underlain by resistant, probably Cambrian, quartz sandstone. The location of the outcrop of the sandstone along County Highway J is indicated by arrows. The contour interval is 10 feet.

west and mark the maximum extent of the Wisconsin Valley Lobe (mainly map unit **gwh,** plate 1). This hilly zone includes the Harrison Hills and the Underdown area in the eastern part of the county and the New Wood area in the western part. Few well constructor's reports or geologic logs are available for these places; however, the relief of individual hills can be used as an estimate of the minimum thickness of Pleistocene sediment. The relief of many hills in the Harrison Hills ranges from 30 to 45 m, indicating that Pleistocene sediment is at least that thick. Some well constructor's reports near the center of the Harrison Hills show that the sediment is locally thicker than about 70 m. The thickness of Pleistocene sediment in the Underdown area probably exceeds 30 m in most places. In the hilly area west of the Wisconsin River, the typical relief of individual hills ranges from about 5 to 10 m. However, in general the Pleistocene sediment probably exceeds about 30 m in thickness in this region, on the basis of information from the few available well constructor's reports.

Little subsurface information is available for the northwestern part of Lincoln County. Pleistocene sediment is judged to be generally less than 30 m thick in this area, especially close to the larger rivers and flowages.

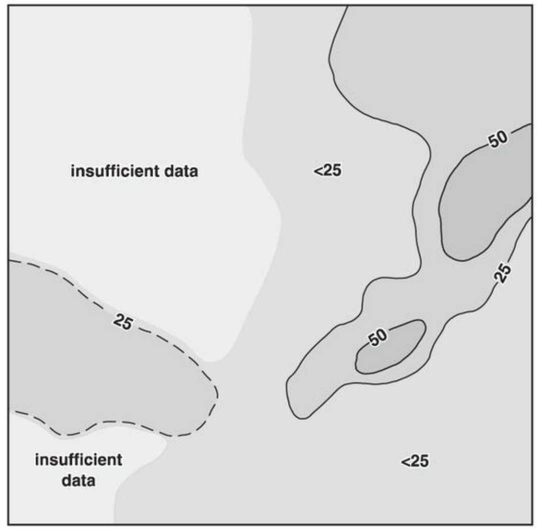


Figure 3. General thickness of Pleistocene sediment covering Precambrian and Paleozoic rock in Lincoln County. Contour interval is 25 m; contour is dashed where uncertain.

Deposits of the Lincoln Formation

Till and other sediment of the Merrill Member of the Lincoln Formation constitute the surface material throughout much of the southern part of Lincoln County (primarily map units **gm** and **gmh,** plate 1). Sediment of the Merrill Member extends southward into northern Marathon County (LaBerge and Myers, 1983; Attig and Muldoon, 1989), to the east into southwestern Langlade County (Mickelson, 1986), to the west into southern Taylor County (Attig, 1993), and possibly southwest into northern Clark County (Clayton and others, 1992).

In general, the Merrill till surface consists of broad, rolling uplands that are stream dissected (fig. 4). Poorly drained areas are common in places, but less so than in the areas of Lincoln County that were covered by the Wisconsin Valley Lobe. The Merrill till is typically less than about 5 m thick on uplands, and the topography is largely bedrock controlled. Primary glacial landforms, such as moraines and drumlins, are generally absent from the surface of the Merrill till, but several subdued, slightly hilly areas (map unit **gmh,** plate 1) that trend approximately northeast to southwest are in the south-central part of the county near Merrill (Stewart, 1973; this study).

Till of the Merrill Member. Till of the Merrill Member of the Lincoln Formation in southern Lincoln County is unsorted, noncalcareous, slightly clayey, silty, gravelly sand (diamicton). Analysis of 20 samples of the till indicated that it is composed of about 60 percent sand, 30 percent silt, and 10 percent clay; however, the grain-size distribution is highly variable (Stewart, 1973). The moist field color is generally dark reddish brown (2.5YR 3/3 to 4/3 on the Munsell scale) but ranges from brown (7.5YR 4/6) to reddish brown (5YR 4/3), similar to that of till and supraglacial debris-flow sediment of the Copper Falls Formation (Stewart, 1973; this study).

Pleistocene sediment of the Merrill Member is primarily a subglacial till sheet throughout north-central Wisconsin; however, supraglacial debris-flow, lake, and meltwater-stream sediment is found in places. The topography of the Merrill till surface does not suggest that large areas of high-relief, hilly glacial topography, similar to those that formed along the margin of the Laurentide Ice Sheet across northern Wisconsin, developed

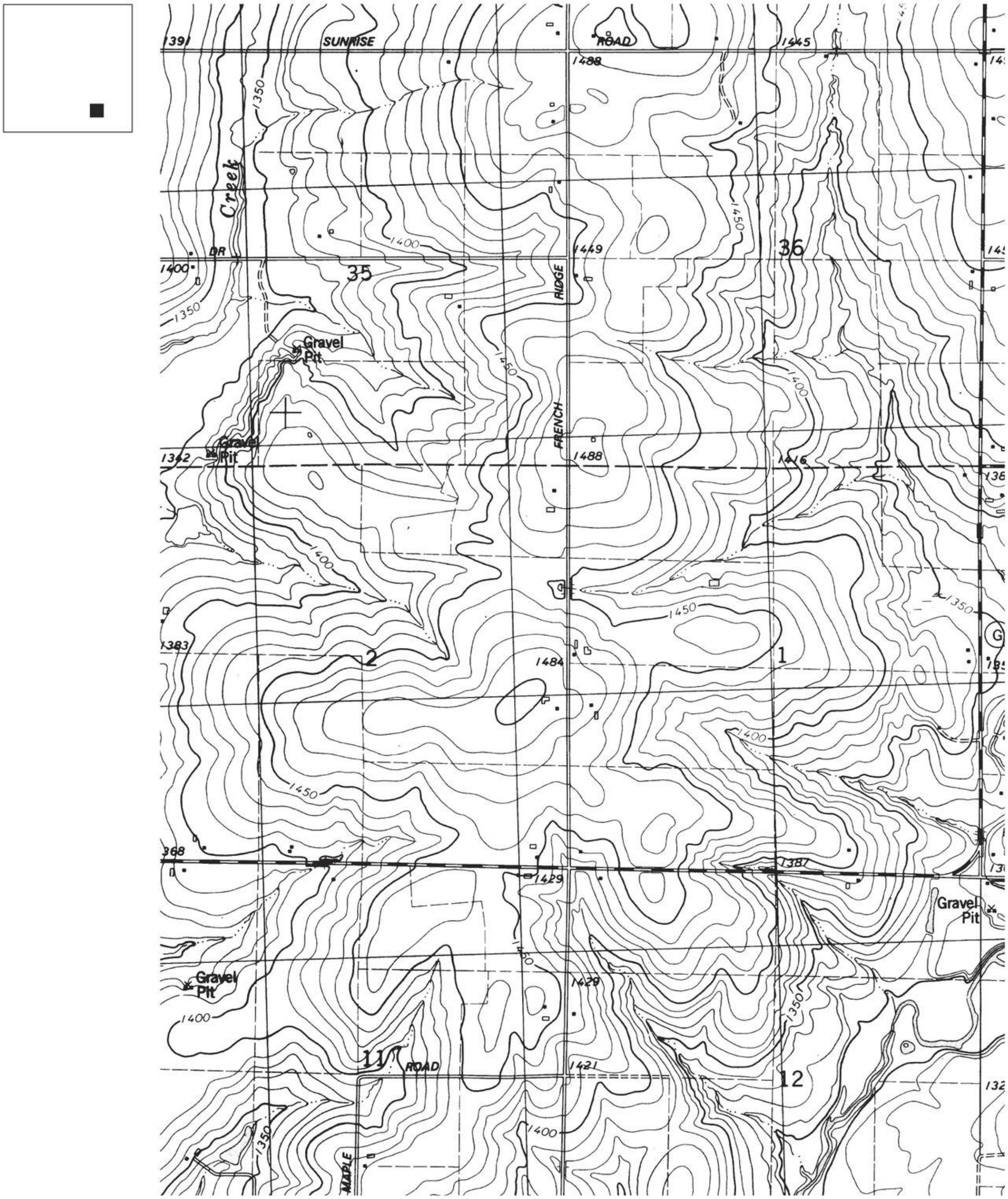


Figure 4. Part of the Pine Dells Quadrangle, Wisconsin (U.S. Geological Survey, 7.5-minute series, topographic, 1982), showing broad, rolling topography on uplands of the Merrill till surface in the southeastern part of Lincoln County. The contour interval is 10 feet.

during ice advance or wastage. Instead, moraines on the till surface appear to have been relatively small and narrow. These observations suggest that the bed conditions of the ice that deposited the Merrill till were considerably different from those of the

Laurentide Ice Sheet in this area. Mickelson and others (1983) and Attig and others (1989) suggested that, at their maximum extent, the lobes of the Laurentide Ice Sheet in northern Wisconsin had subpolar thermal regimes and were frozen to the bed in a zone possibly up to 20 km wide near the ice margin. In contrast, we suggest that the glacier that deposited the Merrill till may have had a thawed, sliding bed all the way to the ice margin.

Glacial history. Two radiocarbon-age estimates from organic material found on top of the Merrill till in eastern Lincoln County are 40,800 BP ± 2,000 (IGS-256) and older than 36,500 BP (IGS-262) (Stewart and Mickelson, 1974, 1976; Dirlam, 1979). In addition, the Merrill till shows a greater degree of weathering of its clay fraction than does sediment of the Copper Falls Formation, which was deposited during the last part of the Wisconsin Glaciation (Stewart, 1973; Stewart and Mickelson, 1976). These observations indicate that the Merrill till was deposited before the last part of the Wisconsin Glaciation and has undergone an extensive period of subaerial weathering. We suggest the Merrill till was probably deposited during the early part of the Wisconsin Glaciation.

The glacier that deposited the till of the Merrill Member of the Lincoln Formation generally advanced southward out of the Lake Superior basin. When the glacier stood at its maximum extent in north-central Wisconsin, ice must have covered all Lincoln County. Fabric measurements made in the Merrill till by Stewart (1973) and the orientations of moraines (Stewart, 1973; Attig, 1993; this study) indicate that ice flowed to the southeast in the southern and southeastern parts of Lincoln County and to the south and southwest in the southwestern part of the county. This pattern of ice flow is similar to that of the Wisconsin Valley Lobe in Lincoln County during the last part of the Wisconsin Glaciation. Similarly, Attig (1993) noted that the map pattern of the outermost extent of the Merrill till in southeastern Taylor County is similar to that of the margins of the Chippewa and Wisconsin Valley Lobes in northeastern Taylor County. These observations indicate the ice that deposited the Merrill till flowed in directions about the same as those of the Laurentide Ice Sheet in north-central Wisconsin.

The pattern of ice wastage during deposition of the Merrill till is shown by the orientations of recessional moraines in the south-central part of Lincoln County near Merrill and in adjacent Taylor County (Attig, 1993) and Langlade County (Mickelson, 1986). The regional pattern of the moraines indicates that the glacier that deposited the Merrill till wasted generally northward and into the Lake Superior basin during deglaciation.

Meltwater-stream sediment. The nature of meltwater drainage from the glacier that deposited the Merrill till was dependent upon the orientation and position of the ice margin relative to the proglacial topography; as a result, it alternated between two configurations. In northern Marathon County and southern Lincoln County, the topography consists of broad, rolling ridges that trend approximately east to west or northeast to southwest. As discussed previously, subsurface records indicate this topography is largely bedrock controlled and covered by thin Pleistocene sediment. As the glacier wasted northward in this area, the landscape immediately adjacent to the ice sloped either toward or away from the glacier, depending on the position of the ice margin.

Where the topography sloped toward the ice margin, meltwater was ponded in ice-marginal lakes in some places. These lakes drained through spillways that crossed drainage divides and eventually joined the Wisconsin River. One example of such a spillway is the valley of Big Cain Creek in southeastern Lincoln County. Big Cain Creek is an underfit stream that occupies a deep, narrow, steep-sided valley (fig. 5). This channel drained meltwater from a lake that formed when the ice margin was at a position just south of the Pine River valley (see plate 1). No significant deposits of lake sediment exist in the southern part of Lincoln County, probably because individual lakes only existed for short periods and there was a paucity of sediment. One exception is an area of sand and gravel in the NE1/4 of sec. 11, T31N, R8E (Doering Quadrangle, U.S. Geological Survey 7.5-minute series, topographic, 1973) that composes a fan-shaped landform that we interpreted to have been a delta. Deposits of sand and gravel also are found in places high in the landscape along the south (north-facing) valley wall of Devil Creek (plate 1).

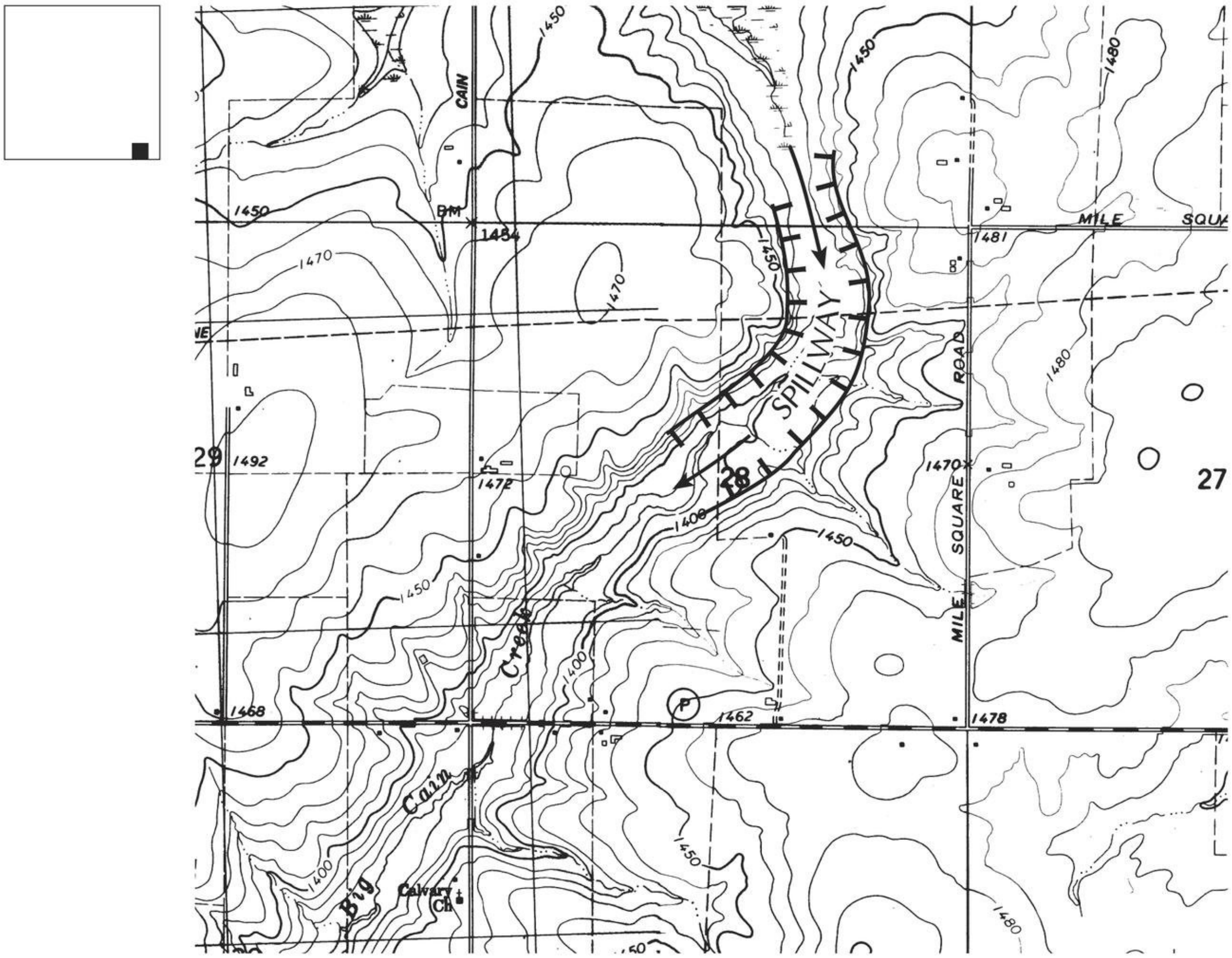


Figure 5. Parts of the Doering and Pine Dells Quadrangles, Wisconsin (U.S. Geological Survey, 7.5-minute series, topographic, 1973 and 1982, respectively), showing part of the stream valley of Big Cain Creek in southeastern Lincoln County. During the wastage of the glacier that deposited the Merrill till, this valley was a spillway that drained meltwater from a small ice-marginal lake. The contour interval is 10 feet.

In places where the topography sloped away from the ice margin, lakes were absent and meltwater drained primarily in streams. In southern Lincoln County, the retreating ice margin was oriented approximately parallel to major stream valleys such as those of the Pine River and Devil Creek. Thus, meltwater flowed parallel to the ice margin and directly into the Wisconsin River valley after these valleys were uncovered by the glacier. The valleys were abandoned shortly after the glacier wasted over the next drainage divide to the north. Deposits of meltwater-stream sediment of the Lincoln Formation are especially prominent in the Pine River valley (map units **sl** and **slc,** plate 1), and numerous sand and gravel pits are found here.

Meltwater-stream sediment also is found in terraces along the Wisconsin River and in an outwash plain north of Merrill. Extensive deposits likely formed elsewhere in the county during ice wastage, but they are now buried by glacial and meltwater-stream sediment of the Copper Falls Formation (discussed later in this report).

