Quaternary Geology of Northern Oconto County, Wisconsin

John W. Attig
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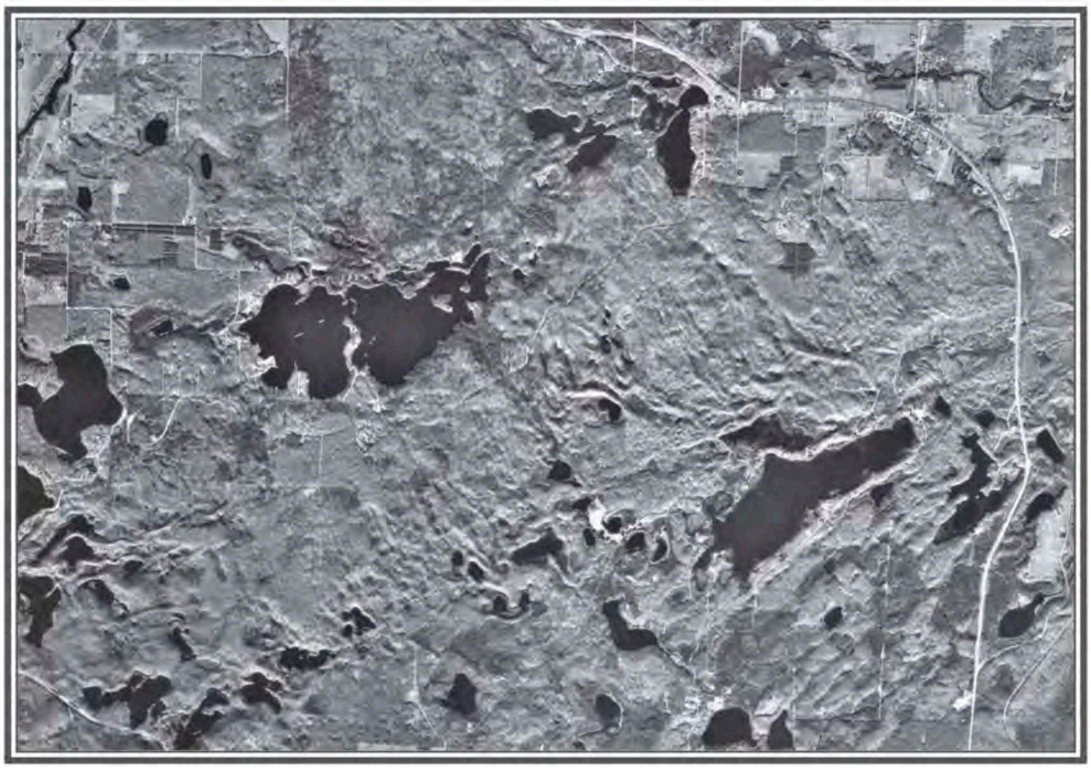

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FIGURES

TABLE

PLATE ***(in back pocket)***

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John W. Attig and Nelson R. Ham

ABSTRACT

Northern Oconto County is characterized by a strong northeast–southwest topographic grain that developed late in the Wisconsin Glaciation when the Langlade and Green Bay Lobes of the Laurentide Ice Sheet advanced over and subsequently melted from the area. In the far northwestern part of the county, the topographic grain is a result of drumlins formed beneath the southwestward-flowing Langlade Lobe. In the remainder of the area, it is produced by moraines, heads of outwash, ice-marginal drainageways, zones of hummocky topography, and other northeast–southwest oriented features that developed along the margin of the Green Bay Lobe as it retreated southeastward. Only in northwestern Oconto County does Precambrian rock strongly influence surface topography.

Along the southeastward-receding margin of the Green Bay Lobe, ice-marginal lakes formed between the ice front and the eastward-sloping land surface to the west. Each time the retreat of the Green Bay Lobe ice margin was interrupted by a readvance, fine-grained lake sediment was incorporated into the base of the glacier. As a result, glacial sediment in the southeastern part of northern Oconto County is finer than that farther west. Windblown sediment, some in well formed dunes, is characteristic of the southeastern part of northern Oconto County.

INTRODUCTION

This report and the geologic map (scale 1:100,000; plate 1) describe the origin and distribution of Quaternary materials and landforms in the northern part of Oconto County, Wisconsin (fig. 1), an area of about 900 km^2. The topography of the study area is characterized by a strong northeast–southwest topographic grain that developed late in the Wisconsin Glaciation when the Laurentide Ice Sheet advanced over and subsequently wasted from the area. In general, land elevation decreases to the southeast, toward the axis of the Green Bay lowland. Surface water in most of northern Oconto County drains to the south in branches of the Oconto River. However, surface water in the northeastern part of the study area drains eastward to the Peshtigo River, and surface water in the far southwestern part of the study area drains southward to the Wolf River. Most of the study area is forested and lies within the Nicolet National Forest.

The data and interpretations presented here are based on field work completed between 1991 and 1993. Field observations were plotted on U.S. Geological Survey topographic quadrangles (scale

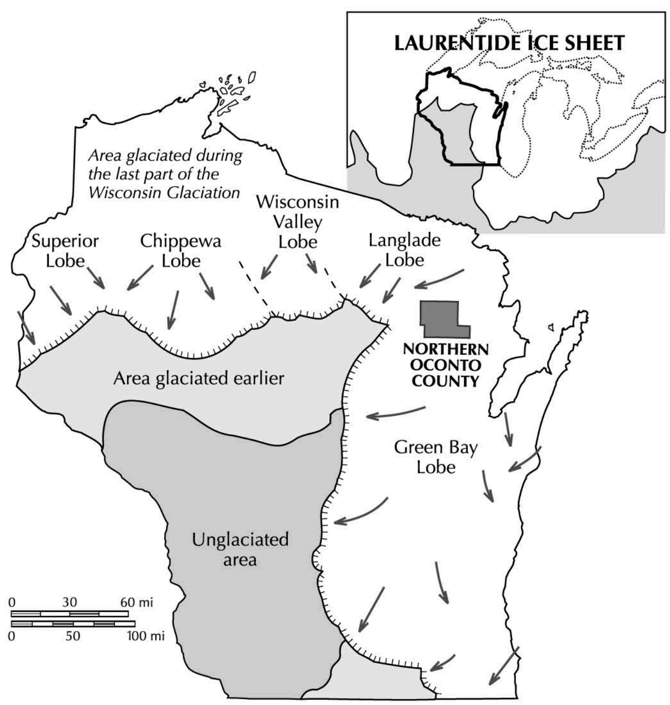


Figure 1. Location of northern Oconto County and the maximum extent of the Laurentide Ice Sheet (hachured line) during the last part of the Wisconsin Glaciation. Arrows show the general direction of ice flow.

1:24,000). Field observations were augmented by examination of stereopairs of black and white (scale 1:20,000) and color infrared (scales 1:24,000 and 1:58,000) aerial photographs. A truck-mounted drill was used to collect samples of subsurface materials. The physical characteristics of selected sediment samples were determined in the Quaternary Laboratory of the Department of Geology and Geophysics at the University of Wisconsin–Madison.

SUBSURFACE GEOLOGY

The thickness of Quaternary sediment and the topography on the surface of the underlying Precambrian rock is poorly known. Much of northern Oconto County is in the Nicolet National Forest where few wells have been drilled. Most available well constructor's reports are from wells clustered around lakes and from concentrations of wells in small communities along major roads. Information from the wells, along with outcrops (Maass, 1993; plate 1), indicates that topographic relief on the surface of Precambrian rock of 15 m or more is common and in places exceeds 30 m. Quaternary sediment is typically less than 25 m thick, but in places is more than 50 m thick.

