Information Circular 59
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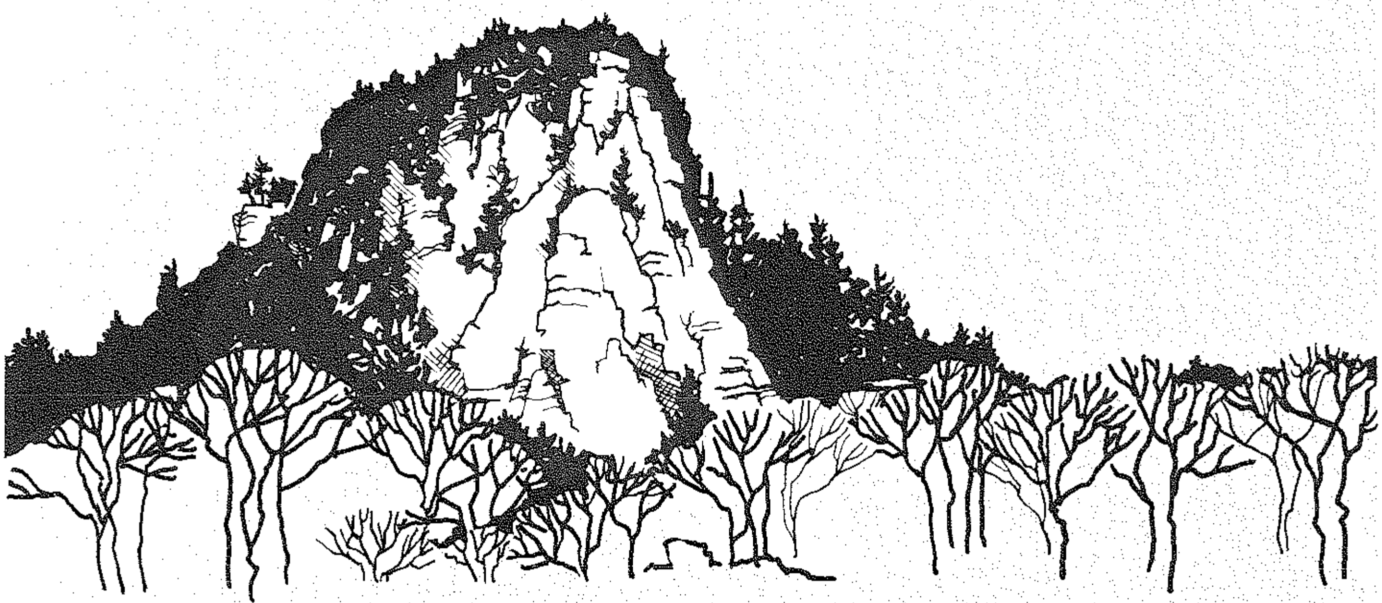
Pleistocene Geology of Adams County, Wisconsin

Lee Clayton



Wisconsin Geological and Natural History Survey

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A description of the geologic materials underlying the surface soil and overlying the Precambrian and Cambrian rock in one of Wisconsin's sand counties

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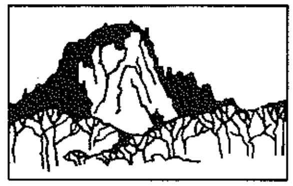
Contents



Figures

Plates (inside back pocket)

Pleistocene Geology of Adams County, Wisconsin

Lee Clayton

ABSTRACT

Adams County, in central Wisconsin, is underlain by Precambrian igneous and metamorphic rock, Cambrian sand and sandstone, and a variety of generally sandy Pleistocene materials. The western part of the county was submerged in glacial Lake Wisconsin; the Pleistocene material there consists primarily of offshore deposits, including sand overlain by silt and clay of the New Rome Member of the Big Flats Formation, which is overlain by sand of the Big Flats Formation. In many areas the Big Flats Formation is overlain by postglacial windblown sand. The east edge of the Lake Wisconsin plain is bordered by sand of the Mapleview Member of the Horicon Formation, which was deposited by meltwater rivers flowing from the Green Bay Lobe of the Laurentide Ice Sheet during the Johnstown Phase of the last part of the Wisconsin Glaciation. The Johnstown moraine is composed of very sandy till of the Mapleview Member of the Horicon Formation. The southeastern part of the county is underlain by offshore silt and clay of the Kewaunee Formation, deposited in the Lewiston Bay of Lake Wisconsin.

INTRODUCTION

This report is a description of the Pleistocene geology of Adams County in central Wisconsin (fig. 1). Emphasis is placed on material below a depth of about 1 m; the material in the upper metre (the surface soil) has been described in detail by Jakel (1984). The Cambrian and Precambrian material below the Pleistocene material are only briefly described.