Landforms of the Wisconsin Valley Lobe

Glacial landforms of the southern part of the Wisconsin Valley Lobe are in distinct zones in Lincoln County. The marginal zone of the lobe is marked by a broad band, up to about 10 km wide, of primarily hilly glacial topography that includes many ice-walled-lake plains (map units **gwh** and **lc,** plate 1; fig. 6).

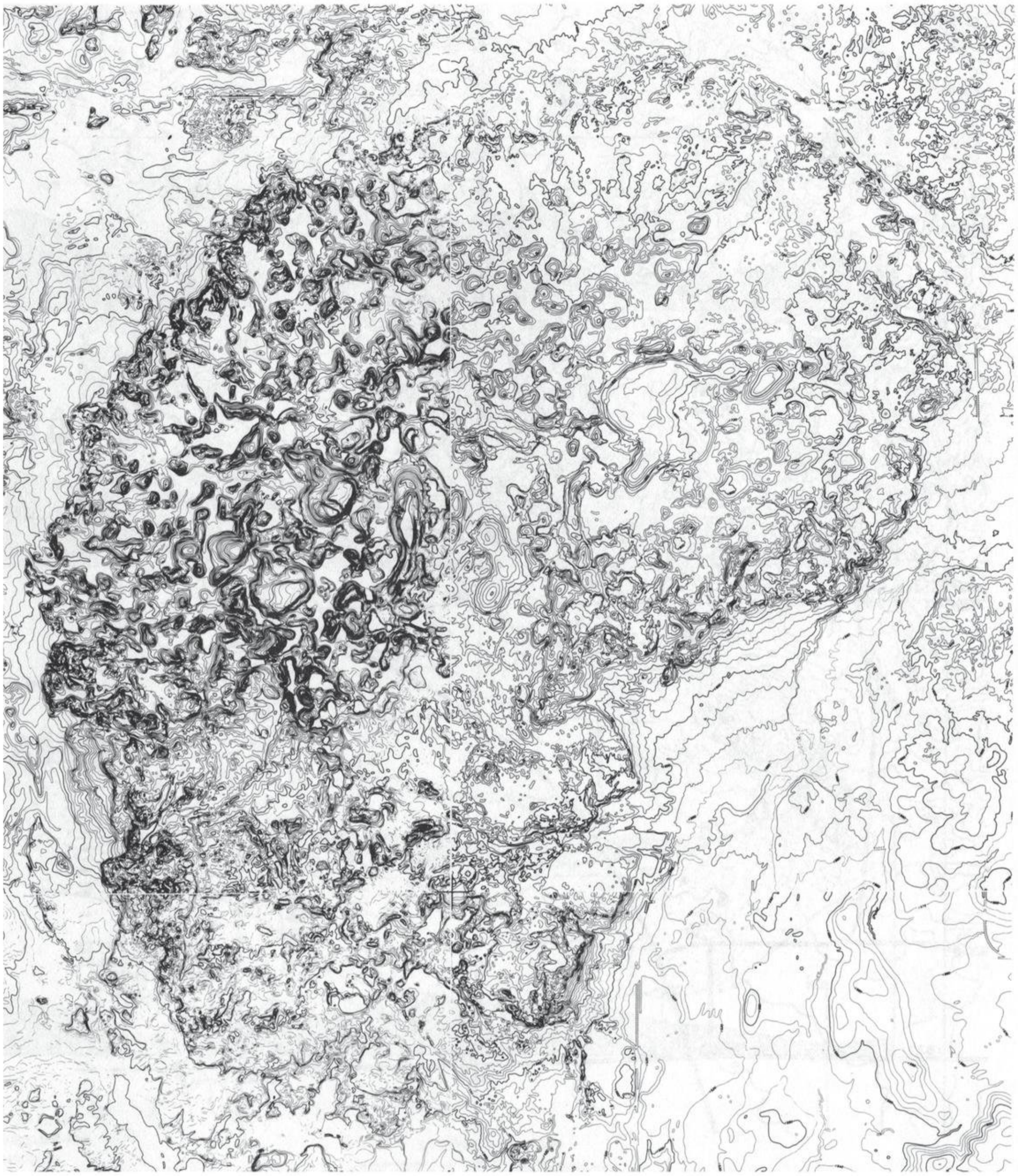


Figure 6. Topographic mosaic of the hilly topography of the Harrison Hills in northeastern Lincoln County and adjacent Langlade County. This area of ice-disintegration topography formed along the southeastern margin of the Wisconsin Valley Lobe. Ice flow was from the northwest and west. The contour interval is 10 feet, except for the upper right side of the map where it is 20 feet; the area shown is about 15 km wide. Compiled from the Bloomville, Gleason, Harrison, and Parrish Quadrangles, Wisconsin (U.S. Geological Survey, 7.5-minute series, topographic, 1982, 1973, 1982, 1973, respectively). Scale 1:100,000.

In places, ice-marginal ridges and outwash fans are on the northern and southern sides of this zone of hills and lake plains, especially in the Harrison Hills and Underdown areas. Drumlins, eskers, recessional moraines, and fans composed of meltwater-stream sediment lie to the north and west of the zone of ice-disintegration landforms that developed along the ice margin. The orientations of drumlins, eskers, and moraines show that the last direction of ice advance was mainly to the southeast, and the direction of ice wastage

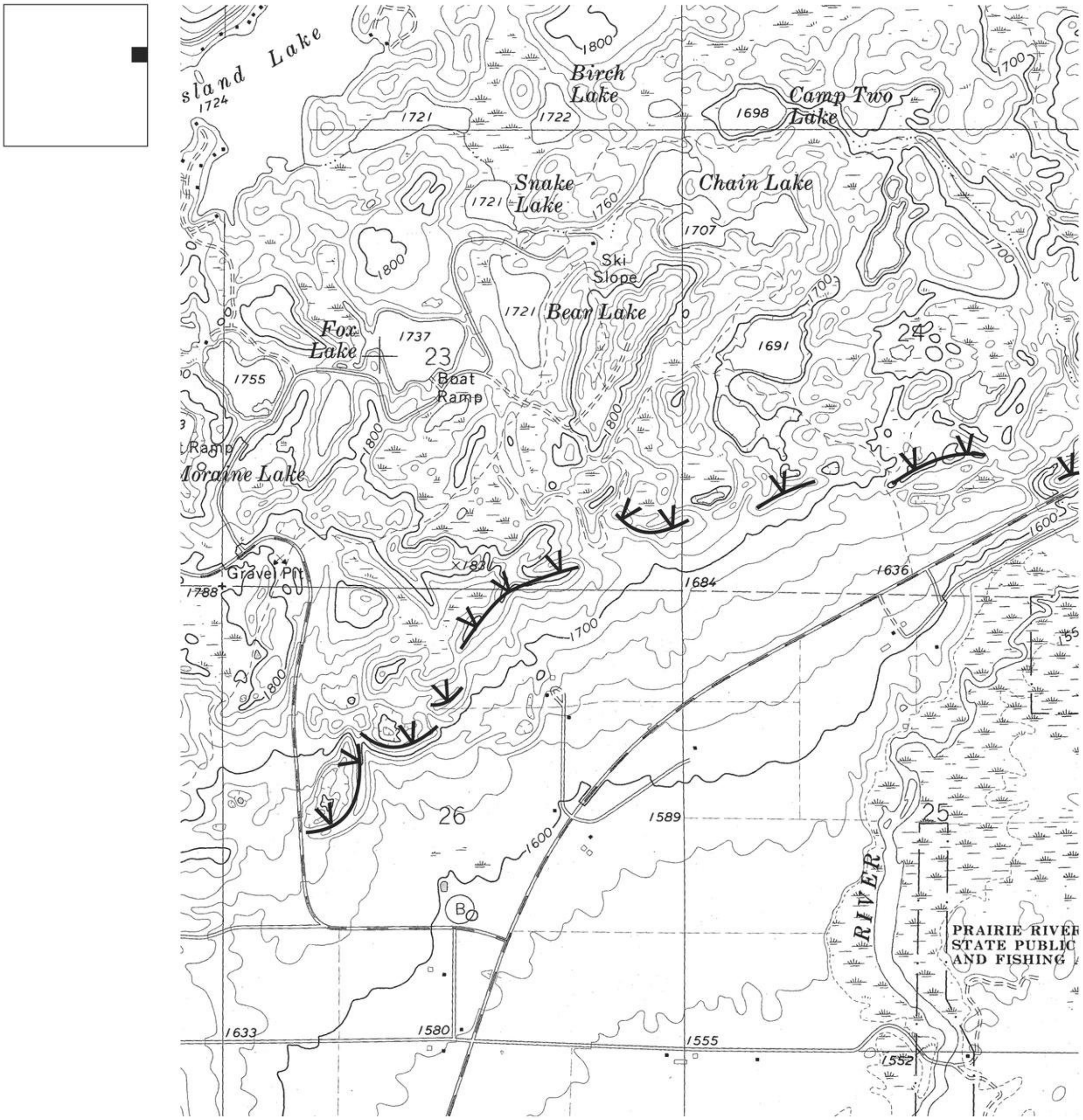
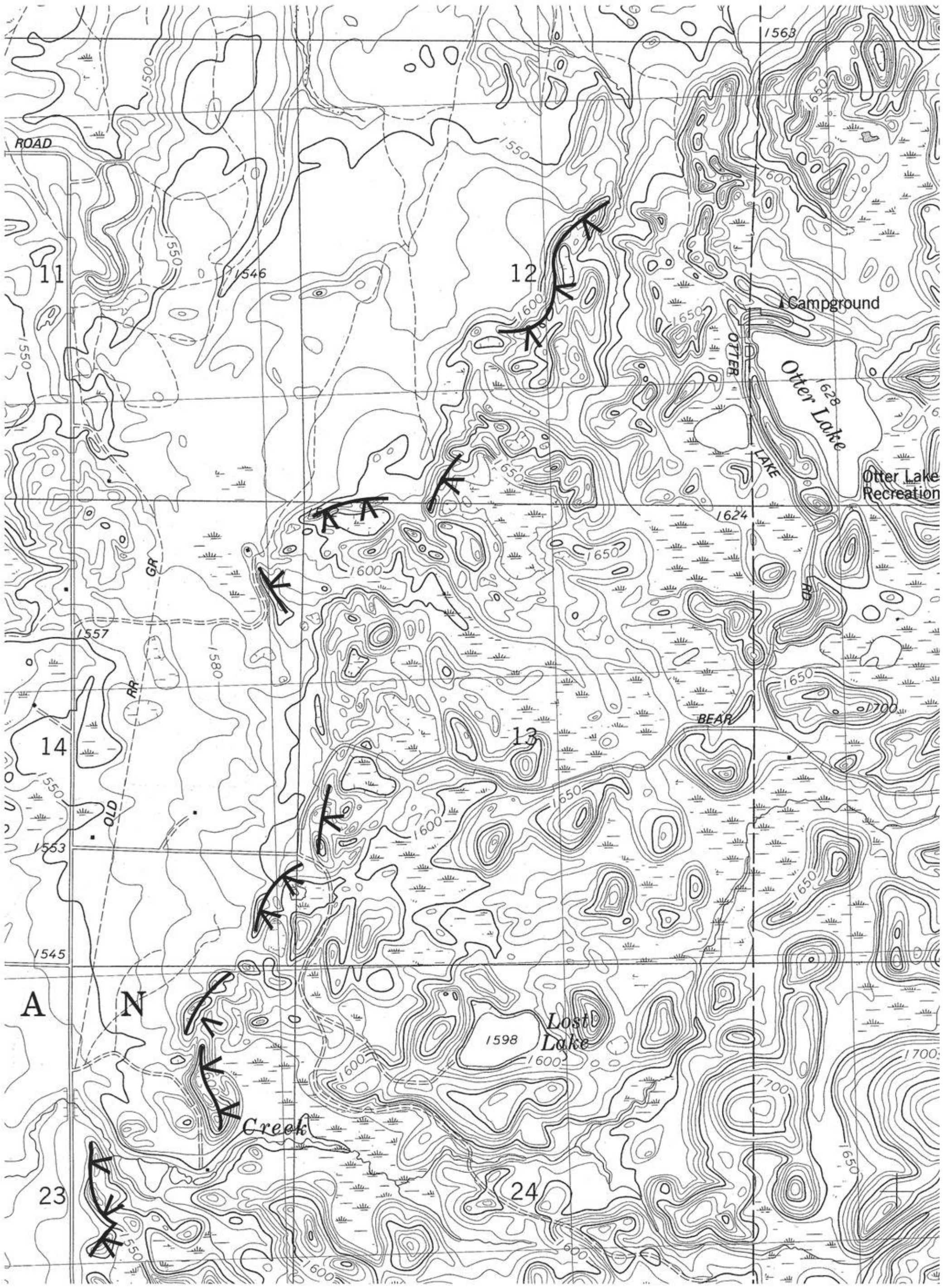


Figure 7*. Part of the Parrish Quadrangle, Wisconsin (U.S. Geological Survey, 7.5-minute series, topographic, 1973), showing segments of an ice-marginal ridge that formed along the outermost extent of the Wisconsin Valley Lobe. The direction of ice flow was from northwest to southeast. The crests of the ridge segments are indicated with symbols; barbs point toward the ice margin, down the former ice-surface slope. A large outwash fan heads at the ridge. The contour interval is 20 feet.*

during deglaciation was to the northwest.

Ice-marginal ridges and outwash fans. The maximum extent of the Wisconsin Valley Lobe in Lincoln County is marked by a prominent, sharp-crested, discontinuous ridge (fig. 7). The ridge segments are typically less than 500 m long and between about 15 and 30 m high. Fans composed of meltwater-stream sediment head at the ridges in most places, indicating that the segments represent a former position of the ice margin.

Other ice-marginal ridges and outwash fans surround and radiate away from the areas of high-relief hills and ice-walled-lake plains in the central parts of the Harrison Hills and Underdown areas (fig. 8). The fans on the northern side of the hilly areas slope



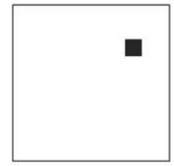


Figure 8. *Part of the Harrison Quadrangle, Wisconsin (U.S. Geological Survey, 7.5-minute series, topographic, 1982) showing segments of an ice-marginal ridge that formed along the up-ice side of the Harrison Hills after the margin of the Wisconsin Valley Lobe wasted to the northwest. The original direction of ice flow was from northwest to southeast in this area. The maximum extent of the Wisconsin Valley Lobe is east of the area shown (see fig. 7). The crests of the ridge segments are indicated with symbols; barbs point down the slope of the stagnant-ice surface. The contour interval is 10 feet.*

Figure 9. View of an exposure in an ice-marginal ridge (left part of photo) and adjacent outwash fan along the southern margin of the Underdown area. The location of this photo is given in the text.

toward the northwest, in the direction of the retreating margin of the Wisconsin Valley Lobe during deglaciation.

The composition of the ice-marginal ridges is not well known because exposures are rare. We observed a 10- to 20-m high exposure through an ice-marginal ridge and an adjacent outwash fan (fig. 9) in a pit along the southwestern margin of the Underdown area along County Highway R, about 800 m east of Highway 51 (NW1/4 NW1/4 SW1/4 sec. 8, T32N, R7E). Most of the sediment exposed in the ridge consists of unsorted, noncalcareous, reddish-brown (5YR 4/4), slightly clayey, silty, gravelly sand (diamicton), considered to be part of the Copper Falls Formation. The average grain-size distribution of ten samples of this sediment was 70 percent sand, 22 percent silt, and 8 percent clay (all values ± 1%). The origin of the diamicton is not well known. It could be subglacial till that was deposited by the stacking of debris-rich ice near the base of the glacier, or it could be very poorly sorted supraglacial sediment that was deposited by debris flows at the ice margin. The sediment exposed in the outwash fans consists primarily of ice-proximal, poorly sorted to moderately well sorted, stratified gravelly sand and sandy gravel. This sediment grades into sorted sand and gravelly sand farther from the maximum extent of the ice margin.

Attig (1993) suggested that the steep, symmetrical slopes of ice-marginal ridges that formed along the margin of the Chippewa Lobe in Taylor County indicate that they were formed primarily by the accumulation of sediment that flowed off the ice surface (supraglacial sediment). Ridges that are more ramp-like would be expected from the stacking of basal sediment by active ice (for example, Krüger, 1993). Many of the ice-marginal ridges that formed in the marginal zone of the Wisconsin Valley Lobe are similar to those described by Attig (1993), and we suggest they formed in a similar way.