Prominent hills of Precambrian rock, such as those southwest of Crooked Lake in the northern part of sec. 22, T32N, R17E, and Butler Rock in the southwestern part of sec. 5, T31N, R18E, are common in the east-central and northwestern parts of the study area. Outcrops of Precambrian rock are common in a northeast–southwest trending band in the south-central and east-central parts of the study area, and also in the northwest and north-central parts of the county shown on plate 1. On plate 1, areas of outcrop of Precambrian rock are shown with symbols. These symbols do not show individual outcrops, but areas where outcrops are common. The locations for the symbols were generalized from our field observations and interpretations of aerial photographs (scale 1:20,000) and from a compilation by Maass (1993). The northwestern limit of the area where nearly continuous Cambrian sandstone overlies Precambrian rock is near the southeasternmost part of the study area (Mudrey and others, 1982).

QUATERNARY SEDIMENT AND LANDFORMS

We do not know how many times that northern Wisconsin was glaciated during the Quaternary Period, the time period that began about 1.6 million years ago. The landforms and materials deposited during early glaciations of northern Oconto County have been buried or obliterated during more recent glaciations. Although ice sheets must have covered northern Oconto County many times, we recognize evidence for only the most recent expansion of the Laurentide Ice Sheet into northeastern Wisconsin during the last part of the Wisconsin Glaciation. The exact timing of events during this most recent glaciation of northeastern Wisconsin is poorly known because few closely limiting radiocarbon dates are available. The timing of events mentioned in this report has been estimated mainly through correlation to distant sites where the timing of glacial events is better known.

During the last part of the Wisconsin Glaciation, two lobes of the Laurentide Ice Sheet advanced across northern Oconto County (fig. 1). The Langlade Lobe advanced toward the southwest across the northwestern part of the study area and the Green Bay Lobe advanced toward the northwest across the remainder of the area. Regional reconstructions of ice-margin positions (Clayton and Moran, 1982; Mickelson and others, 1983; Attig and others, 1985) indicate that the Green Bay and Langlade Lobes of the Laurentide Ice Sheet had advanced over northeastern Wisconsin by about 20,000 years ago. It is well documented that the Laurentide Ice Sheet had melted from northeastern Wisconsin before about 12,000 years ago because many radiocarbon dates determined from samples of wood indicate that the Two Creeks Forest was growing in the Green Bay lowland east of the map area by that time (Broecker and Farrand, 1963; Black and Rubin, 1967–68; Black, 1976).

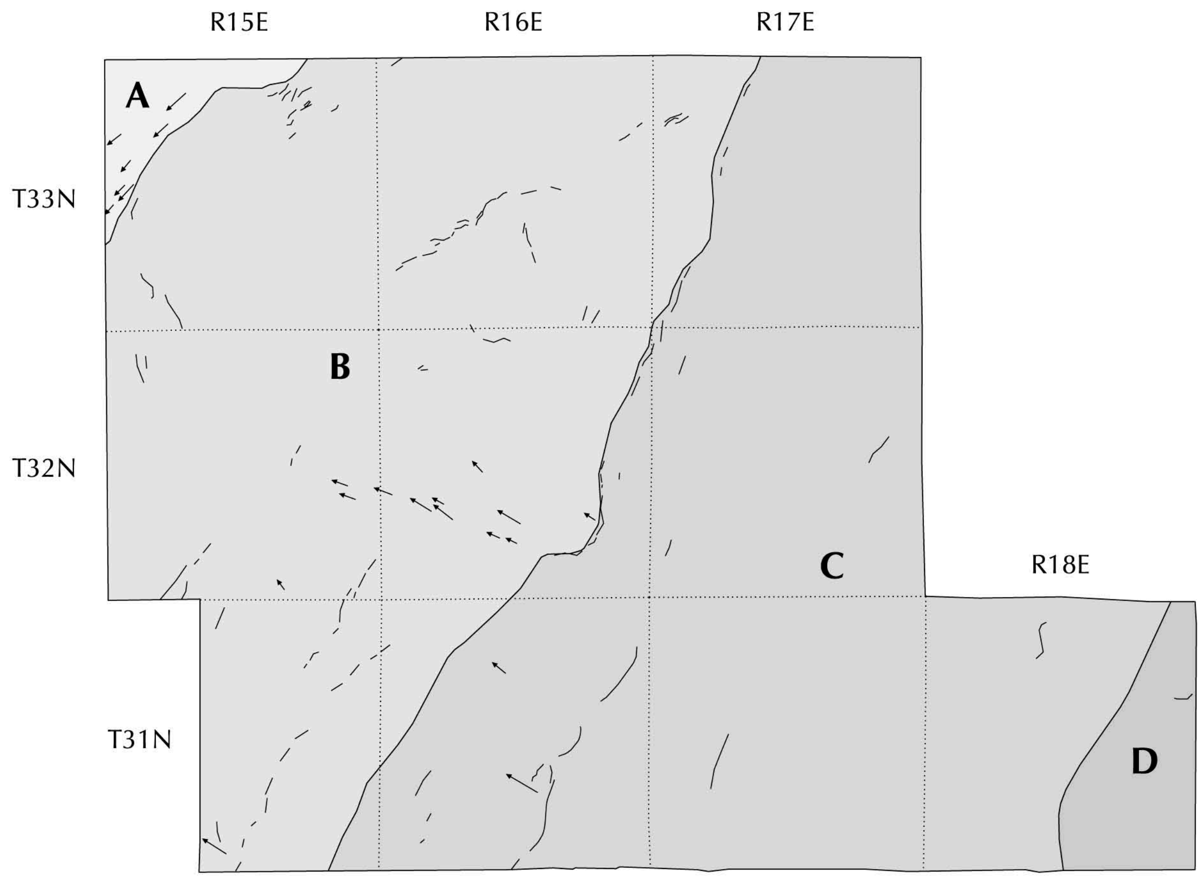


Figure 2. Distribution of drumlins (arrows), ice-marginal ridges (line segments), and lithostratigraphic units in northern Oconto County. *A.* Nashville Member of the Copper Falls Formation; *B.* Mapleview Member of the Holy Hill Formation; *C.* Silver Cliff Member of the Kewaunee Formation; *D.* Kirby Lake Member of the Kewaunee Formation.

Although some prominent hills in northern Oconto County have cores of bedrock, most topographic features are the result of Quaternary glaciation. Northern Oconto County lies on the western side of the Green Bay lowland and land-surface elevation decreases southeastward. The interaction of the southeastward-sloping land surface and the margin of the southeastward-wasting Green Bay Lobe greatly influenced the distribution of Quaternary materials and produced many of the distinct glacial landforms described in this report.

Glacial sediment and landforms

The areas shown as glacial sediment on plate 1 are underlain by very poorly sorted mixtures of unstratified to weakly stratified gravel, sand, silt, and clay. Some of this material is till that was deposited by lodging or melting out from the ice with very little or no reworking by water. Some of the glacial sediment melted out of the ice and subsequently flowed to its present position. This debris-flow sediment is typically at least somewhat sorted and stratified as a result of reworking by water. Too few outcrops are available to differentiate these genetic types of material on plate 1 and therefore they are lumped together as glacial sediment. Debris-flow sediment is typically present in areas of glacial sediment on plate 1 where a pattern indicating hummocky topography is shown. In areas shown as glacial sediment without the pattern indicating hummocky topography, debris-flow sediment is typically thin, patchy, or absent.

In northern Oconto County glacial sediment is typically sandy, but generally becomes siltier to the southeast. This glacial sediment has been divided into four lithostratigraphic units; from oldest to youngest, they are the Nashville Member of the Copper Falls Formation, the Mapleview Member of the Holy Hill Formation, and the Silver Cliff and Kirby Lake Members of the Kewaunee Formation (fig. 2) (McCartney, 1979; McCartney and Mickelson, 1982; Mickelson and others, 1984).