Aldo Leopold's (1949) Sand County Almanac made many people aware of the "sand counties," an ill-defined group of counties on Wisconsin's central sand plain. The central county of this group, and the one for which the name "sand county" would have been most appropriate, is Adams County. The Cambrian rock exposed in mounds scattered throughout the county consists primarily of quartz sandstone and sand. The Pleistocene material, which covers most of the rest of the county, consists largely of sand.

The western half of the county, on the plain of glacial Lake Wisconsin, is primarily windblown sand overlying offshore sand (with some subsurface beds of offshore silt and clay). The plain is flat to undulating, except where interrupted by sand dunes (primarily in the northwest) or by small valleys cut after Lake Wisconsin drained (primarily in the south). Except for the southeastern corner, the eastern half is largely sand deposited by glacial meltwater and slightly gravelly, silty sand (till) deposited by glaciers. The meltwater-stream deposits occur in a nearly flat plain lying west of the prominent ridge of the Johnstown moraine. East of the moraine the topography is undulating to hilly. The southeastern corner of the county is the least sandy part; low areas are underlain by undulating silt and clay deposited in Lake Wisconsin. Most of the sand grains in these Pleistocene deposits were derived from the Cambrian sand and sandstone in counties to the east. They are well rounded, composed of quartz, and average about 0.4 mm in diameter.

This report is based on several weeks of field work during the summers of 1984 and 1985. Contacts on plate 1 were drawn using 1:20,000 aerial-photograph stereopairs taken in 1965 for the U.S. Department of Agriculture and 1:24,000 topographic maps (with 5-ft or 10-ft contour intervals) made by the U.S. Geological Survey. Additional lithologic information was derived from 1:20,000 soil maps (Jakel, 1984), from water-well construction reports in the files of the Wisconsin Geological and Natural History Survey, from logs of wells drilled for the Wisconsin Conserva-

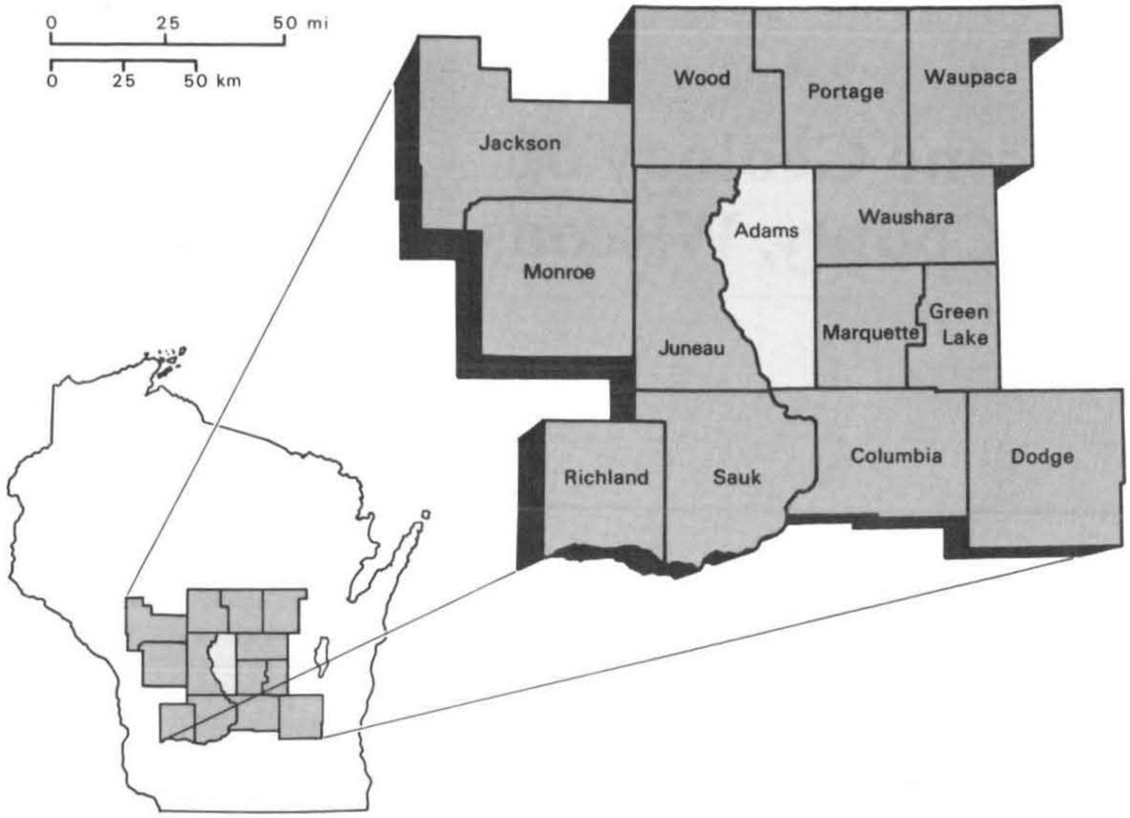


Figure 1 Location of Adams County in Wisconsin.

tion Department Emergency Conservation Work Water Table Survey (Forest Protection Division CCC Ground Water Survey), summarized by Harloff (1942), and from logs of holes drilled by Brownell (1986).