Hills. A broad zone of hills, ice-walled-lake plains, and disintegration ridges is just north of the maximum extent of the Wisconsin Valley Lobe in Lincoln County (map units **gwh** and **lc,** plate 1). The hills consist of round to elongate, smooth hills that formed in areas of stagnant glacial ice. Many closed depressions are between the hills. Although hills are the dominant landforms in this terrain, circular and linear disintegration ridges are more common in places. The ridges do not appear

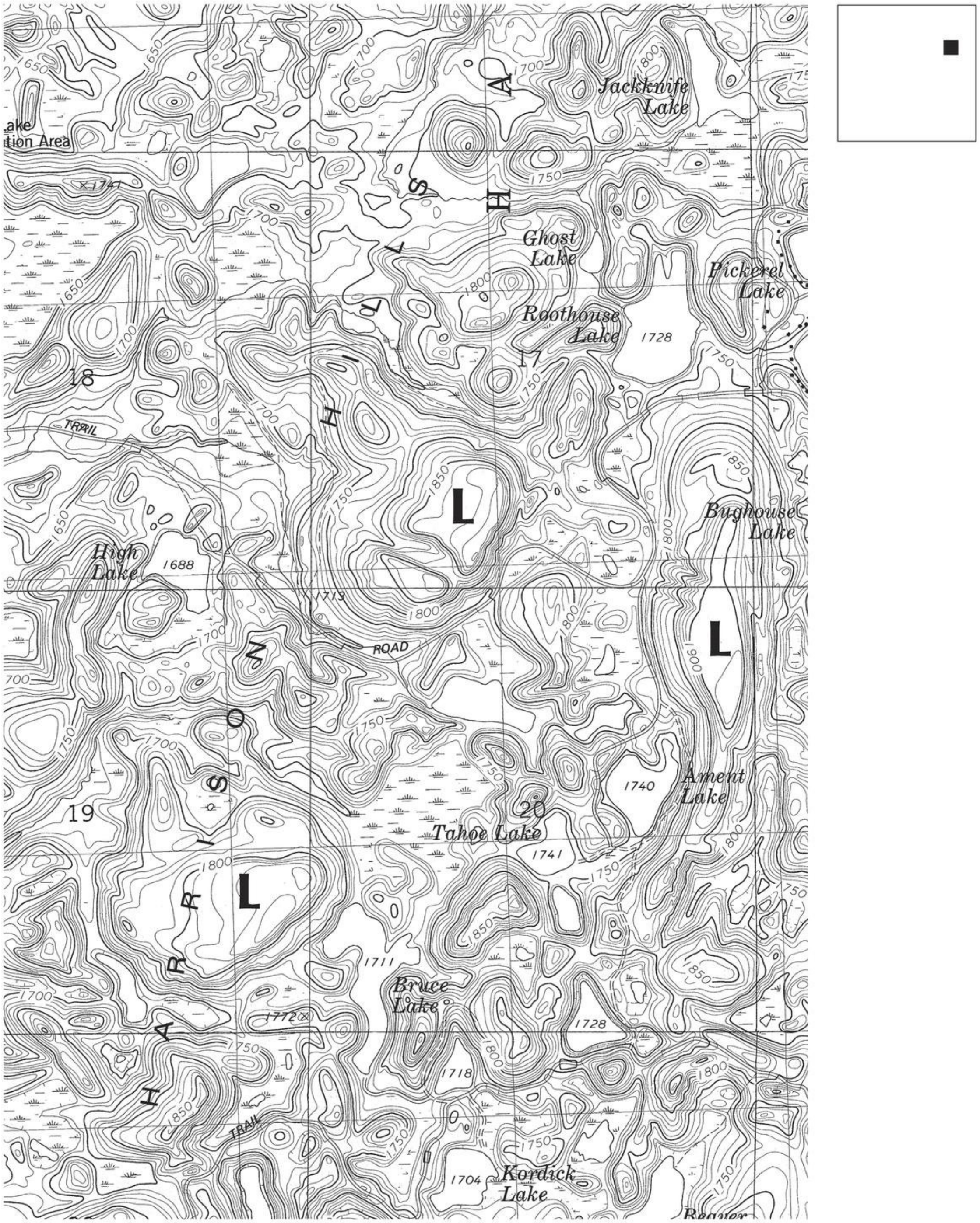


Figure 10. Part of the Harrison Quadrangle, Wisconsin (U.S. Geological Survey, 7.5-minute series, topographic, 1982), showing an area of high-relief hilly glacial topography and three ice-walled-lake plains (L) in the west-central part of the Harrison Hills. The contour interval is 10 feet.

to have a preferred orientation. We recognize two distinct populations of hills in this area: high-relief and low- to moderate-relief hills. High-relief hills are found primarily in the Harrison Hills and Underdown areas (fig. 10). The relief between the summits of individual hills and adjacent low areas ranges from about 10 to 60 m over horizontal distances of about 500 m, and the maximum relief is about 70 m. The high local relief results in generally steep

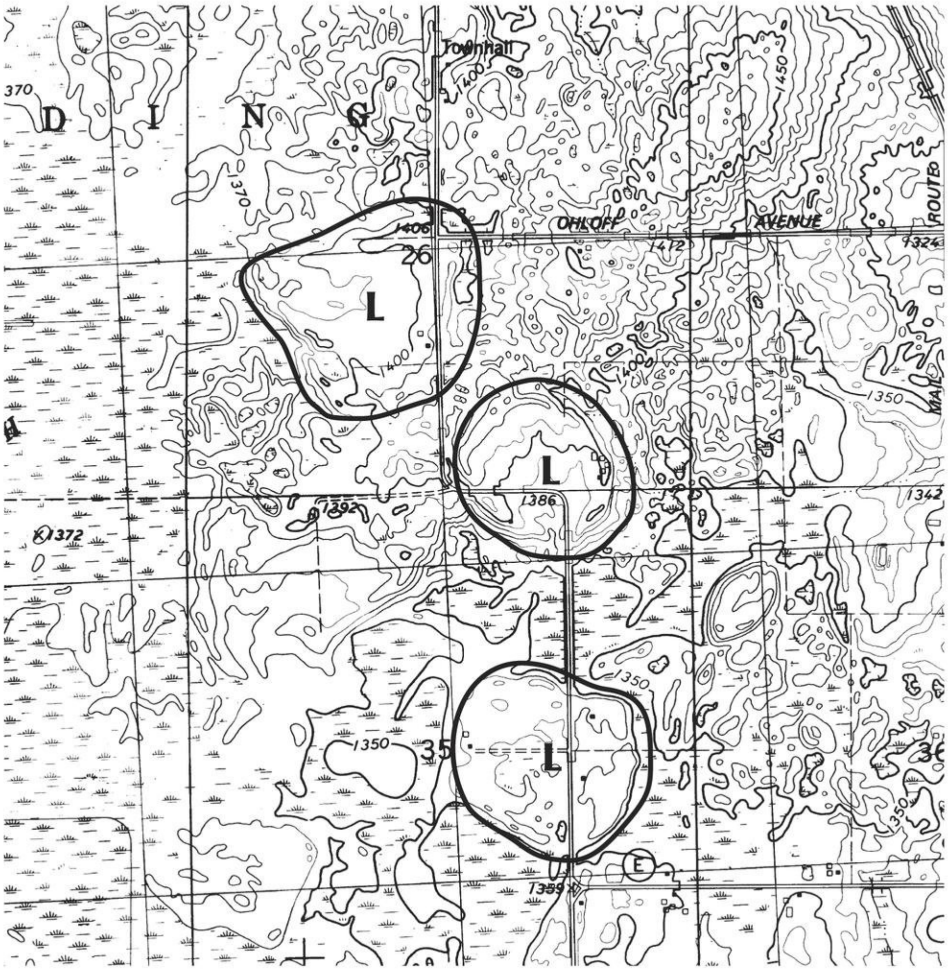
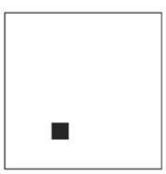


Figure 11. *Part of the Alexander Lake Quadrangle, Wisconsin (U.S. Geological Survey, 7.5-minute series, topographic, 1978), showing an area of low-relief hilly topography and several prominent ice-walled-lake plains (L) along the former southern margin of the Wisconsin Valley Lobe. The contour interval is 10 feet.*



slopes. Low areas between the hills typically contain poorly drained areas (wetlands) that are from about 50 m to more than 500 m wide. Many wetlands that are too small to show at the scale of plate 1 are present throughout the hilly areas.

Low- to moderate-relief hilly topography is seen primarily along the former southern and southwestern margins of the Wisconsin Valley Lobe (fig. 11). Here, the relief of individual hills is about 5 to 10 m, and slopes are relatively gentle.

Few exposures exist in the hills because there are few roads. In the Harrison Hills, examination of a number of shallow (typically 1 to 3 m high) exposures in areas of high-relief hills indicates that, at least near the surface, they are underlain by a variety of sediment types, but primarily noncalcareous, reddish-brown (5YR 4/4 to 4/6), unsorted to crudely stratified, slightly clayey, silty, gravelly sand (diamicton). In places, some parts of hills are underlain by sorted sand, gravelly sand, and sandy gravel. Some hills are also capped by laminated silt and clay, indicating that the sediment originally accumulated in supraglacial lakes that subsequently collapsed when the underlying ice melted.

Material from several test holes drilled up to 20 m deep in hilly topography in the Har–rison Hills showed little downhole variability in grain-size distribution (commonly less than 5%) except in the upper few meters. This uniform sedi–ment is typically unsorted or very poorly sorted, noncal–careous, reddish-brown (5YR 4/4 to 4/6), slightly clayey, silty, gravelly sand (diamicton), which is similar to that observed in the surface exposures. The average grain-size distribution for 46 samples of the diamicton from drillholes and surface exposures is 80 percent sand, 13 percent silt, and 7 percent clay (fig. 12). The distribution is nearly identical to that measured by Nelson (1973) for samples from the same sediment in the Harrison Hills (80% sand, 17% silt, and 3% clay for 12 samples). Nelson (1973) referred to this sediment informally as the Bass Lake till.

The origin of the uniform diamicton from hills in the Harrison Hills is not clear. The sediment must have originated at the glacier bed because there were no valley walls along the ice sheet or nunataks from which sediment could fall onto the ice surface. However, the presence of ice-walled-lake plains, the morphology and distribution of the hills, and the character of the hill sediment indicate that most of the sediment melted out on the ice surface and accumulated into hill forms by the process of topographic inversion. This mechanism was suggested by Gravenor

(1955) and Gravenor and Kupsch (1959) for the formation of "prairie mounds" and "circular disintegration ridges" in east-central Alberta, and also suggested by Clayton and Moran (1974) for the formation of hills in North Dakota. For this process to have occurred in the marginal zone of the Wisconsin Valley Lobe, a large volume of sediment must have been eroded at the bed and then transported upward in the ice column near the margin, where it subsequently melted out on the ice surface, became unstable, and flowed downslope. Attig and others (1989) have suggested that the Wisconsin Valley Lobe had a subpolar thermal regime, which would have enhanced shearing and thrusting of basal sediment toward the ice surface in the marginal zone of the glacier, thus providing the source for supraglacial sediment.

The presence of ice-walled-lake plains high in the landscape indicates that considerable debris was on the ice surface during their formation; otherwise, there would be no source of lake sediment and the surrounding landscape underlain by stagnant, buried ice would not have been stable long enough to allow ice-walled lakes to develop. The shapes and distribution of the hills do not reflect structures that are known to develop at the base of ice sheets, such as crevasses or thrust planes, nor do they have any preferred orientation that might be expected due to glacial flow, such as streamlining. Instead, the patterns and sizes of many of the hills are similar to those of sinkhole depressions that have been observed on the surfaces of many modern, stagnant glaciers (Clayton, 1964, 1967; Clayton and Moran, 1974).

Although much of the sediment in the hills is uniform in texture and color, pebble fabrics measured for this study (fig. 13) and by Nelson (1973) (fig. 14) showed considerable variability in strength and orientation. Surface exposures of the diamicton commonly show dark, reddish-brown layers of sediment that are up to a few centimeters thick and are typically folded or faulted; in places, sorted sediment is adjacent to or above the diamicton. All of these observations suggest that the uniform sediment was deposited by relatively viscous (low water content) debris flows or by slumping on the ice surface, followed by collapse due to melting of buried ice. The flows were probably similar to type 1 flows

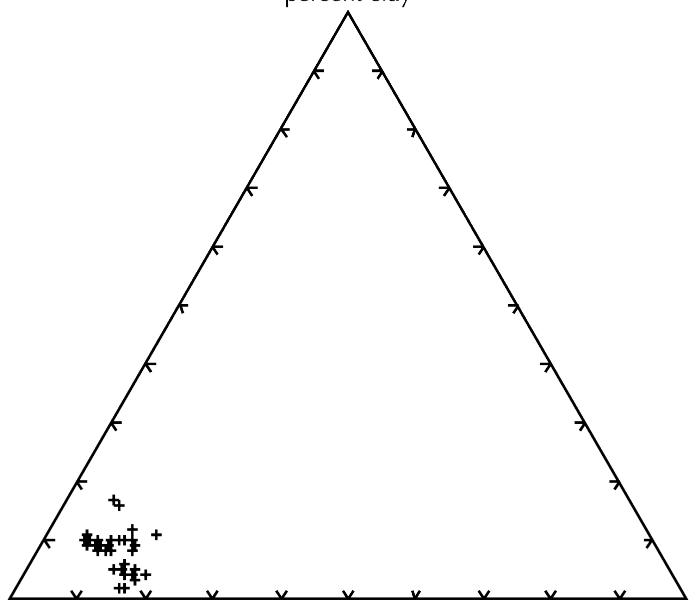


Figure 12*. Grain-size distribution of the finer-than-2 mm fraction of 46 samples (15 overlap in this figure) of uniform sediment (average sand:silt:clay ratio, 80:13:7) collected from surface exposures and drillholes in the Harrison Hills.*

described by Lawson (1979, 1982) at the Matanuska Glacier, Alaska, which typically have little water (8% to 14% by weight), little or no sorting, and weak or variable pebble fabrics. Some of the uniform diamicton recovered from test holes drilled to the base of the hills may be sediment that melted out at the bed of the glacier (subglacial till).

Ice-walled-lake plains. Ice-walled-lake plains (Clayton, 1967; Clayton and Cherry, 1967) are the preserved, nearly flat, offshore bottoms of lakes that were surrounded by stagnant ice. These landforms are a conspicuous part of the landscape in the areas of hilly topography that mark the outer part of the Wisconsin Valley Lobe in Lincoln County (map unit **lc,** plate 1). Especially in areas of high-relief hilly topography, ice-walled-lake plains are typically the highest areas of the landscape. The lake plains consist primarily of a flat, bowl-haped, or convex-upward plain (figs. 10 and 11). Raised rims are preserved in some places along their margins. In most parts of Lincoln County, ice-walled-lake plains are in densely forested areas. As a result, most of the lake plains shown on plate 1 (map unit **lc**) were identified on the basis of interpretations made

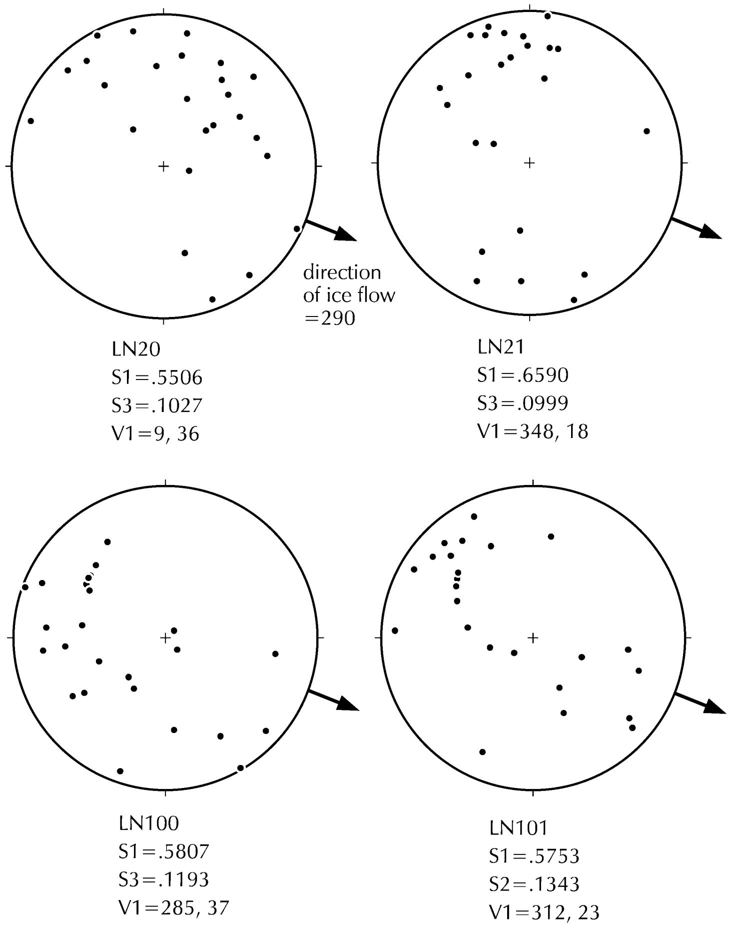


Figure 13*. Lower-hemisphere, equal-area net projections of the orientations of the long axes of prolate pebbles in diamicton in the Harrison Hills. Twenty-five pebbles were measured for each fabric, and only pebbles with long-to-short axis ratios greater than about 3:2 were measured. Fabrics LN20 and LN21 were measured in one hill; LN100 and LN101, in another. Arrows indicate the approximate direction of ice flow of the Wisconsin Valley Lobe. S1 is the principal eigenvalue, which is a measure of the strength of the clast orientations.*

from aerial photographs, topographic maps, and soil maps. A particularly good example of an ice-walled-lake plain is located in the northeastern part of the Harrison Hills (fig. 15).

The lake plains are commonly the only extensive, flat surfaces in areas of hilly topography, and the former offshore plains are typically underlain by fine sediment and lack surface boulders. As a result, the surfaces of many lake plains in north-central Wisconsin have been cleared for agriculture, and some lake plains are used as sources of clay.