(The Mapleview Member was formerly included in the Horicon Formation, which has been renamed the Holy Hill Formation by Mickelson and Syverson, 1997). The area shown as being underlain by glacial sediment of the Kirby Lake Member on plate 1 (map unit **gk**) may include some glacial sediment of the Middle Inlet Member of the Kewaunee Formation.

Nashville Member of the Copper Falls Formation

Glacial sediment of the Nashville Member was transported into the area shown on plate 1 by the southwestward-flowing ice of the Langlade Lobe. It is draped over bedrock uplands in the north-central and northwestern parts of the map area (map unit **gc,** plate 1; fig. 2). It extends westward into northern and northeastern Langlade County (Mickelson, 1986) and northwest throughout much of Forest County (Simpkins and others, 1987). In Forest County, Simpkins and others (1987) concluded that older glacial sediment is present in places beneath the Nashville Member. Older glacial sediment is present at the surface in Langlade County beyond the maximum extent of the Langlade Lobe (Mickelson, 1986). However, we did not recognize glacial sediment deposited before the Nashville Member in northern Oconto County.

Glacial sediment of the Nashville Member is typically sandy, brown, and non-dolomitic (table 1), except near its southeastern extent, where it is slightly dolomitic in places. There, small fragments of dolomite are common and some samples effervesce weakly on contact with dilute hydrochloric acid. The slightly dolomitic character of the Nashville Member near its southeastern limit is probably the result of mixing with dolomitic glacial sediment of the Mapleview Member of the Holy Hill Formation (fig. 2; map units **gh** and **ghh,** plate 1), which was deposited by the northwestward-flowing Green Bay Lobe. Mixing likely resulted from shifts in the position of the boundary between the Langlade and Green Bay Lobes. Shifting of the boundary is well documented by the intersecting glacial striations on bedrock at several sites along the northern edge of the map area (Thwaites, 1943). These striations record southwest and northwest flow directions, parallel to the flow directions of the Langlade and Green Bay Lobes, respectively. Northeast–southwest trending drumlins underlain by glacial sediment of the Nashville Member are found in northwestern Oconto County (figs. 2 and 3; arrow symbol, plate 1).

Table 1. *Typical physical characteristics of the lithostratigraphic units in northern Oconto County. Grain-size distribution for the less-than-2-mm fraction is summarized from Mickelson and others (1984) and for samples we collected. Numbers in parentheses indicate the number of samples we report on.*

	Mickelson and others (1984)	This study		
Stratigraphic unit	**Sand:silt:clay**	**Sand:silt:clay**	**Color**	**Dolomitic**
Kewaunee Formation				
Middle Inlet Member	64:28:8	—	brown	yes
Kirby Lake Member	36:47:17	—	reddish brown	yes
Silver Cliff Member	61:32:7	63:32:5 (12)	reddish brown	yes
Holy Hill Formation				
Mapleview Member	77–83:13–19:4–6	78:17:5 (5)	brown	yes
Copper Falls Formation				
Nashville Member	77:16:7	77:15:8 (4)	brown	typically no

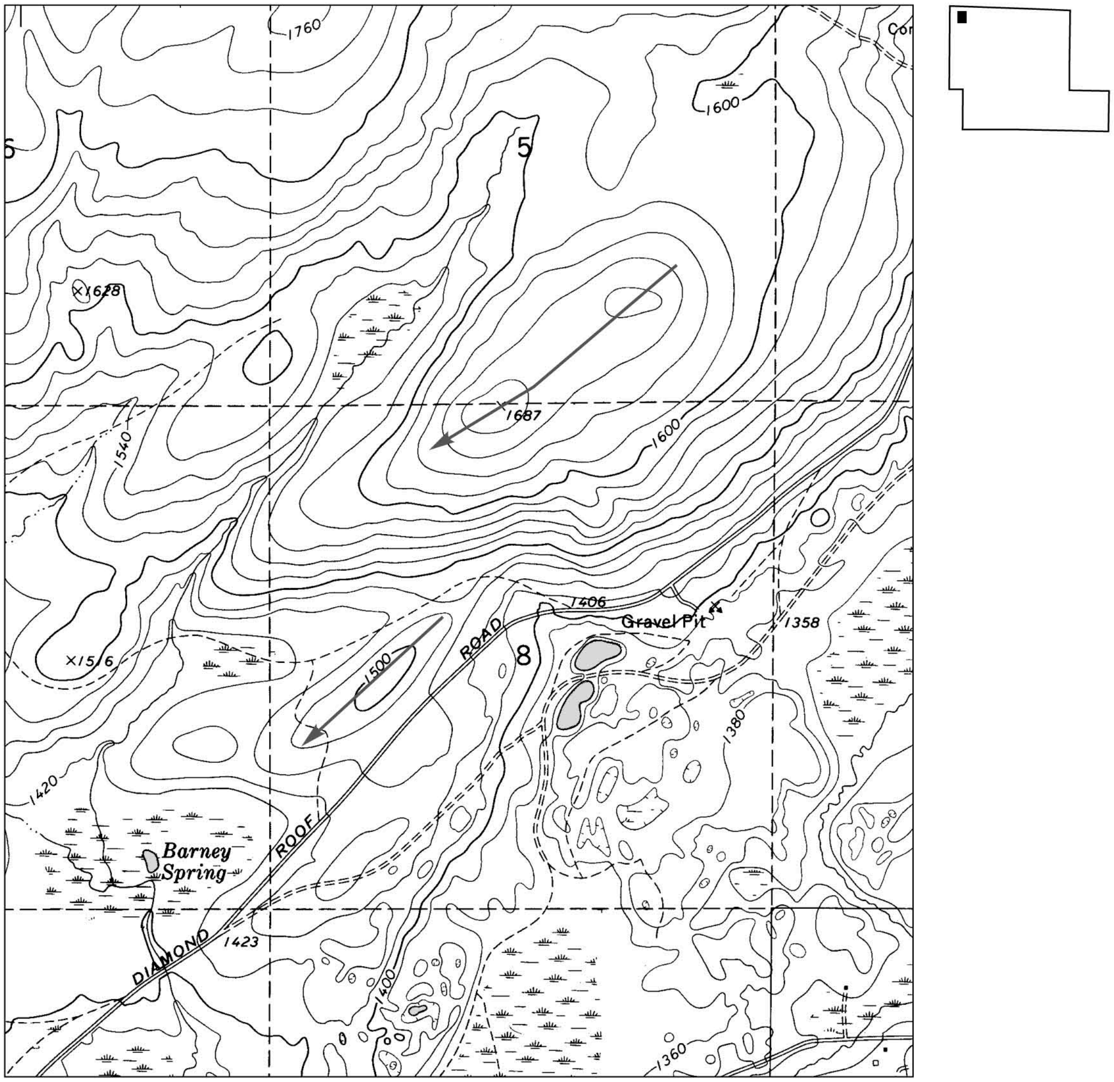


Figure 3. Part of the Reservoir Pond Quadrangle, Wisconsin (U.S. Geological Survey, 7.5-minute series, topographic, 1972, scale 1:24,000), showing drumlins in an area underlain by glacial sediment of the Nashville Member of the Copper Falls Formation. The glacial sediment overlies a bedrock upland in the northwest part of the map area. Arrows indicate direction of ice flow. Contour interval, 20 ft.

Mapleview Member of the Holy Hill Formation

Glacial sediment of the Mapleview Member was transported into northern Oconto County by the Green Bay Lobe, the axis of which was oriented north–northeast to south–southwest and was east of the area shown on plate 1. In the area shown on plate 1, ice of the Green Bay Lobe was flowing northwestward. The Mapleview Member, the surface unit of glacial sediment in the central and western parts of northern Oconto County (map units **gh** and **ghh**, plate 1; fig. 2), extends westward into Langlade County as far as the outermost moraine of the Green Bay Lobe, northward into Marinette County, and southward into Shawano County (McCartney, 1979; Mickelson and others, 1984; Mickelson, 1986). Glacial sediment of the Mapleview Member is typically sandy, brown, and, in contrast to the Nashville Member of the Copper Falls Formation, it is dolomitic (table 1).