I acknowledge the helpful suggestions made by J.W. Attig, D.M. Mickelson, and K.R. Bradbury, who reviewed the manuscript of this report.

PRECAMBRIAN MATERIAL

Precambrian rock is exposed at the surface in Hamilton Mounds, in sec. 31, T. 20 N., R. 7 E., and sec. 36, T. 20 N., R. 6 E., in northeastern Adams County (map unit **PC,** plate 1). Greenberg and Brown (1983, p. 39-44) described this material. A quarry exposes a small granitic intrusion overlain by quartzite similar to that of the Baraboo Range. The mounds are flanked by Cambrian sandstone and conglomerate.

Elsewhere in the county, Precambrian rock is deeply buried under Pleistocene or Cambrian material. Five wells are known to have penetrated Precambrian rock (plate 2). Three in Adams penetrated Precambrian rock at 85 m ("pink quartzite"), 87 m ("granite"), and 96 m; another, 4 km northwest of Friendship, penetrated "decomposed igneous rock" at 81 m; and another, 5 km south of White Creek, penetrated "granite" at 64 m.

CAMBRIAN MATERIAL

Late Cambrian sandstone or sand crops out in many places in Adams County (map unit **C,** plates 1 and 2). The most prominent outcrops are steep-sided hills rising above the plain west of the Johnstown moraine. Eight of the largest are named "mound" (such as Friendship Mound, which is 100 m high) or "bluff" (such as Quincy Bluff); others are Elephants Back, Dorro Couche, Roche a Cri, and Preston Cliffs. Eleven smaller isolated hills of sandstone have been named "rock" (such as Rabbit Rock), and several are unnamed. The best-known outcrops are those of the Wisconsin Dells in the southwest corner of the county and in adjacent Sauk and Columbia Counties.

As much as 200 m of Cambrian stratigraphic section occurs in Adams County, but only the upper half is exposed. Ostrom (1978) and Twenhofel and others (1935, p. 1728-1729) described the section exposed on Friendship Mound, on the north edge of Friendship. There, the Precambrian rock is overlain by about 150 m of the Elk Mound Group (map unit **Ce** on plate 1); the lower 128 m is the Mt. Simon Formation (fig. 2). In this region, the base of the Mt. Simon contains some conglomerate and fine-grained sediment, but the bulk of it consists of quartz sand and sandstone with well rounded grains; only the upper 22 m of the Mt. Simon is exposed in the base of Friendship Mound.

The Eau Claire Formation, which overlies the Mt. Simon Formation in southern Wisconsin, consists primarily of sand and sandstone, but also contains some glauconite grains. In Adams County the Eau Claire Formation is generally thin or absent; on Friendship Mound it is less than 1 m thick (Ostrom, 1978). Around the base of Spring Bluff and Horseshoe Bluff, 1 to 2 m of Eau Claire Formation is exposed (M. E. Ostrom, field identification, July 1985); in a borrow pit in NW1/4SW1/4NE1/4 sec. 11, T. 17 N., R. 7 E.), the Eau Claire consists largely of shale.

The overlying Wonewoc Formation consists of a lower Galesville Member and an upper Ironton Member (Ostrom, 1978). The Galesville is 16 m thick on Friendship Mound and consists of well rounded grains of quartz sand and sandstone. The Ironton Member is 6 m thick on Friendship Mound and also contains well rounded quartz sand and sandstone, but it tends to be more poorly sorted than the sand of the Galesville.

The Elk Mound Group is overlain by the Tunnel City Group, which in Adams County consists largely of the Mazomanie Formation and is about 30 m thick (Ostrom, 1978). It contains well rounded grains of quartz sand and sandstone. The top of the unit is marked by a topographic bench. The Tunnel City Group is overlain by the St. Lawrence Formation and perhaps also the Jordan Formation on the tops of the highest hills, probably including Rattle Snake Mound, Quincy Mound, and Friendship Mound in the west-central part of the county, and an unnamed hill in the SW1/4 sec. 31, T. 16 N., R. 7 E. The St. Lawrence and Jordan Formations are probably less than 10 m thick on most of these hills. The St. Lawrence Formation consists of dolomite; the Jordan Formation, of sand and sandstone. The Tunnel City Group, St. Lawrence Formation, and Jordan Formation are included in map unit **Ct** on plate 1.

The Cambrian sandstone of map units **Ce** and **Ct** (plate 1) is generally overlain by 1 m or more of sand weathered from the sandstone, especially in flat areas. This, in turn, is overlain by 1 m or less of windblown silt. Much of the Cambrian material, especially that seen in outcrop, is lithified sandstone, but the less well exposed Cambrian sand is often too poorly cemented to be considered sandstone.