Five test holes and many hand-auger borings were drilled into three accessible ice-walled-lake plains to provide samples for a study of the composition of the lake sediment. Ground-penetrating radar profiles were run across two of the lake plains to aid in interpretations of subsurface relationships. Information from the test holes and radar profiles indicates that the offshore plains are underlain primarily by clayey silt (typically less than 10% sand, 60% to 70% silt, and 20% to 30% clay). Several samples of offshore sediment recovered from a drillhole in one ice-walled-lake plain were rhythmically laminated. It is not known whether the laminations formed annually (varves). The edges of the lake plains are underlain primarily by sorted sand, gravelly sand, or sandy gravel that was deposited near the lake shore. In some cases the rim ridges may include poorly sorted, debris-flow deposits.

On the basis of their work in hilly areas of the Missouri Coteau in North Dakota, Clayton and Cherry (1967) recognized two end members of uncoalesced ice-walled-lake basins: 1) those that formed in an unstable environment with thin supraglacial sediment on the surface, and 2) those that formed in a stable environment with thick supraglacial sediment on the adjacent ice surface (fig. 16). They observed that the unstable-environment lake plains are characterized by concave-upward profiles, relatively thin lake sediment, and prominent rim ridges. In addition, these lake plains typically are low in the landscape. In contrast, the stable-environment lake plains typically have convex-upward profiles, lack well defined rim ridges, typically are high in the landscape, and are underlain by relatively thick lake sediment (Clayton and Cherry, 1967).

The stable-environment lakes presumably formed where the buried ice was thick and well insulated and melted very slowly, thus allowing a deep lake basin to form. The unstable-environment lakes formed where the ice was thinner, not well insulated, and melted rapidly (Clayton and Cherry, 1967).

The morphology, composition, and setting of ice-walled-lake plains in Lincoln County are similar to those of the two end members described by Clayton and Cherry (1967). In areas of high-relief hilly topography, such as the Harrison Hills and the Underdown, ice-walled-lake plains are typically the highest parts of the landscape, have convex-upward profiles, and appear to be underlain by thick lake sediment (stable environment; fig. 10). Rim ridges are generally absent or poorly preserved at the margins of the lake plains. In contrast, ice-walled-lake plains in areas of lower-relief hilly topography (fig. 11) along the former southern and southwestern margins of the Wisconsin Valley Lobe generally occupy low areas in the landscape, have concave-upward profiles, and have well defined rim ridges (unstable environment). The rim ridges of these lake plains likely contain a significant quantity of debris-flow deposits.

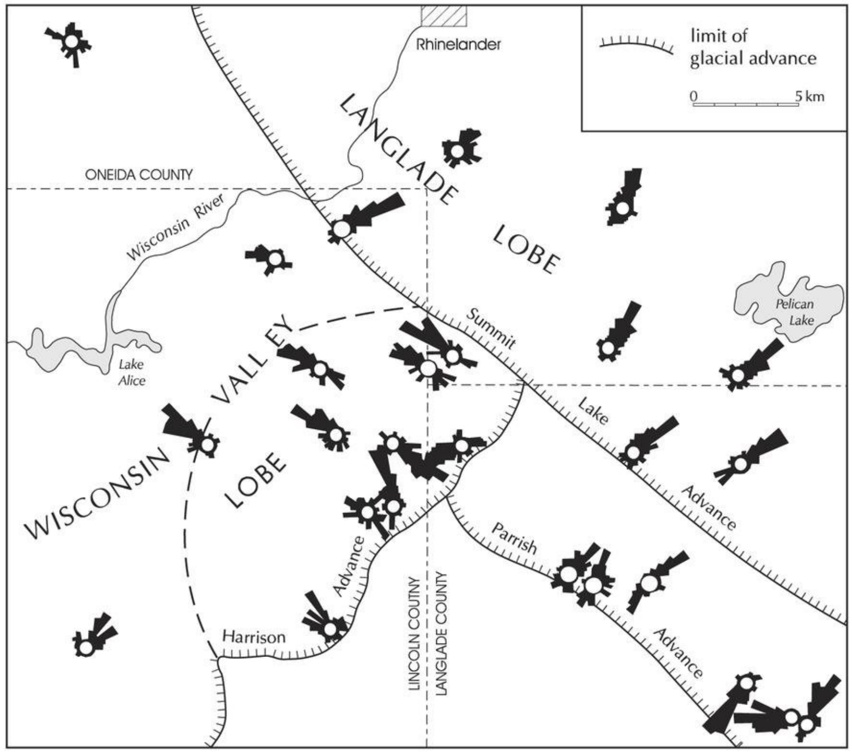


Figure 14. Northeastern Lincoln County, and adjacent Langlade and Oneida Counties; map shows the positions of the Parrish, Summit Lake, and Harrison moraines, and rose diagrams of pebble fabrics measured in till by Nelson (1973). The dashed line outlines the Harrison Hills. Note the variability in fabric strengths and orientations in the area of hilly glacial topography (from Nelson, 1973).

Small moraines near Irma. A series of more than 35 small (less than 4 m high) parallel ridges is present in the central part of Lincoln County near Irma. The crests of these landforms are shown in figure 17 and on plate 1, and they are clearly visible on black and white aerial photographs (fig. 18; scale, 1:20,000). The ridges are best preserved on uplands, such as Irma and Chase Hills, in the E1/2 of T33N, R6E and the W1/2 of T33N, R7E (see the Irma Quadrangle, U.S. Geological Survey 7.5-minute series, topographic, 1982). The ridges are found between 6 and 15 km behind the maximum extent of the Wisconsin Valley Lobe in eastern Lincoln County, and they lie between a region of low-relief drumlins to the northwest and the broad zone of hilly glacial topography to the southeast. The best preserved and most accessible set of ridges is found on Irma Hill (fig. 18), approximately 1 km east of Irma. Prior to this study, these landforms had not been studied in detail, although Nelson (1973) noted their presence on aerial photographs.

The form, composition, and origin of the ridges have been discussed by Ham (1994) and Ham and Attig (1994). In summary, the ridges trend generally northeast to southwest; however, in places their orientation varies as a result of the influence of the underlying topography. The general orientation of the ridges is parallel to that of the margin of the Wisconsin Valley Lobe during deglaciation. One of the ridges can be traced discontinuously for about 10 km, beginning at the proximal side of an ice-marginal fan, over several bedrock hills, and through intervening valleys. In places where the ridge crosses a valley, it extends into the valley beyond the average position of the ridge on adjacent uplands.

The ridges are between 1 and 4 m high, up to 1 km long, and spaced between 40 and 80 m apart. The width of each ridge is difficult to measure precisely because they are not discrete, narrow ridges separated by low, flat areas. Instead, they have a wave form. The ridges are distinctly asymmetrical, having a steeper proximal (up-ice) slope and a more gentle distal (down-ice) slope. On Irma Hill, twelve ridges on the south side of the hill have an average proximal slope of $13^{o} \pm 2^{o}$ and an average distal slope of $9^{o} \pm 2^{o}$.

In 1993 road construction resulted in a 1-km exposure through about 20 of the ridges. On the basis of study of this exposure, Ham (1994) and Ham and Attig (1994) interpreted the ridges to be composed primarily of subglacial till on their proximal sides and debris-flow sediment on their distal sides. The cores of the ridges, below the till and debris-flow sediment, consist of deformed, sorted sand, sandy gravel, and silt that were deposited in meltwater streams and ponds. We observed

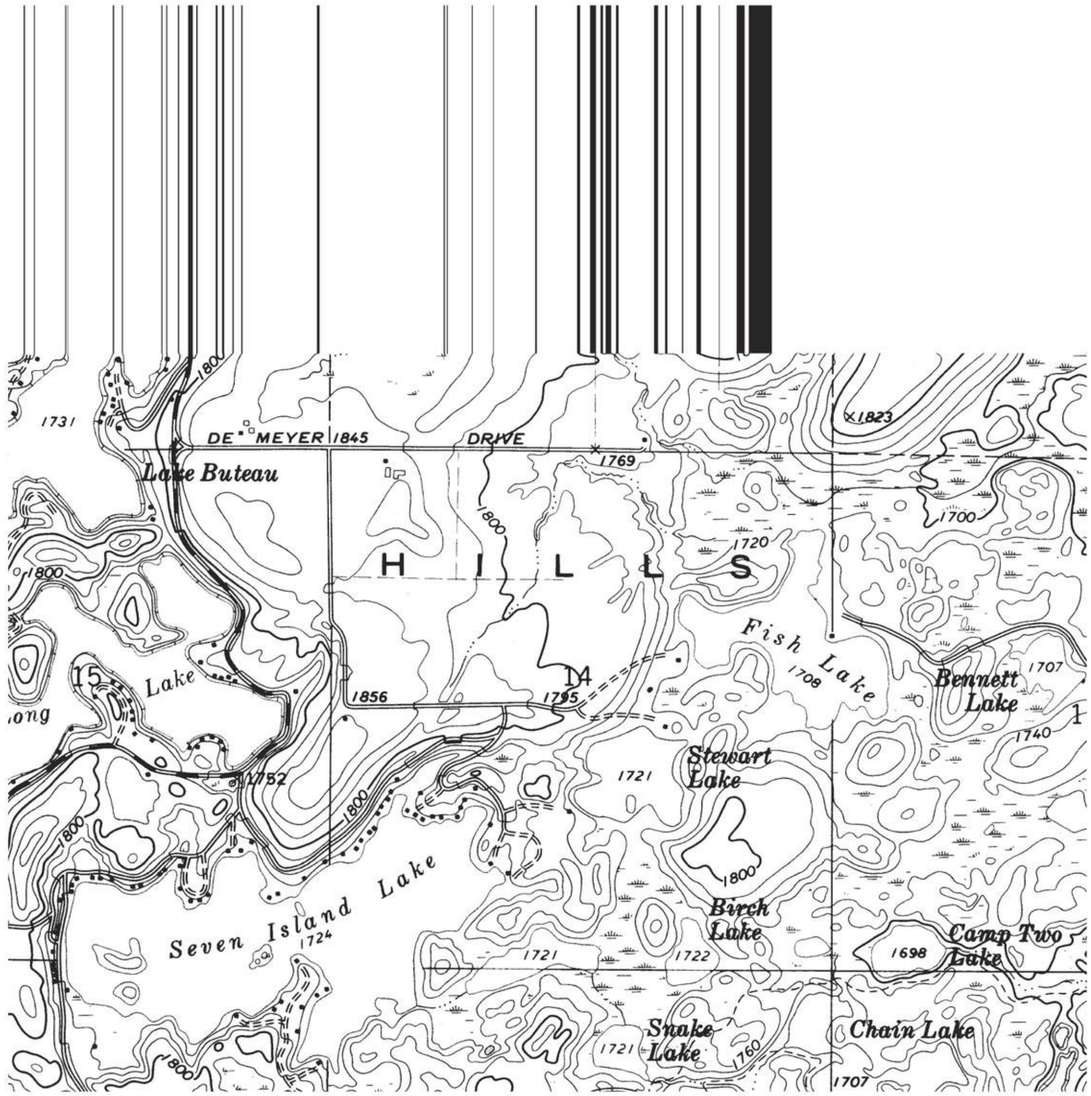


Figure 15. *Part of the Parrish Quadrangle, Wisconsin (U.S. Geological Survey, 7.5-minute series, topographic, 1973), showing an ice-walled-lake plain. Contour interval is 20 feet.*

up to 1 m of postglacial hillslope sediment in the uppermost part of the exposure.

The composition, morphology, and orientation of the ridges suggest they formed individually at the margin of the Wisconsin Valley Lobe during deglaciation (Ham, 1994). The ridges probably formed by a sequence of processes that consisted of the pushing of sorted, ice-marginal sediment by the glacier, partial overriding by the glacier and deposition of subglacial till on the proximal sides of the ridges, and deposition of supraglacial debris-flow sediment on the distal sides of the ridges (fig. 19; Ham, 1994; Ham and Attig, 1994). The ridges are similar to several types of annual moraines from some modern glaciers (for example, Andersen and Sollid, 1971; Boulton, 1986); this similarity suggests a new ridge may have formed each year as a result of minor winter advances of the ice margin during deglaciation (fig. 20). If this assumption is valid, then the net annual rate of ice-surface lowering of the Wisconsin Valley Lobe can be calculated on the basis of an estimate of the ice-surface gradient from the slope of a lateral moraine on Irma Hill and the spacing of the ridges. Ham (1994) calculated that the net annual rate of ice-surface lowering when the ridges formed during deglaciation was between about 1.9 and 5.7 m/yr.

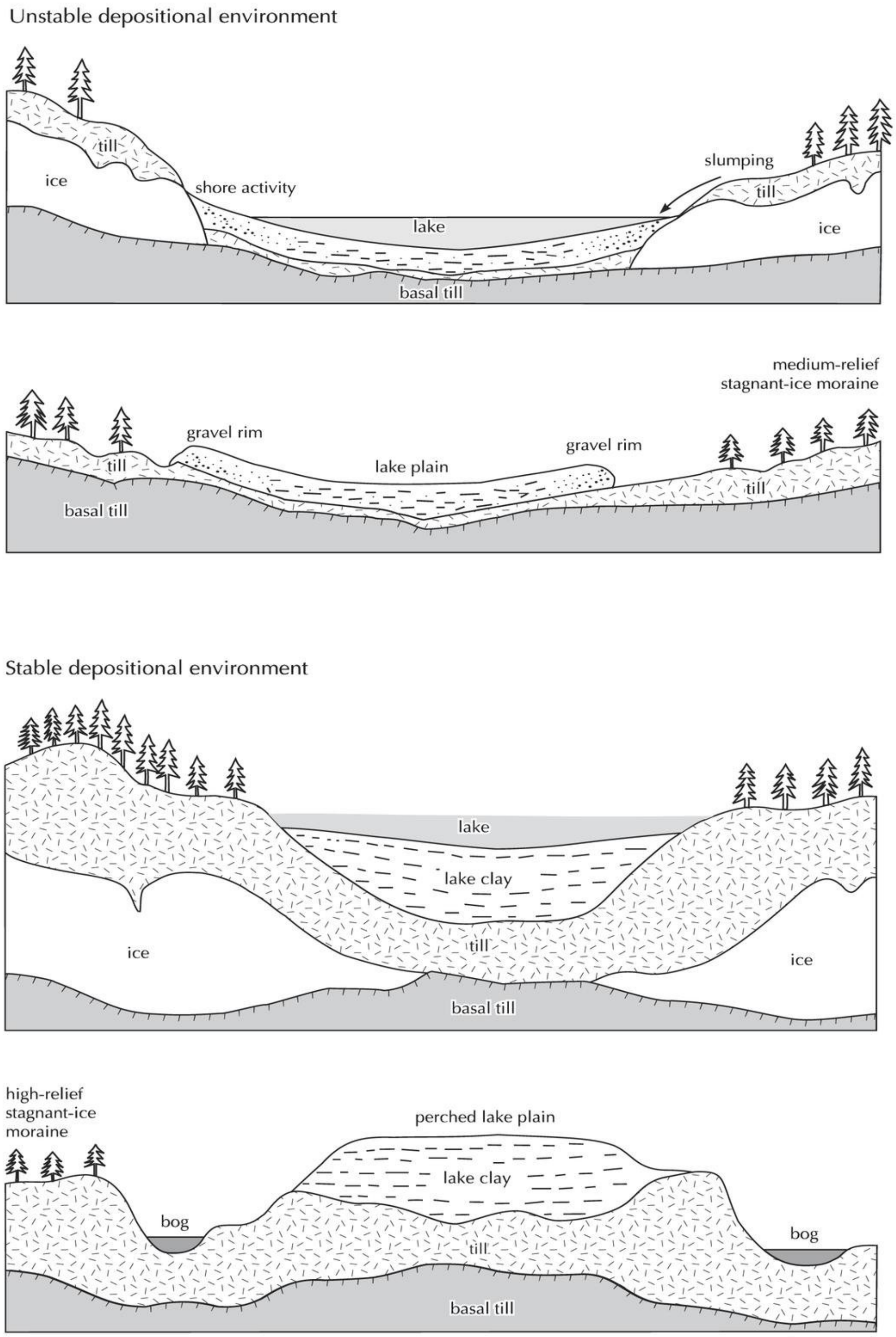


***Figure 16**. Schematic diagram illustrating the formation and morphology of ice-walled-lake plains in unstable and stable depositional environments (from Clayton and Cherry, 1967).*

Other ice-marginal features. We recognized several other ice-marginal features that mark recessional positions of the Wisconsin Valley Lobe. These landforms are prominent ridges composed primarily of collapsed meltwater-stream sediment (map unit **scc,** plate 1) and moraines (indicated by symbols on plate 1). The orientation of these landforms is gener-

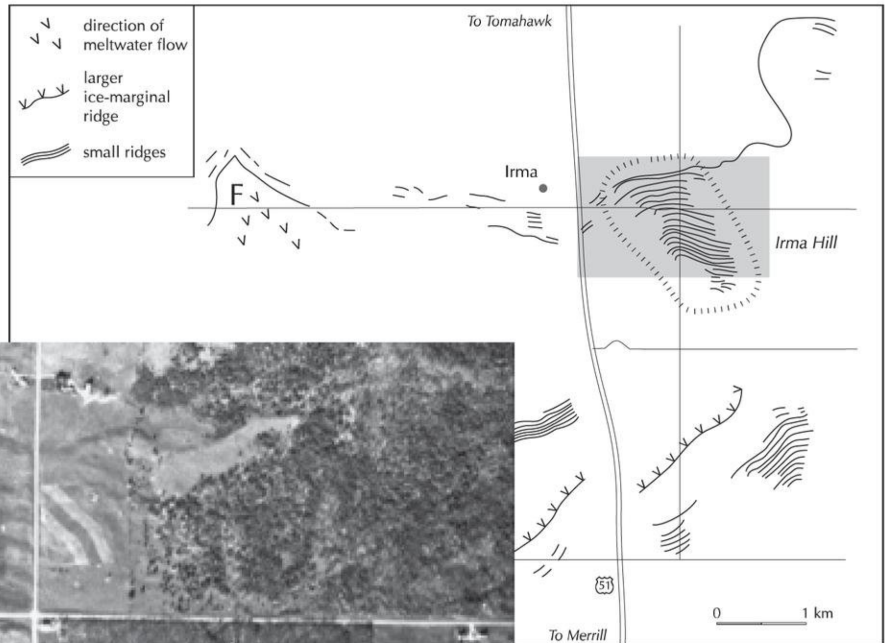


Figure 17. Map of the central part of Lincoln County, Wisconsin, near Irma, showing orientations of the crests of the small, parallel ridges in the study area. The letter F shows the location of an ice-marginal fan composed of meltwater-stream sediment.