In northern Oconto County glacial sediment of the Mapleview Member is primarily in a series of northeast–southwest trending hummocky uplands (map units **gh** and **ghh,** plate 1). In these uplands glacial sediment of the Mapleview Member is typically interbedded with sandy meltwater-stream sediment. This interbedding developed in outwash

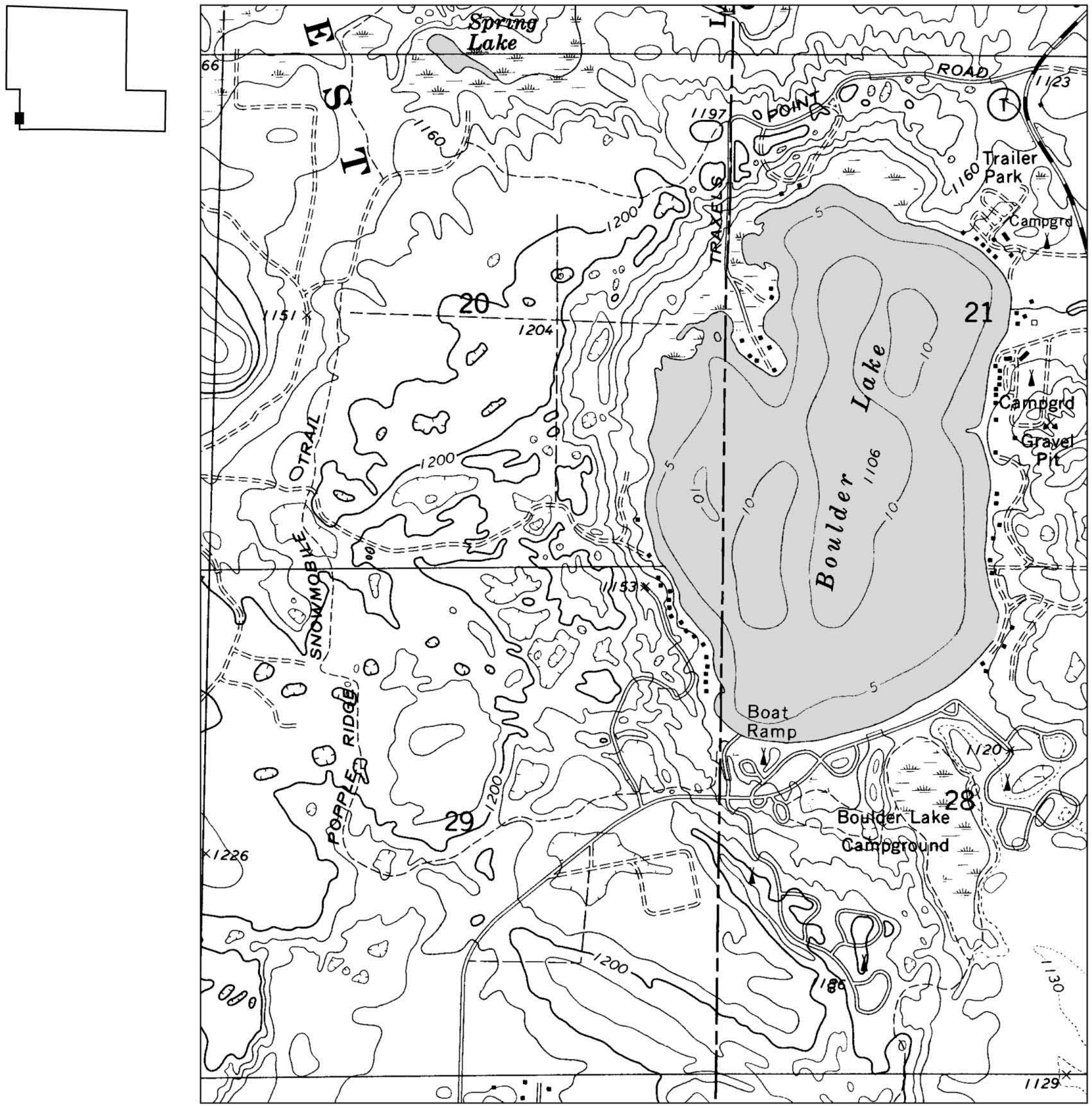


Figure 4. *Part of the Langlade Quadrangle, Wisconsin (U.S. Geological Survey, 7.5-minute series, topographic, 1973, scale 1:24,000), showing an outwash head west of Boulder Lake that has an elevation of about 1,200 ft above sea level. The outwash surface southeast of Boulder Lake is at an elevation of about 1,130 ft above sea level and rises in elevation eastward. Boulder Lake occupies a depression that formed where an ice block melted. Contour interval, 20 ft.*

heads where meltwater-stream sediment was deposited in contact with the glacier front. Subsequent wasting of the glacier resulted in complex intermixing of glacial and meltwater-stream sediment. The formation of outwash heads in the study area is discussed in more detail in the *Meltwater-stream sediment and landforms* section of this report. Discrete, sharp-crested moraines are common in the eastern parts of most of the outwash heads where the ice was in contact with the meltwater-stream sediment. Boulder Lake, in the southwest part of plate 1, occupies an ice-block depression adjacent to an outwash head (fig. 4). Glacial sediment of the Mapleview Member also underlies a number of southeast–northwest trending drumlins in the central and southwest parts of the map area (fig. 2; plate 1).

The moraines and northeast–southwest trending hummocky uplands underlain by glacial sediment of the Mapleview Member have been referred to as the Bowler moraines by Thwaites (1943). These features (plate 1) mark several