<table>
<tr><td rowspan="5">Pleistocene</td><td colspan="5">unnamed units</td></tr>
<tr><td colspan="5">Kewaunee Formation</td></tr>
<tr><td rowspan="3">Big Flats Formation</td><td>unnamed member</td><td rowspan="3">Horicon Formation</td><td>unnamed member</td><td rowspan="3">Mapleview Member</td></tr>
<tr><td>New Rome Member</td><td>New Rome Member</td></tr>
<tr><td>unnamed member</td><td>unnamed member</td></tr>
<tr><td rowspan="7">Cambrian</td><td colspan="5">Jordan Formation</td></tr>
<tr><td colspan="5">St. Lawrence Formation</td></tr>
<tr><td>Tunnel City Group</td><td colspan="4">Mazomanie Formation</td></tr>
<tr><td rowspan="4">Elk Mound Group</td><td rowspan="2">Wonewoc Formation</td><td colspan="3">Ironton Member</td></tr>
<tr><td colspan="3">Galesville Member</td></tr>
<tr><td colspan="4">Eau Claire Formation</td></tr>
<tr><td colspan="4">Mt. Simon Formation</td></tr>
<tr><td colspan="6">PRECAMBRIAN</td></tr>
</table>

Figure 2 Stratigraphic units in Adams County. The New Rome Member and the two unnamed members are part of both the Big Flats and Horicon Formations; these three members were deposited at the same time as the Mapleview Member of the Horicon Formation.

PLEISTOCENE MATERIAL

The Pleistocene material in Adams County consists primarily of glacial, stream, lake, and windblown sediment deposited around the margin of the Green Bay Lobe of the Laurentide Ice Sheet during the Wisconsin Glaciation and earlier glaciations. This section and plate 1 are organized according to the origin of the material.

Glacial sediment

The glacial sediment (till) of Adams County (map units **gm**, **gd**, and **go** in plate 1) is typically brown (5YR or 7.5YR 4 or 5/4 on the Munsell scale). It consists of roughly 10 percent gravel-sized material (larger than 2 mm). Boulders as large as 1 m occur in the sediment and are scattered on the land surface. On the basis of analyses of till in Portage County (Clayton, 1986b), the smaller-than-gravel fraction probably consists of about 90 percent sand (0.06 to 2 mm), 5 percent silt (0.002 to 0.06 mm), and 5 percent clay (smaller than 0.002 mm). Nearly half the sand is in the 0.25 to 0.5 mm range. As would be expected from likely paths of glacial movement (fig. 3), the till, especially the sand fraction, was derived primarily from Cambrian sand and sandstone. About half the pebbles (2 to 64 mm) were derived from Paleozoic dolomite. A few percent consist of chert and sandstone, and the rest are Precambrian igneous and metamorphic rock types, especially the more resistant varieties. In most places the upper few metres have been leached of carbonates.

The till in Adams County underlies surfaces with several different forms. The most conspicuous is the