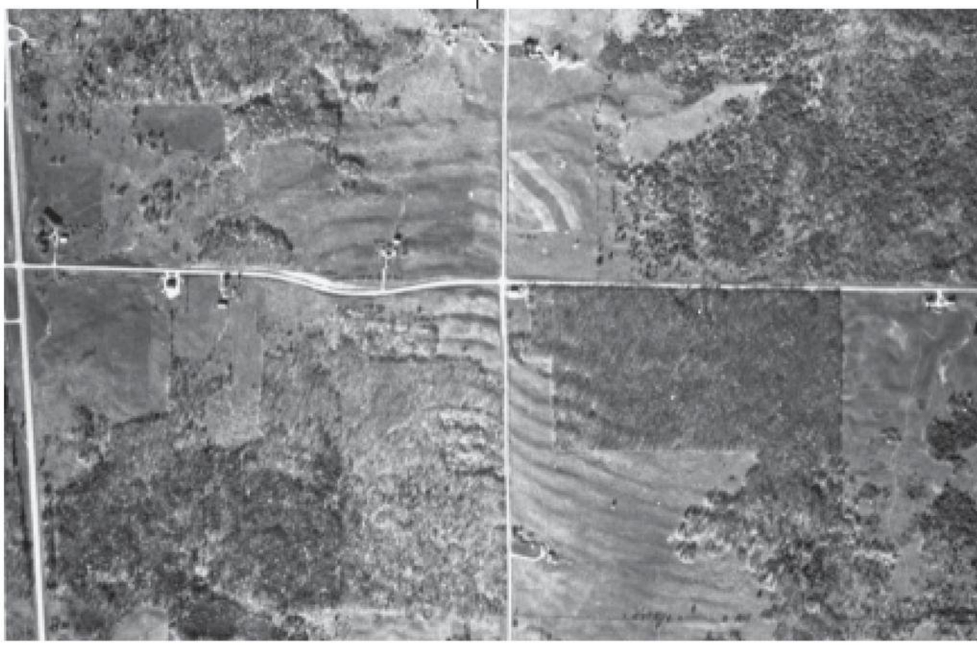


Figure 18. Aerial photograph of small, parallel ridges on Irma Hill. North is at the top of the photograph, and the width of view is about 2.2 km. Ice flow was toward the south, approximately perpendicular to the ridge crests. Irma, Wisconsin, is just to the left (west) of the area shown.

ally northeast to southwest, which indicates that the active ice of the Wisconsin Valley Lobe wasted toward the northwest during deglaciation.

Drumlins. Drumlins formed beneath the Wisconsin Valley Lobe are present throughout northwestern Lincoln County. These streamlined hills are typically less than 10 m high (fig. 21). The orientations of the drumlin crests are shown with arrows in map unit **gw** on plate 1. Most of the drumlins are nearly parallel to one another, and their orientations indicate that the latest direction of ice flow of the Wisconsin Valley Lobe was toward the southeast. The complex shapes of several drumlins in the far northwestern part of the county suggest that the Wisconsin Valley Lobe flowed toward the south or southwest during a slightly earlier phase of glaciation.

The composition of the drumlins is known only from examination of shallow (generally less than 1.5 m) surface exposures and information from a few test holes. Few well constructor's reports are available for these streamlined areas. Shallow roadcuts and material from test holes drilled into the crests of four drumlins indicate that they are underlain primarily by diamicton, probably of the Copper Falls Formation. The sediment is typically unsorted, slightly clayey, silty, gravelly sand that is brown to reddish brown (typical field colors 7.5YR 5/3, and 5YR 4/3 to 5YR 4/4) and noncalcareous.

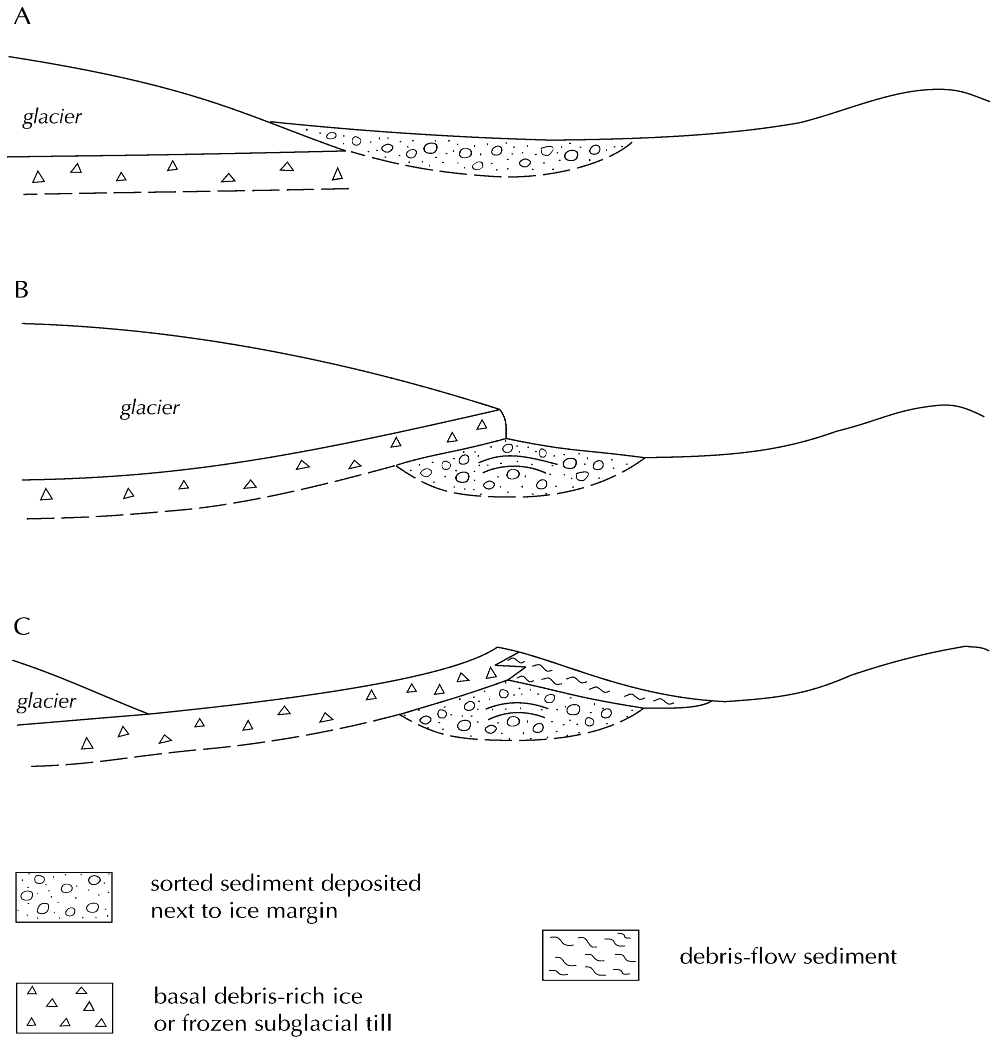


***Figure 19**. Schematic diagram illustrating a conceptual sedimentologic model for the formation of the small, parallel ridges of the south-central part of the Wisconsin Valley Lobe near Irma. The sequence of formation is discussed in the text.*

The average grain-size distribution for 29 samples is 65 percent sand, 25 percent silt, and 10 percent clay (fig. 22).

The average grain-size distribution of the drumlin sediment is similar to that of the Merrill till in the southern part of Lincoln County (about 60% sand, 30% silt, and 10% clay for 20 samples; Stewart, 1973). This observation raises the possibility that the drumlins may be erosional bedforms com–posed mainly of till of the Merrill Member of the Lincoln Formation. However, Stewart (1973) reported that the field color of the Merrill till is typically dark reddish brown (2.5YR 3/3 to 4/3), which is somewhat darker than the sediment samples from the drumlins (typically reddish brown, 5YR 4/4). This color difference suggests that the drumlins are composed of till of the Copper Falls Formation instead of till of the Merrill Member. These till units are difficult to distinguish in the field on the basis of color, texture, and composition. However, Stewart (1973) and Stewart and Mickelson (1976) were able to differentiate between these two units primarily on the basis of the degree of weathering of the clay fraction in their weathering profiles. Analysis of clay min–eralogy may help to distinguish between the Merrill till and till of the Copper Falls For–mation in the streamlined areas of northwest-ern Lincoln County, but this seems unlikely. If the drumlins are erosional bedforms, the thin weathering profile in the upper part of the till has probably been removed.

On aerial photographs, low-relief (less than 5 m) hilly topography is visible on the surfaces of some drumlins in northwestern Lincoln County. The presence of the hilly topography shows that in some places the drumlins are draped by thin supraglacial sediment, probably less than 5 m thick, deposited as the Wisconsin Valley Lobe wasted back from its maximum extent. Those local areas characterized by low-relief hilly topography are not shown on plate 1.

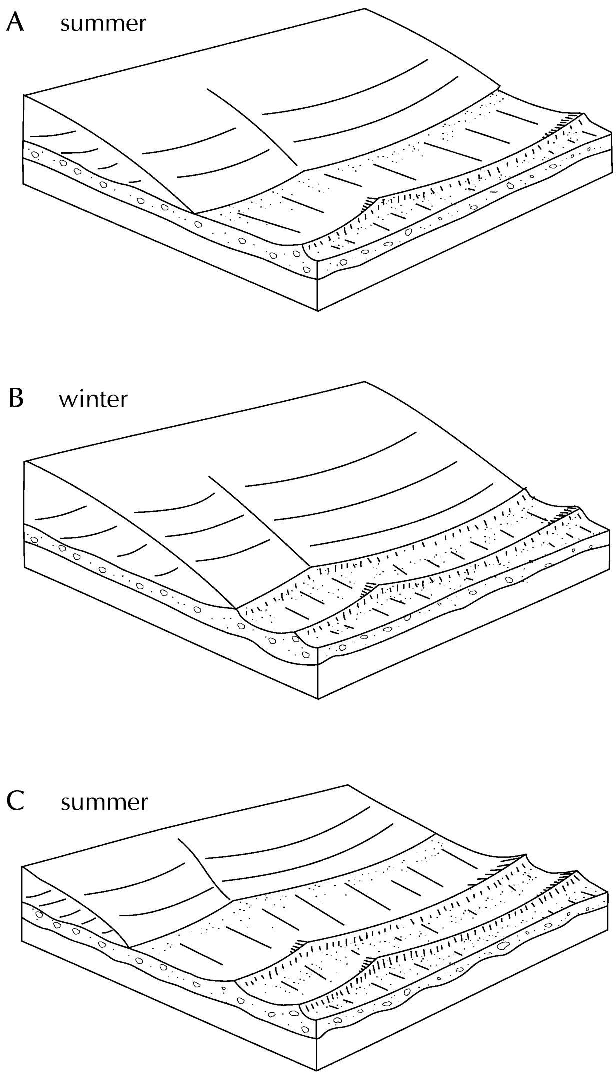


__Figure 20__. Schematic diagram showing the sequence of events in the formation of a moraine over the course of one year during deglaciation of the Wisconsin Valley Lobe. __A.__ The ice margin retreated to a position at the end of summer (ablation season). __B.__ During the following winter (accumulation season) the margin advanced to form an ice-marginal ridge. Because the ice sheet was wasting back during deglaciation, the ice margin generally did not advance the same distance that it retreated during the ablation season. __C.__ During the following summer, the margin retreated again and isolated a new moraine, and a new depositional sequence began.

Eskers and tunnel channels. Several eskers are prominent features of the northwestern and north-central parts of Lincoln County. Two long but discontinuous eskers are along the Spirit River, Spirit River Flowage, and along the Somo River, Little Somo River, and Somo Lake (fig. 23). The esker segments are typically less than 15 m high; more commonly, they are less than 10 m high. Another large, prominent esker segment begins at a point south of Tomahawk in north-central Lincoln County (fig. 24; NE1/4 sec. 3, T34N, R6E) and trends toward the east and southeast. The esker appears to end in an area of collapsed meltwater-stream sediment (NE1/4 sec. 17, T34N, R7E; map unit **scc,** plate 1) that marks a position of the ice margin of the Wisconsin Valley Lobe as it wasted back from its maximum extent. This esker ridge is generally 15 to 20 m high and is composed of well sorted sand, sandy gravel, and gravelly sand. Sand and gravel pits can be found in this and other eskers in Lincoln County. The patterns of all the esker segments in the northwestern part of the county indicate that an integrated, dendritic, englacial and subglacial meltwater drainage system developed in the Wisconsin Valley Lobe during deglaciation, and meltwater flowed mainly to the southeast. Assuming the direction of water flow in the esker tunnels was controlled by the glaciostatic pressure of the overlying ice, the ice surface must have sloped toward the southeast during deglaciation, which is consistent with the general orientations of drumlins and moraines in the area.

On the basis of surface topography only, no obvious tunnel channels are found in the southern part of the Wisconsin Valley Lobe area. Somo Lake and the Spirit River Flowage are in steep-sided channels that may have been part of a tunnel-channel system beneath the Wisconsin Valley Lobe. However, a tunnel channel cannot be traced with any confidence to the former ice margin. A conspicuous gap, now occupied by the North Branch River between the Harrison Hills and Underdown areas, may have been the location of the mouth of a tunnel channel beneath the Wisconsin Valley Lobe. Alternatively, the river

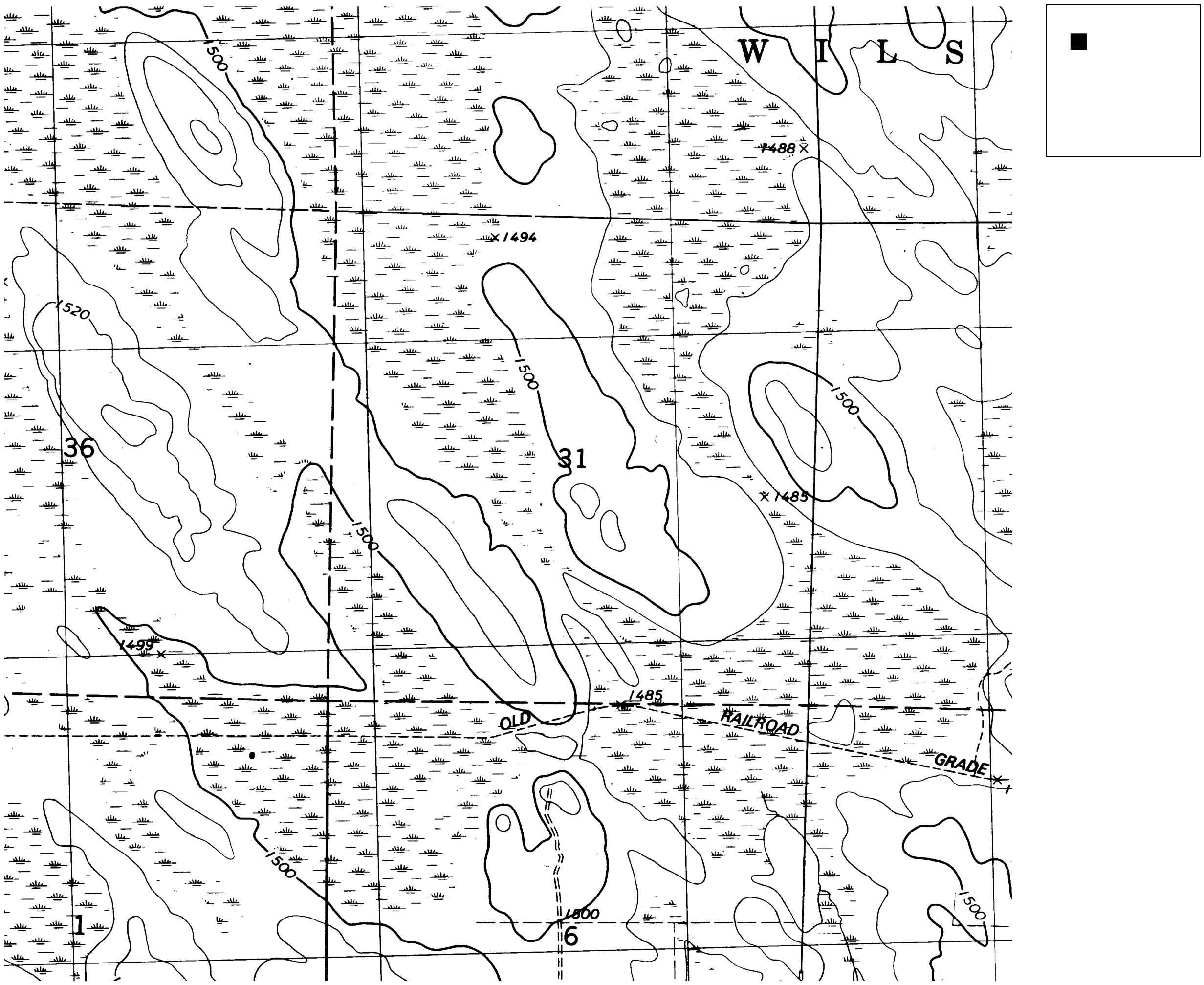


Figure 21. Part of the Spirit Falls Quadrangle, Wisconsin (U.S. Geological Survey, 7.5-minute series, topographic, 1978), showing drumlins in northwestern Lincoln County. The contour interval is 10 feet.

may simply occupy an abandoned subaerial meltwater drainageway.