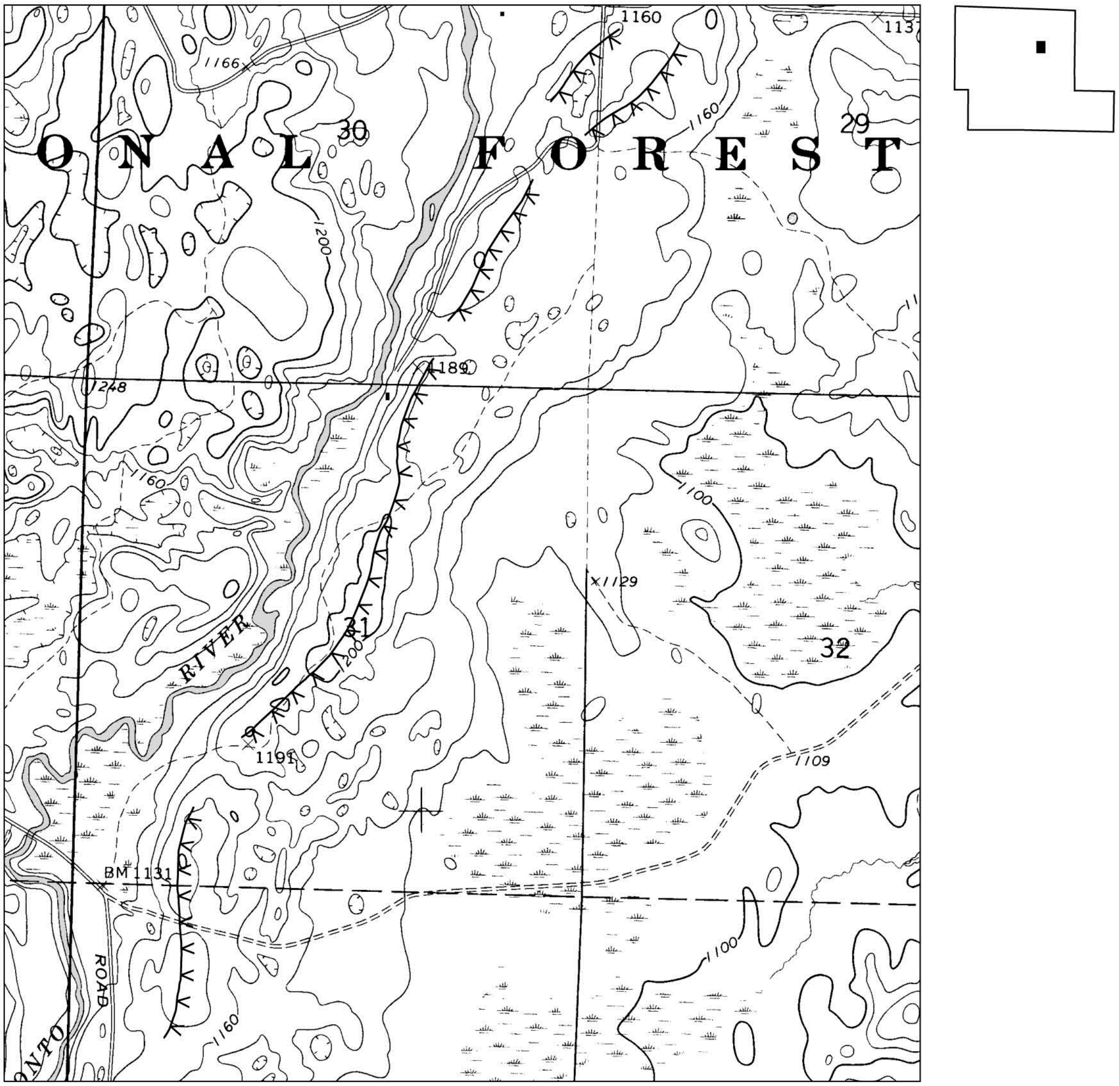


Figure 5. Part of the Wheeler Lake Quadrangle, Wisconsin (U.S. Geological Survey, 7.5-minute series, topographic, 1972, scale 1:24,000), showing the Mountain moraine, which marks the western extent of the Silver Cliff Member of the Kewaunee Formation. Symbols indicate the crest of moraine segments. Contour interval, 20 ft.

places where the margin of the Green Bay Lobe stabilized or readvanced as its margin generally retreated southeastward into the Green Bay lowland. The exact time of formation of the Bowler moraines is unknown.

Silver Cliff Member of the Kewaunee Formation

In the eastern and south-central parts of the map area, glacial sediment of the Silver Cliff Member is the surface material (fig. 2; map units **gs** and **gsh,** plate 1). In some areas this sediment is blanketed by up to 1 m of windblown sand (map unit **gsw**, plate 1). Glacial sediment of the Silver Cliff Member is typically reddish brown, dolomitic, and sandy; however, the less-than-2-mm fraction typically contains more silt than that of the Nashville or Mapleview Members (table 1). The Silver Cliff Member extends northward into Marinette County and southward through Oconto County (McCartney, 1979). The western limit of the Silver Cliff Member is marked by the Mountain moraine (McCartney, 1979). In northern Oconto County the Mountain moraine consists of a broad band of gently rolling to hummocky glacial topography with a discontinuous moraine along much of its western edge (fig. 5; map units **gs** and **gsh,** plate

1). Leverett (1929) noted a major, nearly continuous moraine in the approximate position of the Mountain moraine. Thwaites (1943, p. 130) traced the Mountain moraine northward through Marinette County and southward to southeastern Wisconsin. He suggested it corresponded to the Waupun and Rush Lake moraines of Alden (1918). In northern Oconto County smaller, less continuous moraines underlain by Silver Cliff glacial sediment lie east of the Mountain moraine (fig. 2; plate 1).

Glacial sediment of the Silver Cliff, Kirby Lake, and Middle Inlet Members of the Kewaunee Formation contains more silt in the less-than-2-mm fraction than the Nashville Member of the Copper Falls Formation or the Mapleview Member of the Holy Hill Formation (table 1). As noted by McCartney (1979), these textural relationships indicate that prior to the advances that deposited the members of the Kewaunee Formation, the margin of the ice sheet wasted far enough to allow for the development of ice-marginal lakes between the ice margin and the western flank of the Green Bay lowland. Subsequent readvances incorporated silt-rich lake sediment. When the Mountain moraine was forming, ice-marginal lake Dunbar existed just to the north of the map area and an early phase of glacial Lake Oshkosh existed to the south (Thwaites, 1943). The exact time of formation of the Mountain moraine is not well known.

Kirby Lake and Middle Inlet Members of the Kewaunee Formation

In the southeastern part of northern Oconto County, glacial sediment of the Kirby Lake Member is found in areas of gently rolling to low-relief hummocky topography (map unit **gk,** plate 1; fig. 2) (McCartney, 1979; McCartney and Mickelson, 1982). Topographic relief is typically less than in areas underlain by the Silver Cliff or Mapleview Members. The Kirby Lake Member is reddish brown, dolomitic, and contains much more silt in the less-than-2-mm fraction than any other glacial sediment in the area (table 1). The western extent of the Kirby Lake Member is probably near the eastern margin of the extensive, nearly flat lake plain, which is peat covered in places, in the southeastern part of the map area (map units **ls**, **lsw**, and **p,** plate 1). No clear moraine is evident east of the lake plain in northern Oconto County. The area immediately east of the lake plain is blanketed by thick windblown sand, some in well formed dunes, that masks the western extent of the Kirby Lake Member. Small outcrops and hand-auger borings confirmed the presence of reddish brown, very silt-rich, dolomitic glacial sediment in the area. However, we observed this sediment only where it was mixed with windblown sediment by slope processes.

Regional studies by McCartney (1979) and McCartney and Mickelson (1982) determined that the Kirby Lake Member is overlain by the Middle Inlet Member and showed the western boundary of glacial sediment of the Middle Inlet Member crossing the extreme southeastern part of northern Oconto County. However, we could not confirm the western extent of the Middle Inlet Member in the area shown on plate 1 because of the lack of outcrops.

The time of deposition of the Kirby Lake and Middle Inlet Members is poorly known, but McCartney and Mickelson (1982) indicated that the Two Creeks Forest grew in eastern Wisconsin between the time of deposition of the two members.

Meltwater-stream sediment and landforms

Much of northern Oconto County is underlain by gravelly sand and sandy gravel deposited by outwash rivers that carried meltwater from the melting glacier. This sediment is shown as map unit **su** (plate 1) where most of the original outwash plain is preserved. It is shown as map unit **sc** (plate 1) where the meltwater-stream sediment was deposited on or adjacent to ice that later melted, resulting in the collapse of the overlying sediment and the destruction of the original depositional surface.

In northern Oconto County the areal distribution of collapsed and uncollapsed outwash, the elevation of outwash plains, and the distribution of moraines reflect the general pattern of ice wastage from the western flank of the Green Bay lowland. Taken together, these features are responsible for much of the strong northeast–southwest topographic grain characteristic of the area.

During deglaciation of northern Oconto County, outwash rivers flowed mainly toward the southwest between the ice margin and the higher land to the west. Deposition of sandy gravel and gravelly sand by these outwash rivers resulted in the formation of several broad outwash plains that slope westward and southwestward. The eastern parts of these outwash plains are typically underlain by interbedded stream and glacial sediment because they were deposited near the ice margin. When the ice margin wasted back, the eastern parts of the outwash plains, the heads of outwash, were left as high points in the landscape (fig. 6A). Collapse features are characteristic of these areas (plate 1). As the ice margin wasted eastward into the Green Bay lowland, successive outwash plains were deposited at lower elevations (fig. 7). Gravel up to 1 m or more in diameter is common in the ice-contact part of each outwash plain; the maximum particle size decreases rapidly as distance from the former position of the ice margin increases. Several hundred meters from the ice-contact face, the sediment is typically gravelly sand that has a maximum grain size of 5 to 10 cm.