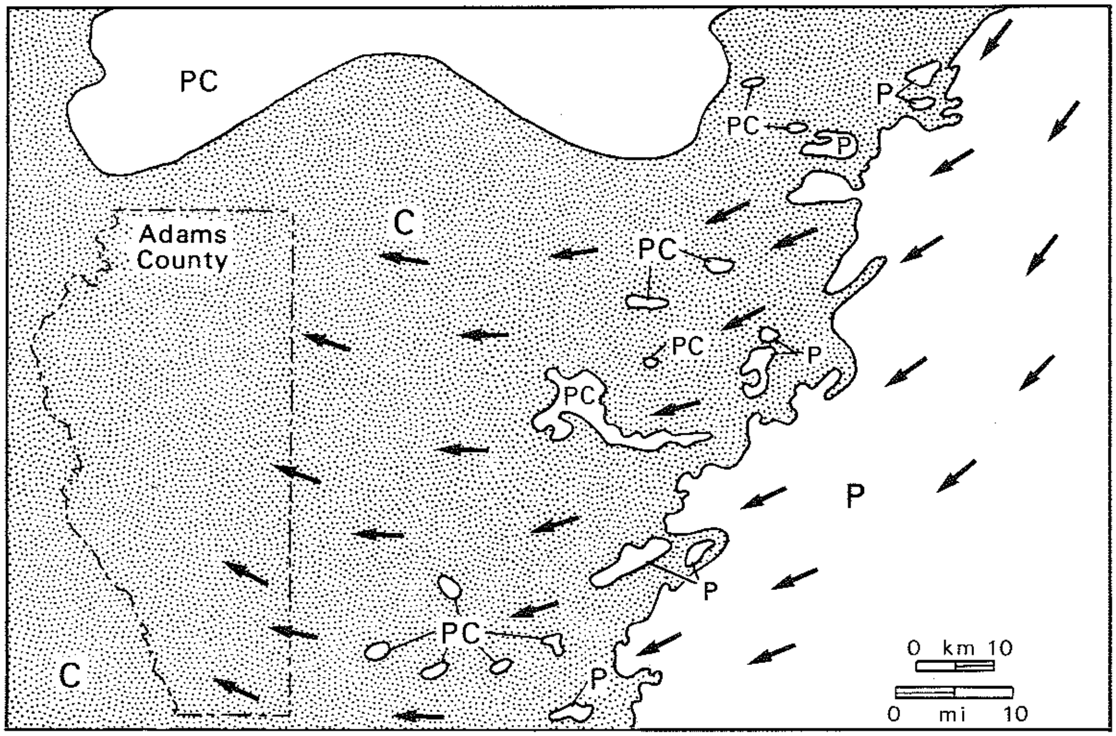


Figure 3 Source of till in Adams County. Arrows show probable direction of glacial movement. Precambrian rock (PC), Cambrian sand and sandstone (dotted area), and Paleozoic carbonate (P) from Mudrey and others (1982).

Johnstown moraine (map unit **gm**, plate 1). It is 0.2 to 1.3 km wide, averaging roughly 0.6 km. It typically rises 5 to 15 m above the sand plain to the west; however, in secs. 11, 14, 15, and 22, T. 17 N., R. 7 E., south of Spring Bluff, it is separated from the plain by a depression (0.4 km wide) that had been occupied by stagnant ice (map unit **sc**, plate 1). The Johnstown moraine marks the westernmost extent of glaciation during the last part of the Wisconsin Glaciation, except in the area of the stagnant-ice depression where the glacier earlier extended west of the Johnstown moraine. The moraine is here referred to by the name "Johnstown" because Alden (1918) traced it from the Johnstown area in southern Wisconsin, but this correlation has not been confirmed. To the north, it corresponds to the Almond or possibly the Hancock moraine of Portage County (Clayton, 1986b), but the correlation near Coloma is uncertain. The thickness of till in the moraine is unknown, but the logs of several water wells suggest that it is a few tens of metres thick in many places. Little information is available on the thickness of the surface till behind the moraine (map unit **gd**, plate 1), but the till of the last glacial advance is probably no more than a few metres thick in most places; it generally overlies older till or meltwater-stream sediment.

Map units **gm** and **gd** on plate 1 are shown above the level of glacial Lake Wisconsin. Shore terraces (map unit **b**) occur at the main high level of the lake, and till also occurs on steeper slopes below that level. This till is included in map unit **go**, which also includes a variety of other materials (such as shore sediment, offshore sediment, and meltwater-stream sediment) that could not be mapped separately. Also included in map unit **go** are areas where the thin till has been eroded away, exposing a variety of older materials, such as offshore sand.

Map units **gm**, **gd**, and **go** also include some slope deposits, probably largely debris flows deposited on the lower parts of slopes after glaciation occurred, but before permafrost disappeared from the area (see section on hillslope sediment). Roughly 0.5 m of windblown silt occurs on more gentle slopes, and some windblown sand occurs on the till where it is adjacent to areas of offshore or stream-deposited sand.

Stream sediment

Stream sediment is shown in shades of red on plate 1. Most stream sediment in Adams County consists of sand (0.06 to 2 mm). Some of the map units on plate 1 are distinguished on the basis of differences in grain size and mineralogy, but topography (flat or hummocky), height above present flood plain, and presumed age are used to distinguish other units.

The youngest stream sediment (map unit **sm**), which underlies modern flood plains, consists primarily of sand but is somewhat coarser and contains more gravel than nearby offshore sand. In places it is overlain by thin silt, peat, or muck. The thickness of the modern stream sediment is unknown, but it is probably no more than a few metres in most places. The cutbanks on the edges of flood plains have scallops with the same curvature as the modern river meanders. Several small construction-material pits occurred on the Wisconsin River flood plain before the dams were constructed.

Along the Wisconsin River, the next oldest widespread stream sediment underlies the Love terraces (map unit **sl** on plate 1), which occur up to 15 m above the modern flood plain near the Portage County border. The main Love terrace can be traced almost continuously southward on either side of the river to T. 15 N., where it is only 2 or 3 m above river level. Southward through the Dells, Love sediment (if present) is probably below today's river level. Northward, the terrace can be traced almost continuously through Wood and Portage Counties (it was named in Portage County; Clayton, 1986b). The sediment of the Love terrace is primarily noncalcareous sand, but scattered pebbles are generally present. A few small construction-material pits occur in this material.

The main Love terrace is about 5 m below the lake-plain level (map units **wn** and **wk**). The Love sediment is coarser than the offshore sediment, which generally lacks pebbles. Unlike the lake plain, the Love terraces have braided stream-channel scars and are largely free of windblown sand. The cutbanks on the east side of the Love terrace in Adams County are straight, unlike the scalloped cutbanks of the modern Wisconsin River.