Glacier-bed conditions and pattern of ice wastage. The origin and distribution of glacial landforms that developed in the southern part of the Wisconsin Valley Lobe can be used to interpret the glacier-bed conditions during ice advance and the regional pattern of ice wastage during deglaciation. The presence of many drumlins in northwestern Lincoln County shows that the glacier bed was at least partly thawed and sliding in this area. In contrast, there are no indications of basal sliding within about 10 to 20 km of the ice margin, which suggests the marginal part of the glacier was probably frozen to the bed (Mickelson and others, 1983, 1986; Attig and others, 1989; Ham and others, 1993; Ham, 1994). These thermal conditions would have enhanced the transport of basal sediment upward in the ice column near the margin and initially led to the formation of broad zones of stagnant, debris-covered, debris-rich ice along the ice margin.

The regional pattern of ice wastage in the marginal part of the Wisconsin Valley Lobe is indicated by the pattern of ice-disintegration landforms. As discussed previously, the general pattern of landforms in areas such as the Harrison Hills and the Underdown consists of a wide zone of hills, ice-walled-lake plains, and kettles bounded on the proximal and distal sides by outwash fans and ice-marginal ridges. The outwash fans on the proximal sides of this hilly terrain slope

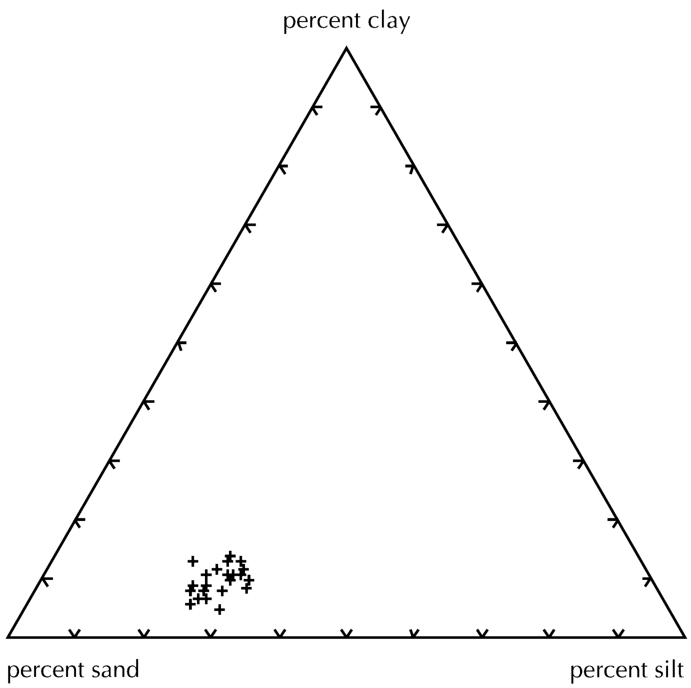


Figure 22. *Grain-size distribution of the finer-than-2 mm fraction of 29 samples of till or till-like sediment (average sand:silt:clay ratio, 65:25:10) from test holes drilled into four drumlins in northwestern Lincoln County.*

toward the direction of the actively retreating margin of the lobe during deglaciation. In addition, in many areas the fans and ice-marginal ridges clearly surround and radiate away from a central zone of hilly topography. These relationships suggest that broad areas of stagnating, debris-covered ice completely separated from the marginal zone of the Wisconsin Valley Lobe as it began wasting northward at the end of the Wisconsin Glaciation (Ham, 1994).

The stagnation and separation of the marginal part of the Wisconsin Valley Lobe probably resulted from two processes. First, the lower part of the Wisconsin Valley Lobe was thin and probably surged to its maximum extent, thus resulting in thin, slow-moving, or stagnant ice. Second, separation of the marginal part of the Wisconsin Valley Lobe during deglaciation was caused by the presence of debris on the ice surface. During the summer melt seasons, cleaner ice farther upglacier melted rapidly; stagnant ice along the margin was insulated by the sediment on the ice surface. The timing of the separation of stagnant ice along the ice margin is poorly known but likely took place between 18,000 and 15,000 years ago (Attig and others, 1985).

The presence of ice-walled-lake plains and high-relief hills, which indicate thick supraglacial sediment and a stable environment (Clayton and Moran, 1974), suggests a progression in the development of ice-disintegration landforms along the ice margin that probably occurred in two distinct phases (Ham and others, 1993; Ham, 1994). During an early stable phase, little melting of buried ice occurred, and ice-walled lakes developed. This was followed by a later unstable phase when buried ice melted rapidly, the debris-covered ice surface collapsed, and ice-walled lakes drained. The second phase is reflected in the present landscape in areas where ice-walled-lake plains are high in the landscape and are surrounded by hilly topography. Figure 25 summarizes our landform model schematically.

The two phases in landform development probably correlate with two stages in the development of the outwash fans. The fans that head at ice-marginal ridges developed during the early stable phase when stream sediment was deposited in front of the ridges at the ice margin. The second stage of fan development occurred when buried ice began to rapidly melt during final ice disintegration. As ice wasted back from the ice-marginal ridges, the fans extended headward through ridge gaps to the interior zone of stagnant ice where hills actively formed and ice-walled lakes drained (Ham, 1994).

The nature and rate of development of this landscape were probably controlled by a number of factors, including the temperature of the stagnant ice, meltwater production, the thickness of debris cover, the nature of meltwater drainage, and regional climate. Attig (1993), Ham and others (1993), and Ham (1994) have suggested that late-glacial climatic conditions controlled the wastage of buried ice. Attig and Clayton (1986, 1992) proposed that permafrost existed in Wisconsin from about 28,000 to 13,000 years ago during the last part of the Wisconsin Glaciation. We suggest that permafrost conditions in northern Wisconsin delayed the wastage of stagnant, buried ice in the marginal zone of the Wisconsin Valley Lobe until shortly after 13,000 years ago, when climatic conditions began to moderate. Florin and Wright (1969), Sollid and Sørbel (1988), and French and Harry (1988) have proposed similar concep-

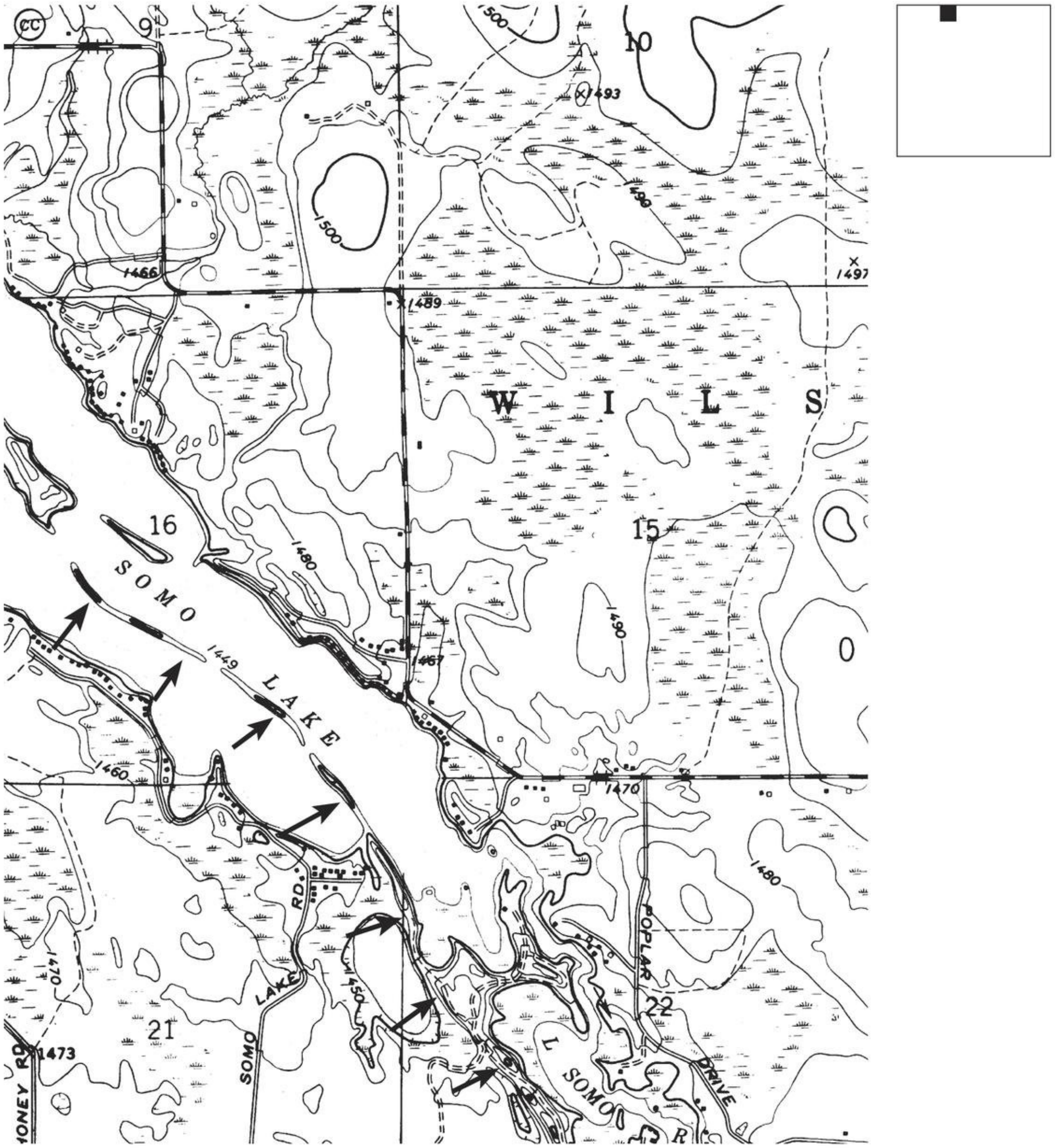


Figure 23. *Part of the Bradley Quadrangle, Wisconsin (U.S. Geological Survey, 7.5-minute series, topographic, 1971), showing part of an esker in Somo Lake and along the Little Somo River. The esker is indicated by arrows, and the contour interval is 10 feet.*

tual models that relate permafrost conditions and the persistence of stagnant, debris-covered glacial ice.

Langlade Lobe

The Langlade Lobe of the Laurentide Ice Sheet advanced southward out of the eastern end of the Lake Superior basin and probably covered part of northeastern Lincoln County twice during the last part of the Wisconsin Glaciation (Nelson, 1973; Mickelson, 1986). However, there is clear evidence for only one ice-margin position of the lobe in Lincoln County, which Nelson (1973) referred to as the Summit Lake moraine. The Summit Lake moraine is a prominent ridge, up to about 30 m high, in the northeastern part of the county (fig. 26). Examination of shallow (less than 2 m) surface exposures showed that the upper parts of the moraine consist primarily of collapsed meltwater-stream sediment (map unit **scc,** plate 1). The sediment is more poorly sorted on the northern side of the moraine.

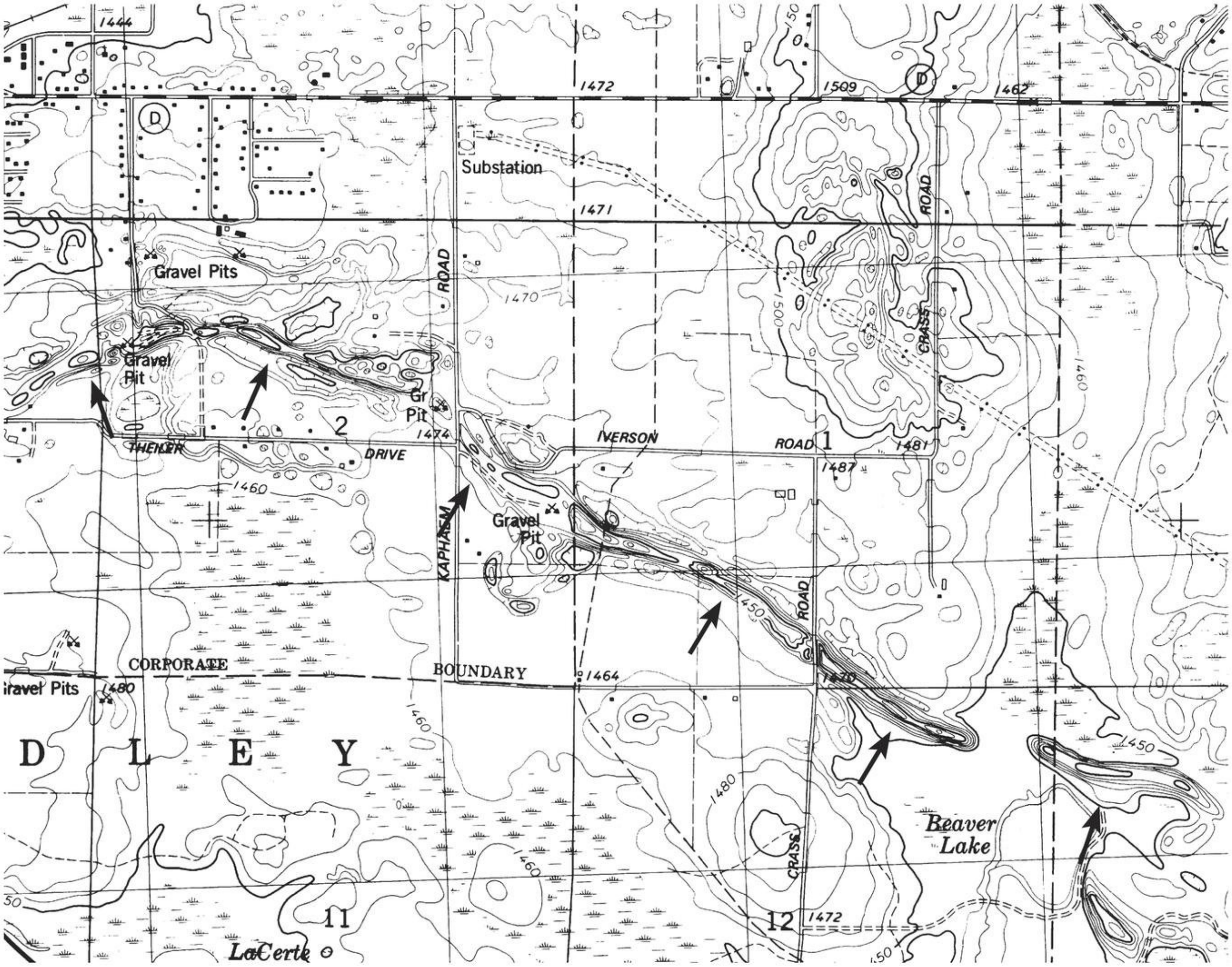
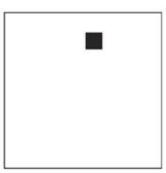


Figure 24. Part of the Tomahawk Quadrangle, Wisconsin (U.S. Geological Survey, 7.5-minute series, topographic, 1982), showing a large esker trending toward the east. The esker is indicated by arrows, and the contour interval is 10 feet.



Till deposited by the Langlade Lobe is included in the Nashville Member of the Copper Falls Formation (Mickelson and others, 1984). Exposures of subglacial till or poorly sorted supraglacial sediment of the Nashville Member were not observed in Lincoln County. Nelson (1973) mapped sediment of the Summit Lake moraine in Lincoln County as "ice-contact stratified drift" because of the general absence of till of the Nashville Member in the upper part of the moraine.

Late Wisconsin meltwater-stream sediment

Adjacent to and beyond the maximum extent of the Wisconsin Valley Lobe, meltwater drained mainly through the broad valleys now occupied by the Prairie and Copper Rivers, and eventually into the Wisconsin River valley. Extensive deposits of meltwater-stream sediment of the Copper Falls Formation are found in terraces in all these valleys, especially along the Prairie River (map unit **sc,** plate 1). It is interesting to note that most of the meltwater in the Prairie and Copper River valleys flowed parallel to the ice margin because uplands existed a few kilometers beyond the maximum extent of the Wisconsin Valley Lobe.