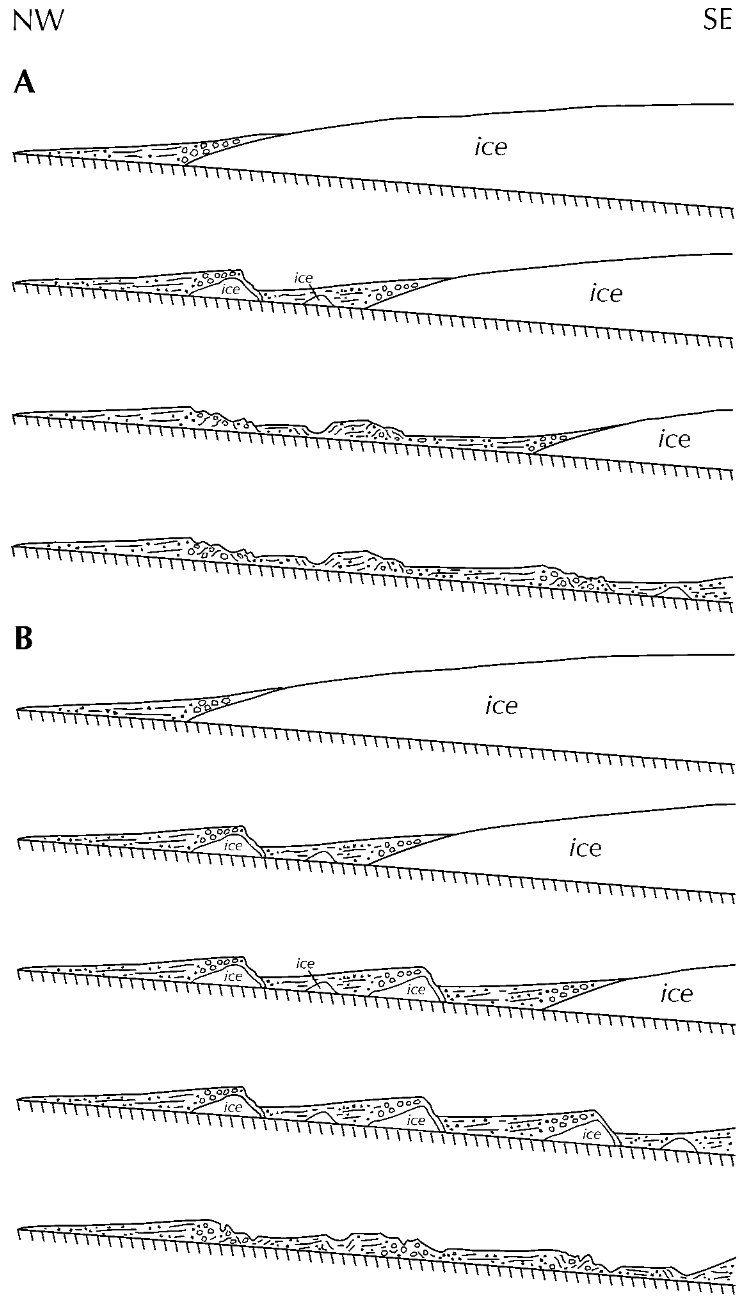


Figure 6. Two possible sequences of events in the development of outwash heads during the wasting of the Green Bay Lobe into the Green Bay lowland. In A and B, The Green Bay Lobe is shown depositing outwash between the ice margin and the west side of the lowland. In A, buried ice melts as the Green Bay Lobe wastes back. In B, buried ice persists until the lobe has receded from the area; the buried ice later melts and the rock debris overlying it collapses.

Broad areas of collapsed meltwater-stream sediment are common throughout the map area, indicating that glacier remnants were commonly buried by stream sediment. If the buried ice survived until the glacier receded from the outwash head and the meltwater stream abandoned the outwash plain, a collapse depression resulted when the ice eventually melted. The melting of buried ice may have happened slowly throughout deglaciation (fig. 6A), or it may have been delayed by cold climate and deeply frozen

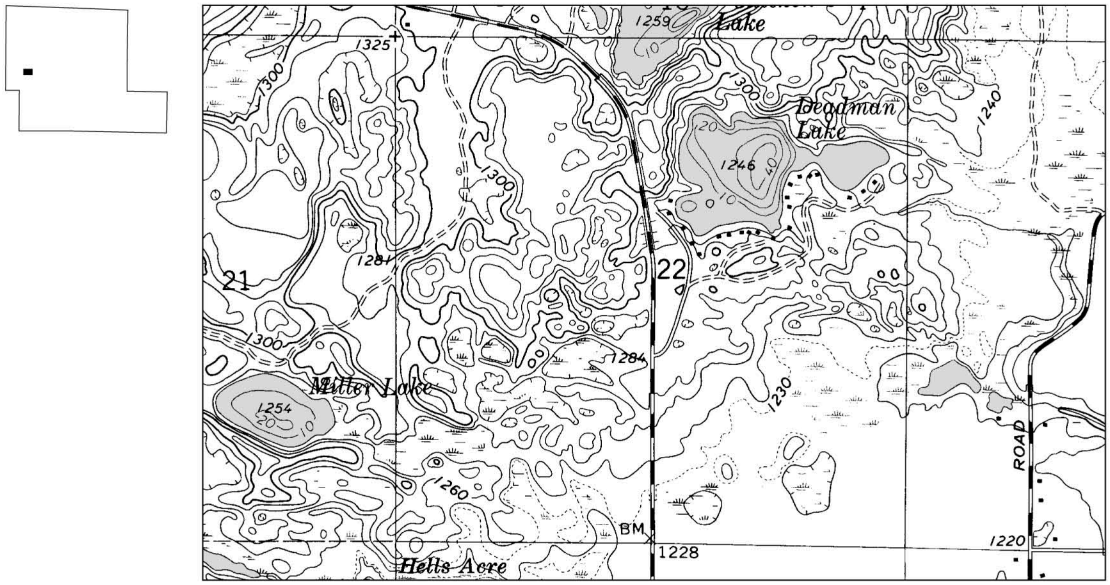


Figure 7. *Part of the Shadow Lake Quadrangle, Wisconsin (U.S. Geological Survey, 7.5-minute series, topographic, 1973, scale 1:24,000), showing the collapsed part of an outwash head in the northwest, and a lower, uncollapsed outwash surface in the southeast. Contour interval, 20 ft.*

ground (fig. 6B). We observed no clear evidence indicating which of these possibilities applies to northern Oconto County.

Lake sediment and landforms

As the Green Bay Lobe wasted southeastward, its western margin blocked the drainage of meltwater into the Green Bay lowland. As a result, meltwater flowed southwestward in rivers between the glacier and the higher land to the west or formed lakes where flow along the ice margin was obstructed. Many small, short-lived lakes must have formed throughout the wastage of the Green Bay Lobe, but the sediment deposited in these lakes was ultimately buried by meltwater-stream sediment.

Larger, more long-lasting lakes also formed along the ice margin. Glacial Lake Dunbar existed just to the north of the map area and an early phase of glacial Lake Oshkosh existed to the south of the map area at the time the Mountain moraine was forming (Thwaites, 1943, p. 130). Later, glacial Lake Oconto formed in the southeastern corner of northern Oconto County (Thwaites, 1943). The sediment deposited in this lake underlies the broad, nearly flat areas shown as map units **ls** and **lsw** in the southeastern part of plate 1, in the central and southwestern parts of T31N, R18E and adjacent parts of T31N, R17E (figs. 8A and 8B). This lake sediment consists of uniform, well sorted fine- to medium-grained sand. Extensive areas of peat and windblown sediment overlie the lake sediment in places. Much of the windblown sediment is in the form of well shaped dunes. In addition to lake sand, the areas shown as map units **ls** and **lsw** (plate 1) probably contain areas of well sorted meltwater-stream sediment that underlies nearly flat surfaces bordering the western margin of the lake. We did not identify any shore features of the lake that would help clarify the water depth and extent of the lake. Detailed work to the south of the area shown on plate 1 is needed to better define the history of ice-marginal lakes in the area.