The thickness of the Love sediment is unknown. Apparently the Wisconsin River became entrenched after Lake Wisconsin drained; later the trench was refilled with sand up to the Love level. The Love sediment was deposited sometime after Lake Wisconsin drained--after at least the second of the Elderon advances of the Green Bay Lobe.

The main Love terrace may have formed during the Winegar advance of the Ontonagon Lobe into Vilas County. The Winegar advance was the major glacial readvance that occurred while the Wisconsin River still received glacial meltwater (Attig, 1985; Attig and others, 1985). Evidence of permafrost, including ice-wedge polygons, occurs on older surfaces, but not on the Love terrace, indicating that the terrace formed after the last major episode of permafrost. In northern Wisconsin, evidence of extensive permafrost occurs only on surfaces formed before the Winegar advance (Attig, 1985; Clayton, 1986a).

Map unit **sp** (plate 1) includes premodern and postglacial noncalcareous sand of the smaller streams in Adams County. The surface of the sand is a few metres above the Love terrace in southwestern Adams County, and unlike the Love terrace, it has ice-wedge polygons (stars on plate 1), indicating it is older than the Love terrace. In the southwestern part of the county, the material of map unit **sp** was derived from the small valleys (map units **se** and **oe**) cut back into the meltwater-stream plain west of the Johnstown moraine after Lake Wisconsin drained. No streams occur today in the smallest valleys, but elsewhere modern streams have cut below the level of the material of map unit **sp**, and in other areas they have deposited sediment on top of the material of map unit **sp**. Near the headwaters of these streams and around sandstone mounds, map unit **sp** probably also includes a variety of hillslope material, including solifluction debris and slopewash sediment.

Map unit **ss** (plate 1) includes noncalcareous quartz sand washed from hills of Cambrian sand and sandstone just west of the Johnstown moraine. Unlike other stream sediment in Adams County, it contains no material derived from glacial sediment. For the most part, it is contemporaneous with the meltwater-stream sediment of map unit **su** and was deposited before Lake Wisconsin drained. Map unit **ss** was, for the most part, deposited by small streams, but slopewash and solifluction were also active in the headwaters of the streams during the time permafrost was present. Since the permafrost melted, most rainwater and much of the snow melt infiltrates rather than runs off.

Map unit **su** (plate 1) consists of sediment deposited by braided meltwater streams before the main Love terrace was formed. Most of this sediment occurs west of the Johnstown moraine and east of the high shore of the main basin of Lake Wisconsin. East of the moraine, meltwater-stream sediment occurs north of the high shore of the Lewiston Bay of Lake Wisconsin (fig. 4). Where it is flat and uncollapsed as a result of being deposited on solid ground, it is included in map unit **su**; where it is hummocky and has been collapsed as a result of being deposited on stagnant glacial ice, it is included in map unit **sc**.

Most meltwater-stream sediment in Adams County is slightly gravelly sand and gravelly sand, generally with stones no larger than about 5 cm. It is generally slightly coarser than the offshore sand deposited at the same time in adjacent parts of Lake Wisconsin. The sediment coarsens eastward toward the Johnstown moraine, where it is typically gravelly sand or slightly gravelly sand, generally with stones no larger than about 0.5 m. The sand fraction is primarily quartz, and the pebbles are about half dolomite and a few percent chert and sandstone; the rest consists of