Meltwater-stream sediment (mainly sand and gravelly sand) was deposited in broad, low terraces throughout much of the north-central part of Lincoln County (map unit **sc,** plate 1). These deposits formed when the Wisconsin Valley and Langlade Lobes

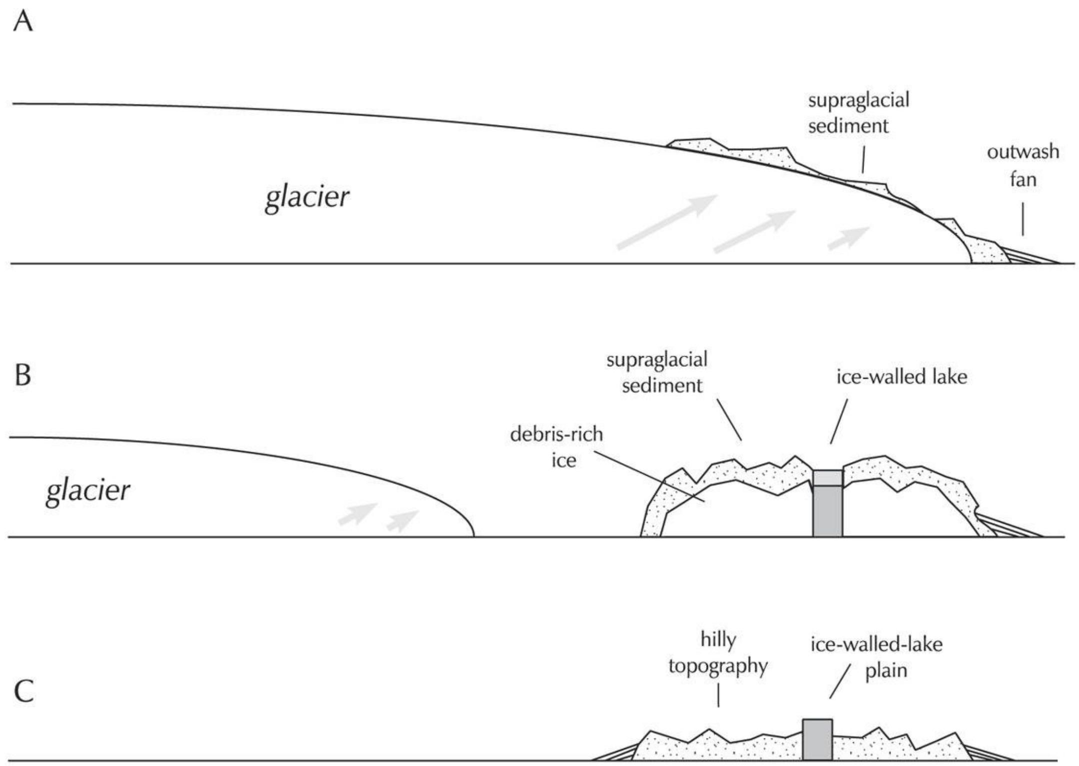


***Figure 25**. Schematic diagram showing the interpreted pattern of ice wastage in the southern part of the Wisconsin Valley Lobe. **A.** The Wisconsin Valley Lobe advances to its maximum extent during the last part of the Wisconsin Glaciation. A cover of debris forms on the marginal part of the glacier. **B.** Between about 18,000 and 15,000 years ago, active ice begins to waste back. A mass of stagnant, debris-covered ice separates from the active ice. During an early stable phase, little of the buried ice melts, the surface is relatively stable, and supraglacial lakes form. Some of these lakes melt to solid ground, forming ice-walled lakes. **C.** During a later unstable phase, the buried ice melts, hills form, and the lakes drain, resulting in ice-walled-lake plains preserved high in the landscape and surrounded by hilly topography. Note that the vertical scale and thickness of supraglacial sediment are greatly exaggerated.*

wasted generally northward during de–glaciation. Isolated, closed depressions (ket–tles) and other extensive areas of collapse topography (map unit **scc,** plate 1) indicate places where meltwater-stream sediment was deposited on top of blocks of stagnant glacier ice that subsequently melted.

Late-glacial events in Lincoln County

The Wisconsin Valley and Langlade Lobes advanced south out of the Lake Superior basin and covered most of Lincoln County during the last part of the Wisconsin Glaciation. No radiocarbon-age estimates are available to precisely define the chronology of the advance and wastage of the Laurentide Ice Sheet in northern Wisconsin (Clayton and Moran, 1982; Mickelson and others, 1983; Attig and others, 1985). However, regional correlation of ice-margin positions between Wisconsin and Minnesota indicates that the ice reached its maximum extent by about 20,000 years ago and began to waste back between about 18,000 and 15,000 years ago (Attig and others, 1985).

The chronology of late-glacial events in Lincoln County is based on mapping of ice-margin positions (Nelson, 1973; this study) and correlation with those positions in adjacent Langlade and Taylor Counties (Nelson, 1973; Mickelson, 1986; Attig, 1993). Ice-margin positions are indicated by the presence of moraines, or in some cases outwash heads. The term "phase" has been used in Wisconsin to define glacial events associated with distinct ice-margin positions (Attig and others, 1985; Clayton and others, 1992; Clayton and Attig, 1993).

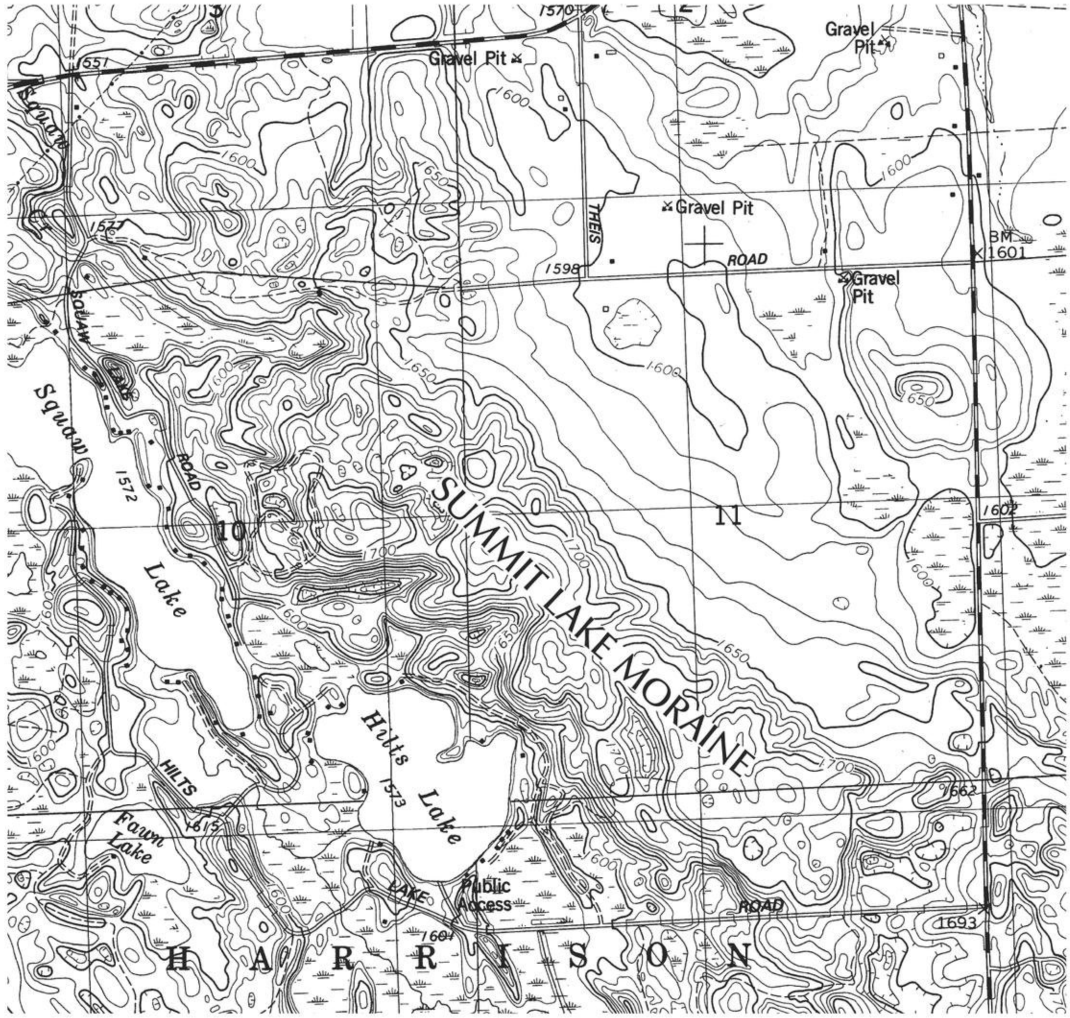


Figure 26. Part of the Lake Julia Quadrangle, Wisconsin (U.S. Geological Survey, 7.5-minute series, topographic, 1982), showing the Summit Lake moraine of the Langlade Lobe in northeastern Lincoln County. Ice flow was from the northeast. Contour interval is 10 feet.

Ice-margin positions of the Wisconsin Valley and Langlade Lobes in Lincoln County and parts of adjacent counties are shown in figure 27. The ice-marginal ridge that defines the outermost extent of the Wisconsin Valley Lobe in southwestern Lincoln County and adjacent Taylor County has been named the Wood Lake moraine (Attig, 1993); the advance of the Wisconsin Valley Lobe that deposited the Wood Lake moraine is included in the Wood Lake Phase (Attig, 1993). This ridge is at the margin of a broad zone of primarily hilly topography and ice-walled-lake plains. The ice-marginal ridge that defines the outermost extent of the Wisconsin Valley Lobe in eastern Lincoln County and marks the edge of the high-relief hilly topography in the Harrison Hills and Underdown areas is called the Harrison moraine (Nelson, 1973); the advance of the Wisconsin Valley Lobe that deposited the Harrison moraine is included in the Harrison Phase. The advances of the Langlade Lobe that deposited the Parrish moraine and later, the Summit Lake moraines are included in the Parrish and Summit Lake Phases, respectively.

There is no clear field evidence for the Parrish moraine in northeastern Lincoln County. Nelson (1973) suggested that the Parrish moraine was continuous across northeastern Lincoln County, but it was overrun and destroyed during the advance of the Wisconsin Valley Lobe that deposited the Harrison moraine. Alternatively, the Parrish moraine may not have been deposited in northeastern Lincoln County; instead, the

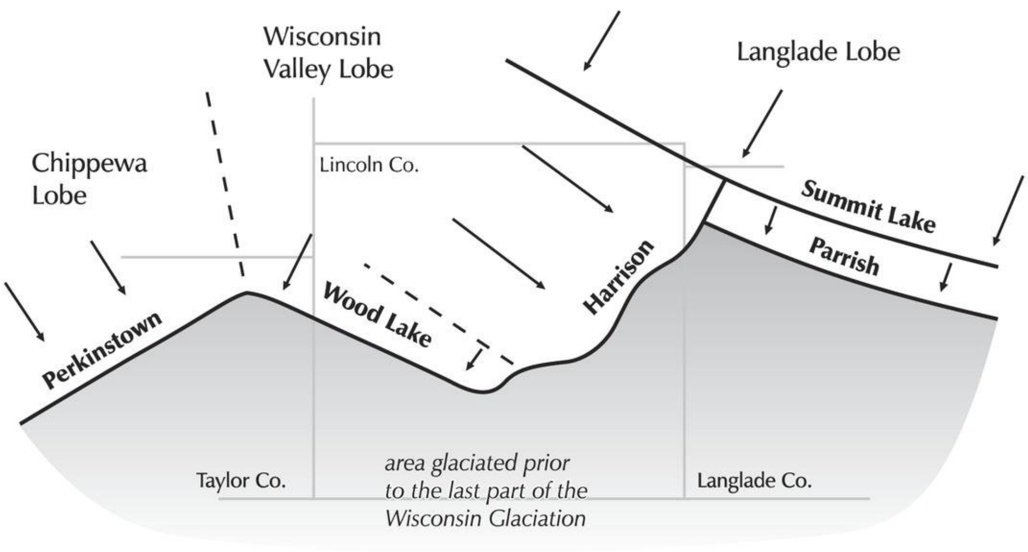


Figure 27. *Ice-margin positions of the Wisconsin Valley, Chippewa, and Langlade Lobes of the Laurentide Ice Sheet in Lincoln County and adjacent parts of Langlade and Taylor Counties. Arrows indicate general directions of ice flow.*

Wood Lake moraine may be the age-equivalent of the Parrish moraine in Langlade County; thus, there may have been a prominent offset along the ice margin.

The Harrison moraine cuts across the Parrish moraine; however, the Summit Lake moraine cuts across the Harrison moraine (fig. 27; Nelson, 1973; Mickelson, 1986). This relationship indicates that the Harrison Phase occurred after the Parrish Phase, but before the Summit Lake Phase.

The Wood Lake moraine is believed to correlate with the Perkinstown moraine deposited by the Chippewa Lobe in central and western Taylor County (Attig, 1993). Drumlin orientations indicate that ice flow during deposition of the Harrison moraine was toward the southeast, at nearly right angles to the southwestward flow during deposition of the Wood Lake moraine. The prominent offset where the Harrison moraine joins the Wood Lake moraine indicates that the Harrison and Wood Lake moraines were deposited by separate ice-flow events. Apparently, southwestward-flowing ice first deposited the Wood Lake moraine, then ice flow shifted to the southeast during deposition of the Harrison moraine. The interval between these two advances was probably brief, and the rapid change in ice flow direction may have been the result of surge-like or ice-stream behavior of the Wisconsin Valley Lobe near the end of the Wisconsin Glaciation (Ham, 1994).

REFERENCES

Andersen, J.L., and Sollid, J.L., 1971, Glacial chronology and glacial geomorphology in the marginal zones of glaciers,Midtdalsbreen and Nigardsbreen, South Norway: *Norsk Geografisk Tidsskrift,* vol. 25, p. 1–38.

Attig, J.W., 1993, Pleistocene geology of Taylor County, Wisconsin: Wisconsin Geological and Natural History Survey Bulletin 90, 25 p.

Attig, J.W., and Clayton, Lee, 1986, History of late Wisconsin permafrost in northern Wisconsin: *American Quaternary Association, Program with Abstracts,* p. 115.

Attig, J.W., and Clayton, Lee, 1992, Conditions beyond the ice margin in Wisconsin during the last glacial maximum: *Geological Society of America, Abstracts with Programs,* vol. 24, p. 3.

Attig, J.W., and Muldoon, M.A., 1989, Pleistocene geology of Marathon County, Wisconsin: Wisconsin Geological and Natural History Survey Information Circular 65, 27 p.

Attig, J.W., Clayton, Lee, and Mickelson, D.M., 1985, Correlation of late Wisconsin glacial phases in the western Great Lakes area: *Geological Society of America Bulletin,* vol. 96, p. 1585–1593.

Attig, J.W., Clayton, Lee, and Mickelson, D.M., 1988, Pleistocene stratigraphic units of Wisconsin 1984–1987: Wisconsin Geological and Natural History Survey Information Circular 62, 61 p.

Attig, J.W., Mickelson, D.M., and Clayton, Lee, 1989, Late Wisconsin landform distribution and glacier-bed conditions in Wisconsin: *Sedimentary Geology,* vol. 62, p. 399-405.

Boulton, G.S., 1986, Push-moraines and glacier-contact fans in marine and terrestrial environments: *Sedimentology,* vol. 33, p. 677–698.

Clayton, Lee, 1964, Karst topography on stagnant glaciers: *Journal of Glaciology,* vol. 5, p. 107–112.

Clayton, Lee, 1967, Stagnant-glacier features of the Missouri Coteau in North Dakota, *in* Clayton, Lee, and Freers, T.F., eds., *Glacial geology of the Missouri Coteau and adjacent areas:* North Dakota Geological Survey Miscellaneous Series, no. 30, p. 25–46.

Clayton, Lee, and Attig, J.W., 1993, Pleistocene mapping at the Wisconsin Geological and Natural History Survey, *in* Aber, J.S., ed., *Glaciotectonics and Mapping Glacial Deposits:* Canadian Plains Research Center, Regina, p. 138–154.

Clayton, Lee, and Cherry, J.A., 1967, Pleistocene superglacial and ice-walled lakes in west-central North America, *in* Clayton, Lee, and Freers, T.F., eds., *Glacial geology of the Missouri Coteau and adjacent areas:* North Dakota Geological Survey Miscellaneous Series, n. 30, p. 47–52.

Clayton, Lee, and Moran, S.R., 1974, A glacial process-form model, *in* Coates, D.R., ed., *Glacial Geomorphology:* Binghamton, State University of New York, p. 89–119.

Clayton, Lee, and Moran, S.R., 1982, Chronology of late Wisconsinan glaciation in middle North America: *Quaternary Science Reviews,* vol. 1, p. 55-82.

Clayton, Lee, Attig, J.W., Mickelson, D.M., and Johnson, M.D., 1992, Glaciation of Wisconsin: Wisconsin Geological and Natural History Survey Educational Series 36, 4 p.

Dirlam, D.M., 1979, Pollen analysis of a mid-altonian peat in Schelke Bog, Lincoln County, Wisconsin [M.S. thesis]: University of Wisconsin, Madison, 24 p.

Florin, M., and Wright, H.E., Jr., 1969, Diatom evidence for the persistence of stagnant glacial ice in Minnesota: *Geological Society of America Bulletin,* vol. 80, p. 695–704.

French, H.M., and Harry, D.G., 1988, Nature and origin of ground ice, Sandhills Moraine, southwest Banks Island, Western Canadian Arctic: *Journal of Quaternary Science,* vol. 3, p. 19–30.

Gravenor, C.P., 1955, The origin and significance of prairie mounds: *American Journal of Science,* vol. 253, p. 475–481.

Gravenor, C.P., and Kupsch, W.O., 1959, Ice disintegration features in western Canada: *Journal of Geology,* vol. 67, p. 48–64.

Greenberg, J.K., and Brown, B.A., 1984, Bedrock geology of Wisconsin (northeast sheet): Wisconsin Geological and Natural History Survey Regional Map Series (scale 1:250,000).

Ham, N.R., 1994, Glacial geomorphology and dynamics of the Wisconsin Valley Lobe of the Laurentide Ice Sheet, Lincoln County, Wisconsin [Ph.D. dissertation]: University of Wisconsin, Madison, 235 p.

Ham, N.R., and Attig, J.W., 1994, Origin of possible annual moraines and rate of ice-surface lowering of the Wisconsin Valley Lobe: *American Quaternary Association, Program and Abstracts,* p. 214.