Glacial Lake Oconto may have been a local lake dammed by ice at about the time the Kirby Lake Member or Middle Inlet Member was being deposited in the southeastern part of the map area. Alternatively, the lake plain may be a remnant of an early phase of glacial Lake Oshkosh that was not covered by later advances of the Green Bay Lobe (Thwaites, 1943).

Windblown sediment and landforms

In northern Oconto County windblown sediment is present in well formed dunes or as a veneer that conforms to the shape of the surface of the underlying material. Stabilized sand dunes are common on sandy outwash and glacial-lake plains in north-

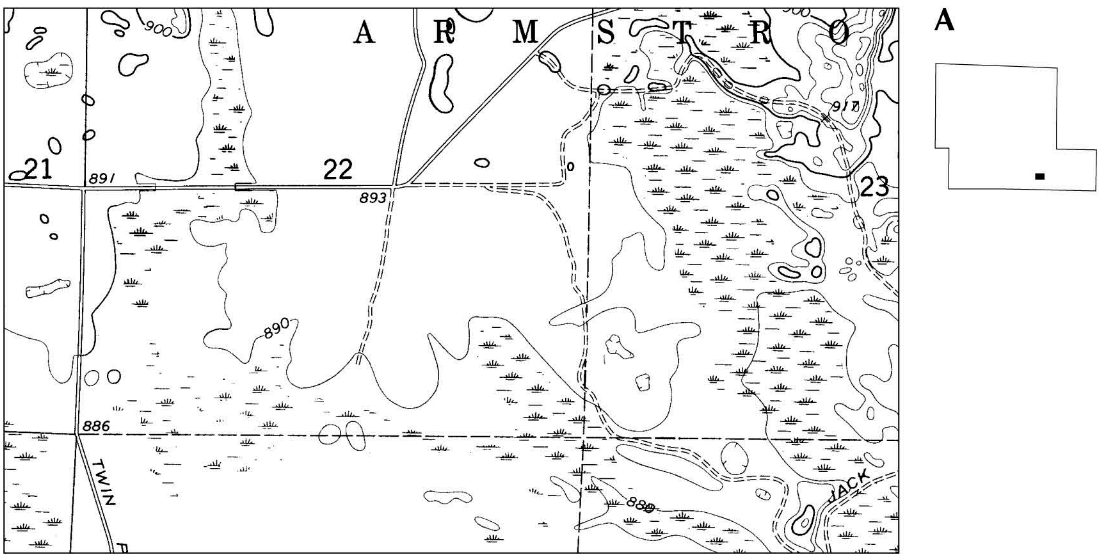
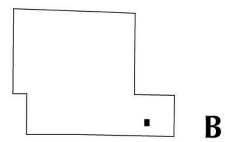
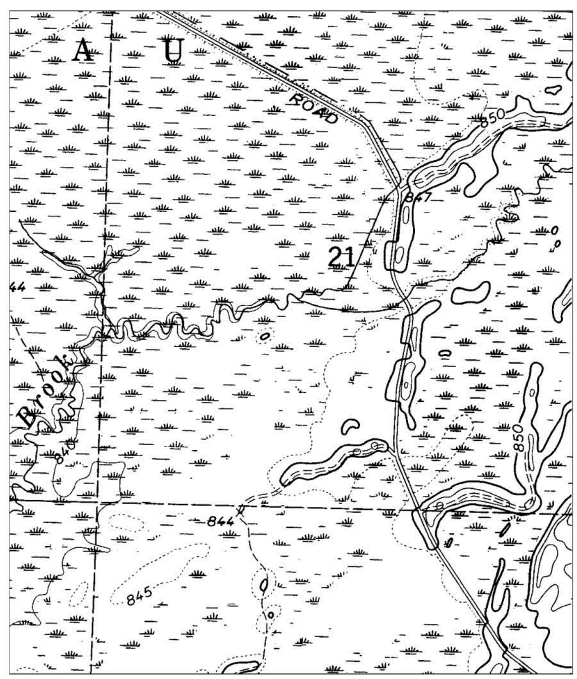


Figure 8. *Part of the Shay Lake Quadrangle, Wisconsin (U.S. Geological Survey, 7.5-minute series, topographic, 1973, scale 1:24,000), showing the lake plain in the southeastern part of plate 1 where few dunes and only small areas of peat are present (A) and where prominent dunes and peat are present (B). Contour interval, 10 ft.*





eastern Wisconsin (Thwaites, 1943). Dunes are typically vegetated by grasses and conifers, such as jack pine, that are suited to dry, sandy soil conditions. Dunes are not forming today, but in places small blowouts and areas of reactivated windblown sand are common. In northern Oconto County, stablized dunes (map unit **ws** and symbol, plate 1) and areas of thin windblown sand covering till, meltwater-stream sediment, and lake sediment (map units **suw, scw, gsw, lsw,** and **gkw,** plate 1) are found in the southeastern part of the map area, primarily in T31N, R18E, in the eastern half of T31N, R17E, and in the southeastern corner of T32N, R17E. The most extensive areas of dunes are on and east of the sandy plain of glacial Lake Oconto (figs. 8A and B).

Most of the sand dunes in the map area are simple or compound parabolic dunes, although some transverse dunes are found in places. Parabolic dunes are crescent shaped; the ends of the crescent point upwind (McKee, 1979). Transverse dunes are slightly sinuous to nearly straight ridges perpendicular to wind-flow direction (McKee, 1979). The upwind sides of the dunes typically have a more gentle slope than the downwind sides. A symbol on plate 1 shows the crests of well formed dunes and the direction of sand transport (fig. 9). The dunes typically are 5 to 10 m high and 250 to 500 m long. They are typically composed of fine sand and silty fine sand, but some slightly coarser grains are common.

Dune orientation is controlled by the direction of the prevailing wind. The long axis of most transverse dunes in the area is oriented northeast–southwest. The ends of the crescents of most parabolic dunes point to the northwest or north–northwest. The orientation of these two types of dunes indicates that at the time of dune formation the prevail-