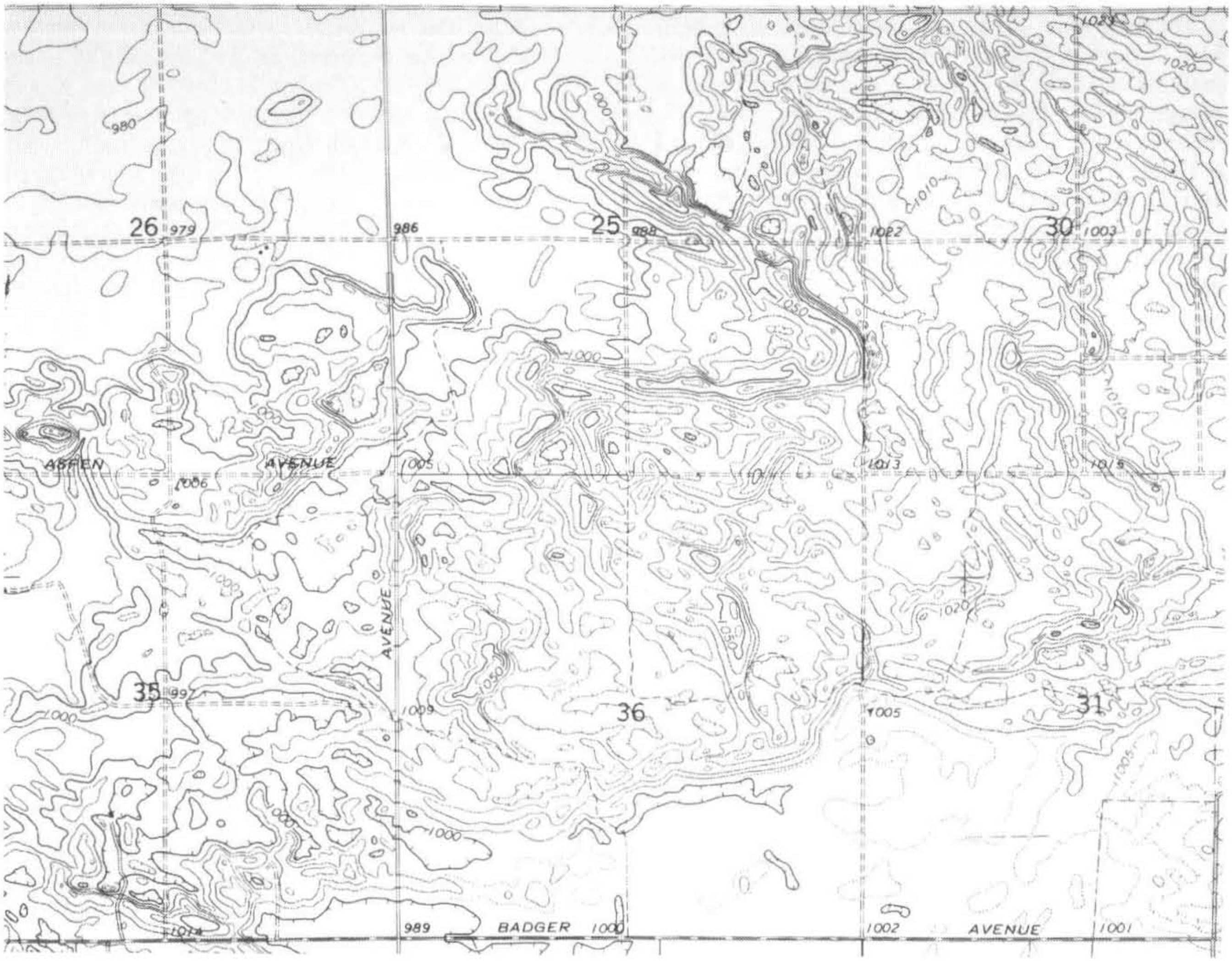


Figure 4 Parabolic dunes in northwestern Adams County (T. 20 N., R. 5 and 6 E.). U.S. Geological Survey Arkdale NE Quadrangle, 7.5 minute series, topographic, 10-ft contour interval. Area shown is 4 km wide.

various igneous and metamorphic rock types. Carbonates have been leached from the upper few tens of metres where the sediment consists largely of sand, but carbonates are leached from no more than the upper few metres where the sediment is gravelly. The largest construction-material pits occur at the west edge of the Johnstown moraine, where the meltwater-stream sediment is coarse, and several small inactive pits occur east of the moraine (plate 1).

The meltwater-stream sediment ranges in thickness from zero at the shore of the main basin of Lake Wisconsin to 10 to 25 m at the Johnstown moraine. East of the moraine the thickness is unknown, but it is unlikely that any is present below the level of the Lewiston Bay of Lake Wisconsin.

Map unit **se** (plate 1) consists of meltwater-stream sand deposited west of the Johnstown moraine. The material is the same as that of map unit **su**, but the topography is different. Map unit **su** consists of a flat plain, only slightly modified since the sand was deposited; map unit **se** consists of the sides of valleys cut back into the sand plain after deposition ceased. The topography is similar to that of map unit **oe**, but the material is different: unit **oe** consists of offshore sediment underlying the stream sediment.

Offshore sediment

Sediment deposited lakeward from the shore zone of now-extinct lakes is shown in shades of blue on plate 1. Present-day lakes are shown in light blue. Material interpreted to be offshore sediment is either coarse or fine grained. Coarse-grained offshore sediment consists primarily of sand deposited by density (turbidity) currents. Meltwater streams were cold and turbid, and therefore dense, causing the water to continue to flow beyond the mouths of the streams and carrying sand out onto the lake bottom. Fine-grained offshore sediment consists of silt and clay carried in suspension far out into the basin, beyond currents flowing fast enough to carry sand.

Map unit **oy** (plate 1) consists of laminated silt and clay in southeastern Adams County. It is generally reddish brown (5YR 4/4 on the Munsell scale is typical), but some is gray. According to water-well logs, it is generally between 5 and 25 m thick, and it generally overlies sand. Except for roughly the uppermost metre, it is calcareous. Some is flat but much of it has undulating to rolling topography as a result of being deposited on top of stagnant glacial ice. The silt and clay of map unit **oy** was deposited in the Lewiston Bay of Lake Wisconsin. The material was carried southward and westward into the bay by meltwater from the west side of the Green Bay Lobe in Adams, Marquette, Waushara, Portage, Marathon, Shawano, and Langlade Counties.