Ham, N.R., Attig, J.W., and Clayton, Lee, 1993, The role of permafrost in the development of hummocky disintegration topography with ice-walled-lake plains in north-central Wisconsin: *INQUA Commission on the Formation and Properties of Glacial Deposits, Program and Abstracts,* p. 6.

Krüger, J., 1993, Moraine-ridge formation along a stationary ice front in Iceland: *Boreas,* vol. 22, p. 101–109.

LaBerge, G.L., and Myers, P.E., 1983, Precambrian geology of Marathon County, Wisconsin: Wisconsin Geological and Natural History Survey Information Circular 45, 88 p.

Lawson, D.E., 1979, Sedimentological analysis of the western terminus region of the Matanuska Glacier, Alaska: United States Army Cold Regions Research and Engineering Lab Report 79-9, 112 p.

Lawson, D.E., 1982, Mobilization, movement, and deposition of subaerial sediment flows, Matanuska Glacier, Alaska: *Journal of Geology,* vol. 90, p. 279–300.

Mickelson, D.M., 1986, Glacial and related deposits of Langlade County, Wisconsin: Wisconsin Geological and Natural History Survey Information Circular 52, 30 p.

Mickelson, D.M., Clayton, Lee, Fullerton, D.S., and Borns, H.W., Jr., 1983, The late Wisconsin glacial record of the Laurentide Ice Sheet in the United States, *in* Porter, S.C., ed., *Late-Quaternary Environments of the United States,* vol. 1, *The Late Pleistocene:* Minneapolis, University of Minnesota Press, p. 3–37.

Mickelson, D.M., Clayton, Lee, Baker, R.W., Mode, W.N., and Schneider, A.F., 1984, Pleistocene stratigraphic units of Wisconsin: Wisconsin Geological and Natural History Survey Miscellaneous Paper 84-1, 15 p.

Mickelson, D.M., Clayton, Lee, and Muller, E.H., 1986, Contrasts in glacial landforms, deposits, glacier-bed conditions, and glacier dynamics along the southern edge of the Laurentide Ice Sheet: *American Quaternary Association, Program with Abstracts,* p. 28–30.

Mudrey, M.G., Jr., Brown, B.A., and Greenberg, J.K., 1982, Bedrock geologic map of Wisconsin: Wisconsin Geological and Natural History Survey (scale 1:1,000,000).

Nelson, A.R., 1973, Age relationships of the deposits of the Wisconsin Valley and Langlade glacial lobes of north-central Wisconsin [M.S. thesis]: University of Wisconsin, Madison, 130 p.

Sims, P.K., Van Schmus, W.R., Schulz, K.J., and Peterman, Z.E., 1989, Tectono-stratigraphic evolution of the Early Proterozoic Wisconsin magmatic terranes of the Penokean Orogen: *Canadian Journal of Earth Sciences,* vol. 26, p. 2145–2158.

Sollid, J.L., and Sørbel, L., 1988, Influence of temperature conditions on formation of end moraines in Fennoscandia and Svalbard: *Boreas,* vol. 17, p. 553–558.

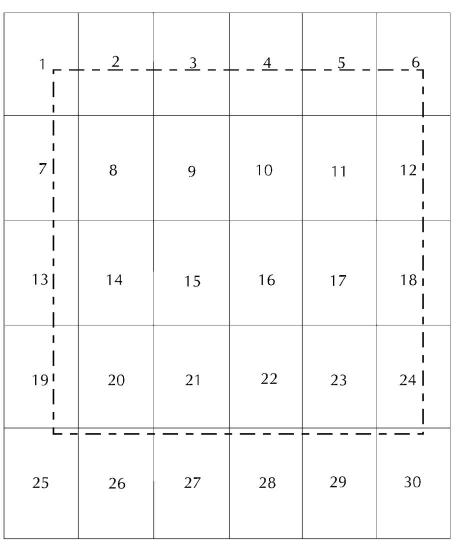
Stewart, M.T., 1973, Pre-Woodfordian drifts of north-central Wisconsin [M.S. thesis]: University of Wisconsin, Madison, 92 p.

Stewart, M.T., and Mickelson, D.M., 1974, Clay mineralogy and relative age of tills in north-central Wisconsin, *in* Knox, J.C., and Mickelson, D.M., eds., *Late Quaternary Environments of Wisconsin:* Wisconsin Geological and Natural History Survey, p. 220–232.

Stewart, M.T., and Mickelson, D.M., 1976, Clay mineralogy and relative age of tills in north-central Wisconsin: *Journal of Sedimentary Petrology,* vol. 46, p. 200–205.

Lincoln County

location diagram



Index to U.S. Geological Survey topographic quadrangles (7.5-minute series; 1:24,000)

1 Brantwood-1979
2 Tripoli-1971
3 Bradley-1971
4 Heafford Junction-1982
5 Woodboro-1982
6 Lake Julia-1982
7 Spirit-1979
8 Spirit Falls-1978
9 Coffee Creek-1978
10 Tomahawk-1982
11 Harrison-1982
12 Parrish-1973
13 Wood Lake-1979
14 Natzke Camp-1978
15 Grandfather Falls-1978
16 Irma-1982
17 Bloomville-1982
18 Gleason-1973
19 Goodrich-1980
20 Fromm Lookout Tower-1978
21 Alexander Lake-1978
22 Merrill-1982
23 Pine Dells-1982
24 Doering-1973
25 Athens-1980
26 Hamburg-1978
27 Little Chicago-1978
28 Brokaw-1982
29 Nutterville-1982
30 Kalinke-1973

BULLETIN 93

PLEISTOCENE GEOLOGY OF LINCOLN COUNTY, WISCONSIN

1997

Wisconsin Geological and Natural History Survey
3817 Mineral Point Road • Madison, WI 53705-5100
James M. Robertson, Director and State Geologist

COVER: *View of an exposure in an ice-marginal ridge (left part of photo) and adjacent outwash fan along the southern margin of the Underdown area.*

ISSN: 0375-8265

Wisconsin Geological and Natural History Survey
Bulletin 93
Pleistocene Geology of Lincoln County, Wisconsin
Plate 1

Nelson R. Ham and John W. Attig
1997

EXPLANATION

Postglacial Sediment

p — **Postglacial sediment of low, typically wet areas.** Unit **p:** peat, muck, or slope sediment covering the glacial, stream, or lake sediment indicated by adjacent map units; low-lying, flat to low-relief surfaces.

sp — **Postglacial stream sediment.** Unit **sp:** silty and sandy sediment deposited by postglacial streams; flat to low-relief floodplains. Mapped where extensive; present but not shown along most streams.

Meltwater-Stream Sediment

sc, scc — **Meltwater-stream sediment of the Copper Falls Formation.** Unit **sc:** sand, sandy gravel, and gravelly sand deposited by streams carrying meltwater away from the Wisconsin Valley and Langlade Lobes; typically coarser near former positions of the ice margin; flat to low-relief surfaces; some collapse depressions (pits) present. Probably includes some meltwater-stream sediment of the Lincoln Formation in the southern part of the county. Unit **scc:** sand, sandy gravel, and gravelly sand deposited on ice; moderate to high-relief surfaces. Original depositional surfaces generally not preserved because of collapse resulting from melting of buried ice.

sl, slc, su — **Meltwater-stream sediment of the Lincoln Formation.** Unit **sl:** sand, sandy gravel, and gravelly sand deposited by meltwater streams flowing away from the ice that deposited till of the Merrill Member of the Lincoln Formation; flat to low-relief surfaces with some collapse depressions (unit **sl**) and hilly areas (unit **slc**); extensive deposits are found in the Pine and Prairie River valleys and along Devil Creek. Unit **su:** meltwater-stream sediment of the Copper Falls and Lincoln Formations, undifferentiated.

Lake Sediment

lc, lch, lu — **Lake sediment of the Copper Falls Formation, deposited in ice-walled or ice-marginal lakes**—Unit **lc:** fine sandy, silty, and clayey laminated offshore sediment; sandy nearshore fans present in places; low-relief, flat, bowl-shaped, or convex-upward surfaces. Ice-walled-lake plains are common in the areas of hilly topography that mark the former marginal zone of the Wisconsin Valley Lobe (unit **gwh**) and typically form the highest parts of the landscape in areas of high-relief hilly topography in the eastern part of the county. Rim ridges typically contain sandy to gravelly, in places poorly sorted, nearshore sediment. Unit **lch:** area of hilly topography underlain primarily by variable, collapsed lake sediment, and supraglacial debris-flow and meltwater-stream sediment; collapse topography resulted from melting of buried ice. Unit **lu:** lake sediment of the Copper Falls and Lincoln Formations, undifferentiated; similar to unit **lc.**

Glacial Sediment

gw, gwd, gu — **Glacial sediment of the Wildcat Lake and Nashville Members of the Copper Falls Formation.** *Areas of gently rolling to low-relief hilly topography*—Unit **gw:** Wildcat Lake Member. Noncalcareous, unsorted, reddish-brown, slightly gravelly and clayey, silty, sandy till deposited by the Wisconsin Valley Lobe; low to moderate relief; deposits are streamlined in northwestern part of county. May be locally draped by up to several meters of variable supraglacial sediment. Unit **gwd:** same as unit **gw** but draped by up to several meters of well sorted sand and gravelly sand. Unit **gu:** till of the Wildcat Lake Member of the Copper Falls Formation and Merrill Member of the Lincoln Formation, undifferentiated.

gwh, gnh, guh — *Areas of moderate to high-relief hilly topography*—Unit **gwh:** Wildcat Lake Member. Collapsed supraglacial sediment; typically brown to reddish-brown, slightly clayey, silty, gravelly sand; poorly sorted to crudely stratified; includes many small areas of collapsed, sorted, meltwater-stream and lake sediment; deposited on stagnant ice of the Wisconsin Valley Lobe. Unit **gnh:** Nashville Member. Probably similar to unit **gwh,** but deposited by the Langlade Lobe; no exposures noted in county. Contact between units **gwh** and **gnh** is poorly controlled. Unit **guh:** collapsed supraglacial sediment of the Wildcat Lake Member of the Copper Falls Formation and Merrill Member of the Lincoln Formation, undifferentiated.

gm, gmh — **Till of the Merrill Member of the Lincoln Formation in areas of rolling to slightly hilly topography.** Noncalcareous, typically unsorted, reddish-brown, slightly gravelly and clayey, silty, sandy till; gently rolling topography (unit **gm**) and slightly hilly topography (unit **gmh**). Crudely stratified to sorted supraglacial sediment is present in places. Topography of the Merrill till surface, in southern part of county, is controlled primarily by topography of the underlying bedrock surface. Precambrian bedrock is close to, or at the surface in many places on uplands.

Scale 1:100,000

KILOMETERS (1 0 1 2 3 4 5 6 7 8 9 10)

MILES (1 0 1 2 3 4 5)

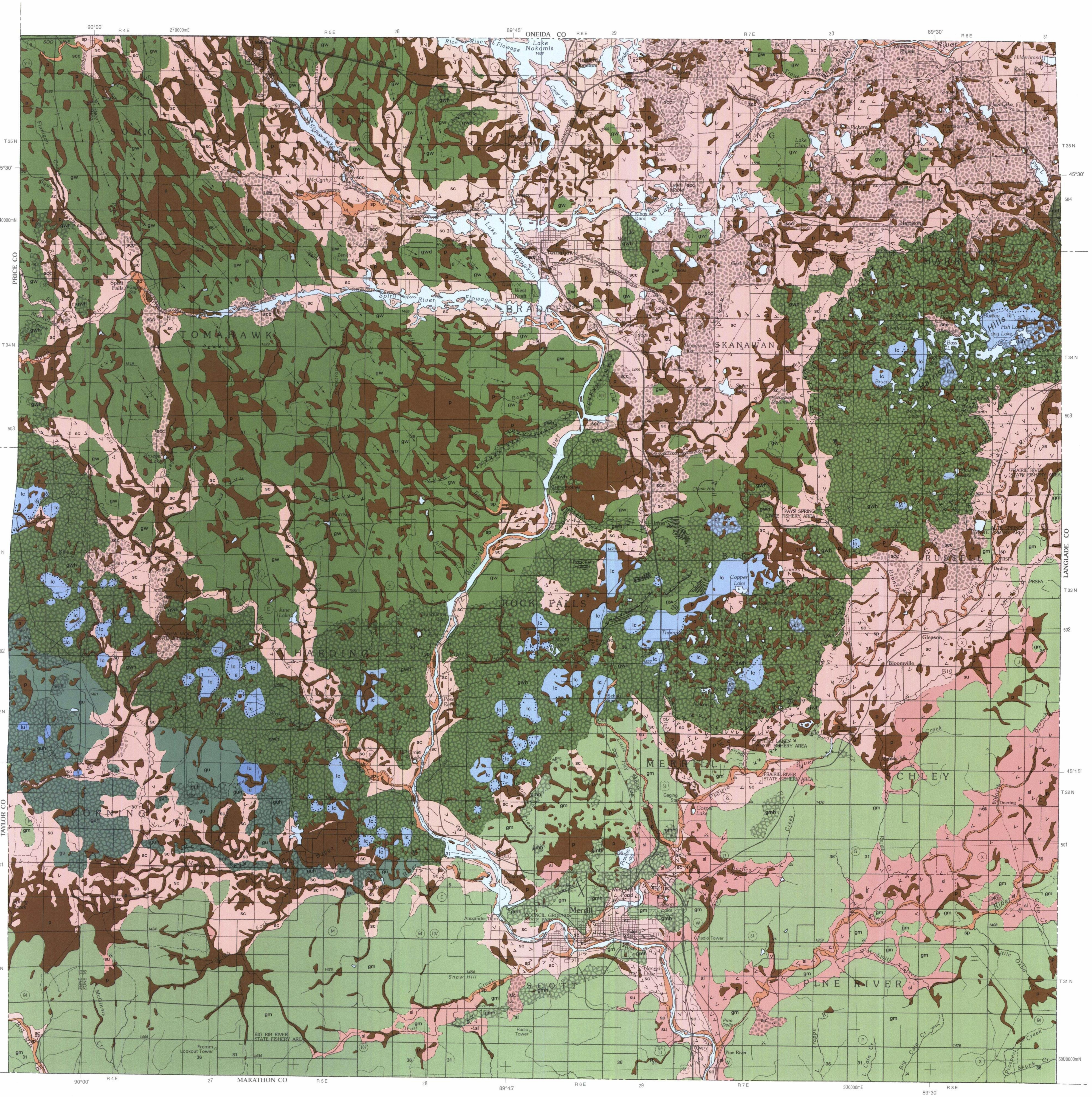
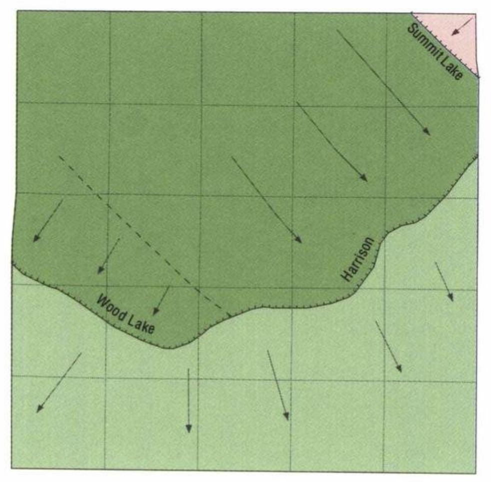
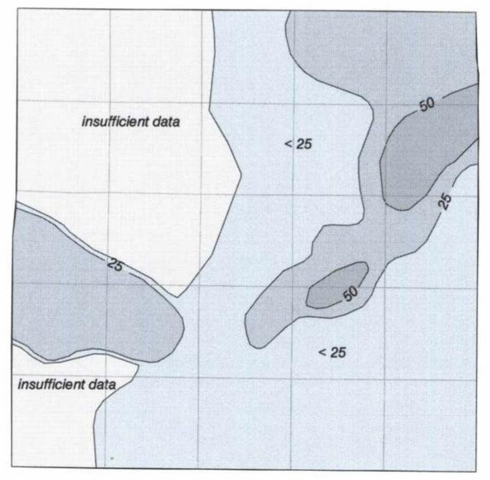


Plate 1. Geologic map of Lincoln County, Wisconsin.

Base map from U.S. Geological Survey County Map Series (Topographic), 1986.



Glacial phases and ice-flow direction (arrows).



Thickness of Pleistocene sediment (contour interval, 25 m). Pleistocene sediment is typically less than 15 m thick on uplands in the southeastern part of the county.

SYMBOLS

- Stream cutbank
- Drumlin (may be asymmetrical)
- Esker
- Ice-contact face. Solid line indicates prominent face; dashed line indicates subdued face. Barbs point up-glacier.
- Ice-marginal ridge. Solid line shows sharply crested ridges; dashed line shows subdued ridges. Barbs point in direction of ice-surface slope when the ridges formed.
- Rim ridge of ice-walled-lake plain.
- Direction of flow of meltwater stream (as indicated by modern surface slope)
- Geologic contact. Solid where position shown on map is judged to be generally within 0.1 km of actual position; dashed where the position shown may be more than 0.1 km from actual position.
- Precambrian or Paleozoic bedrock outcrop. Paleozoic rock is known to crop out only on Irma Hill.
- Crest of small, parallel ice-marginal ridge.

Published by and available from
Wisconsin Geological and Natural History Survey
3817 Mineral Point Road • Madison, WI 53705-5100
James M. Robertson, Director and State Geologist