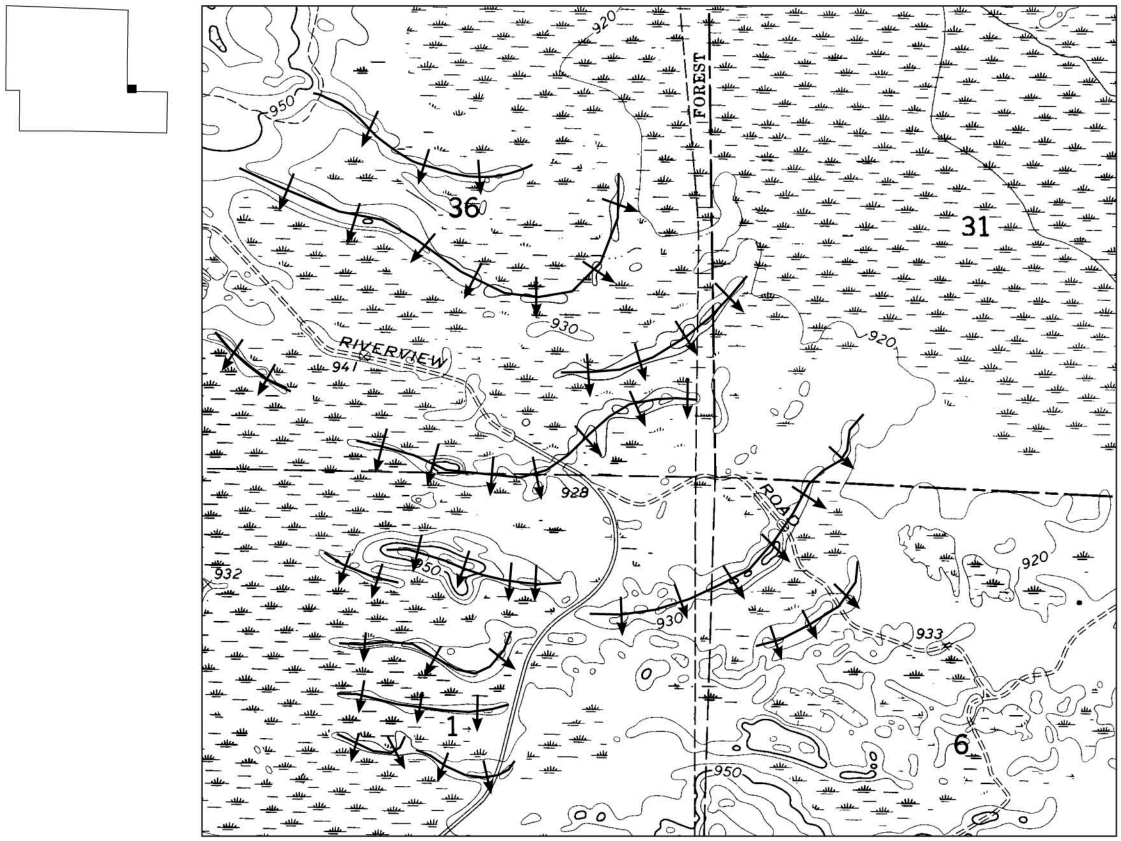


Figure 9. *Part of the Shay Lake Quadrangle, Wisconsin (U.S. Geological Survey, 7.5-minute series, topographic, 1973, scale 1:24,000), showing well developed dunes. Symbols show the crest of the dunes; arrows, the direction of sand transport. Contour interval, 10 ft.*

ing direction of sand-transporting wind was from the northwest. In contrast, southwest wind dominates during the summer months in northeastern Wisconsin today (Knox, 1996).

It is likely that the major period of dune formation immediately followed the draining of the glacial lake in the southeastern part of the map area. At that time a broad, nearly flat area of well sorted fine sand deposited on the lake bottom became exposed to the wind. The large number of well formed dunes downwind of the plains of drained glacial lakes indicates that the well sorted sandy lake sediment was a major source of windblown sand. The surfaces of outwash plains, eskers, and other landforms with dry, sandy surfaces, such as sparsely vegetated sandy glacial and stream sediment, also must have served as sources. We have not observed peat or other postglacial sediment between dune sand and underlying glacial, stream, or lake sediment in surface exposures or in samples from drillholes; this indicates dunes actively formed immediately following deglaciation and the draining of ice-marginal lakes. During the middle Holocene Epoch, when warm, dry conditions prevailed in the middle of North America, it is likely that some dunes reactivated, and some may have formed. Today, windblown sediment in northeastern Wisconsin is reactivated in places if fire or other disturbances destroy the vegetative cover.

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REFERENCES

Alden, W.C., 1918, The Quaternary geology of southeastern Wisconsin: U.S. Geological Survey Professional Paper 106, 356 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,* v. 96, p. 1585–1593.

Black, R.F., 1976, Quaternary geology of Wisconsin and contiguous upper Michigan, *in* Mahaney, W.C., ed., *Quaternary Stratigraphy of North America:* Dowden, Hutchinson, and Ross, Stroudsburg, Pennsylvania, p. 93–117.

Black, R.F., and Rubin, M., 1967–68, Radiocarbon dates of Wisconsin: *Wisconsin Academy of Sciences, Arts and Letters Transactions,* v. LVI, p. 99–115.

Broecker, W.C., and Farrand, W.R., 1963, Radiocarbon age of the Two Creeks Forest Bed, Wisconsin: *Geological Society of America Bulletin,* v. 74, p. 795–802.

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

Knox, P.N., 1996, Wind atlas of Wisconsin: Wisconsin Geological and Natural History Survey Bulletin 94, 47 p.

Leverett, Frank, 1929, Moraines and shore lines of the Lake Superior region: U.S. Geological Survey Professional Paper 154-A, 72 p.

Maass, R.S., 1993, Compilation of outcrops of Precambrian rock in northern Oconto County and adjacent segments of Forest, Langlade, Marinette, and Menominee Counties, northeastern Wisconsin: Wisconsin Geological and Natural History Survey Open-File Report 93-7.

McCartney, C.L., 1979, Stratigraphy and compositional variability of till sheets in part of northeastern Wisconsin: Ph.D. thesis, University of Wisconsin–Madison, 147 p.

McCartney, M.C., and Mickelson, D.M., 1982, Late Woodfordian and Greatlakean history of the Green Bay Lobe, Wisconsin: *Geological Society of America Bulletin,* v. 93, p. 297–302.

McKee, E.D., 1979, Introduction to a study of global sand seas, *in* McKee, E.D., A study of global sand seas: U.S. Geological Survey Professional Paper 1052, p. 1–19.

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, 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. plus appendixes.

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* Wright, H.E. Jr., ed., *Late Quaternary Environments of the United States,* Volume 1, Porter, S.C., ed., *The late Pleistocene:* Minneapolis, Minnesota, University of Minnesota Press, p. 3–37.

Mickelson, D.M., and Syverson, K.M., 1997, Quaternary geology of Ozaukee and Washington Counties, Wisconsin: Wisconsin Geological and Natural History Survey Bulletin 91, 56 p.

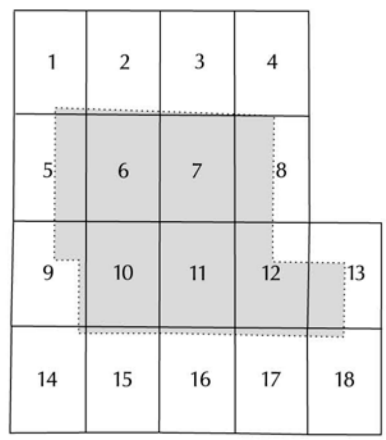
Mudrey, M.G., Jr., Greenberg, J.K., and Brown, B.A., 1982, Bedrock geology of Wisconsin: Wisconsin Geological and Natural History Survey map, scale 1:100,000.

Simpkins, W.W., McCartney, M.C., and Mickelson, D.M., 1987, Pleistocene geology of Forest County, Wisconsin: Wisconsin Geological and Natural History Survey Information Circular 61, 21 p.

Thwaites, F.T., 1943, Pleistocene of part of northeastern Wisconsin: *Geological Society of America Bulletin,* v. 54, p. 87–144.

Northern Oconto County
location diagram

Index to U.S. Geological Survey topographic quadrangles
(scale 1:24,000)



1 Wabeno-1972
2 Otter Lake-1972
3 McCaslin Mountain-1972
4 Roaring Rapids-1972
5 Reservoir Pond-1972
6 Townsend-1972
7 Wheeler Lake-1972
8 Thunder Mountain-1972
9 Langlade-1973
10 Shadow Lake-1973
11 Mountain-1973
12 Shay Lake-1973
13 White Potato Lake-1973
14 Markton-1973
15 Fredenberg-1973
16 Breed-1973
17 Hickory Corners-1973
18 Kelly Lake-1973

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Part of National High Altitude Photograph 297-116 (1980; scale 1:58,000) showing a northeast–southwest trending band of high relief hummocky topography. This band marks the position at which the margin of the Green Bay Lobe stabilized for some time during its general retreat eastward into the Green Bay lowland. Lakewood, Wisconsin, in the northeast part of the photograph, is on an outwash plain deposited by rivers carrying meltwater and sediment beyond the ice margin. The closed depressions in the plain indicate where ice blocks buried in the outwash melted. A similar outwash plain can be seen in the northwestern part of the photo.