Map units **ou** and **oc** consist of sand and slightly pebbly sand, similar to that of map units **su** and **sc.** Map unit **ou** consists of flat-lying material deposited on solid ground; **oc** consists of hummocky sand deposited on stagnant glacial ice. The material of map units **ou** and **oc** is interpreted as offshore sediment deposited in the north end of the Lewiston Bay of Lake Wisconsin because it occurs below the probable lake level of the time it was deposited. However, much of unit **ou** is only a short distance below lake level, and lake level is imprecisely known; as a result, some of map units **ou** and **oc** may actually consist of shore sediment or stream sediment.

Map unit **om** (plate 1) consists of offshore sand deposited in the main basin of Lake Wisconsin (fig. 4). This material also underlies windblown sand of map units **wk** and **wn** and the stream sediment of map unit **su** west of the Johnstown moraine; it also occurs in map unit **oe** (plate 1). It is generally medium to fine sand (0.1 to 0.5 mm), but it becomes coarser eastward toward shore, where some slightly pebbly (pebbles generally no larger than about 2 cm) sand is present. Here, the material consists primarily of well rounded quartz grains. Like the meltwater-stream sand, it contained some dolomite grains that have since been largely or totally leached. It is flat-bedded or cross-bedded, and dips down the regional slope toward the axis of the basin and southward down the axis. This suggests that most of it was deposited by meltwater flowing westward from the margin of the Green Bay Lobe, but some of it was deposited by meltwater carried into the lake from north-central Wisconsin by the Wisconsin River. This deposit is 20 m or more thick in parts of southern Adams County, but is less than 1 m thick under the windblown sand in the west-central part of the county.

Offshore silt and clay underlies the offshore sand in much of the county. It is reddish brown, gray, or brown and horizontally laminated, and is a fraction of a metre to several metres thick. It is generally calcareous, averaging about 25 percent carbonates (Brownell, 1986). Where the overlying sand has been leached of carbonates, the upper metre of the silt and clay may also be leached. The silt and clay is within 1 or 2 m of the surface in the west-central part of the county and is exposed in stream and reservoir cutbanks, in deep road cuts, in valley sides in map unit **oe** (plate 1) in southern Adams County. The silt and clay in turn overlies offshore sand like that above it, and one or two more beds of silt and clay occur at depth in some areas (plate 2).

Map unit **on** (plate 1) consists of offshore sand in a lake dammed up on the east side of sandstone hills by the rising level of the meltwater-stream plain. Map unit **oi** (plate 1) consists of offshore sand deposited in a lake that was surrounded by stagnant glacial ice.

Shore sediment

The features called "shore terraces" on plate 1 (map unit **b**) are flat to undulating benches at an elevation of about 290 to 295 m. Included are wave-built benches and wave-cut benches, and perhaps small deltas. The shore sediment is generally no more than a few metres thick and consists of sand and slightly gravelly sand, with some gravelly sand and sandy gravel. Grain composition is similar to the stream sediment described previously. Other shore deposits, too small to map, occur at the same elevation, at the contact between map units **gd** and **go** (plate 1). Several small construction-material pits occur in shore-terrace sediment in southeastern Adams County.

The terrace was formed around the shore of the Lewiston Bay of glacial Lake Wisconsin, after the glacier melted back from the Johnstown moraine but before it melted back far enough for the lake to drain around the east end of the Baraboo Hills. Removal of some of the weight of the ice caused the earth's crust to rebound; as a result, the shoreline is several metres lower than the high shoreline of the main basin of Lake Wisconsin, west of the Johnstown moraine.

Shore sediment also occurs around the main basin of Lake Wisconsin, but it is too poorly known to be mapped precisely. Beaches have been mostly destroyed by solifluction and wind erosion. The approximate position of the shoreline is indicated by a heavy dashed line on plate 1, between map units **wn** or **om** and map units **ws, su, ss,** or **Ce.** Small shore deposits also occur at the same elevations on hills of sandstone farther west (map unit **Ce,** plate 1), but for clarity the line has been omitted on plate 1.

Earlier positions of the eastern shoreline of the main basin are indicated on plate 1 by line symbols for shore-ice collapse trenches in map unit **su.** Clayton and Attig (1982) reported that these trenches probably formed where the meltwater-stream sediment was deposited on top of ice along the shore of Lake Wisconsin. The shore ice persisted as long as permafrost was present, but melted along with the permafrost. Melting caused the overlying sand to collapse, producing the trenches.

Windblown sediment

Windblown sediment is shown in shades of yellow on plate 1. Windblown silt is indicated by map units **wt** and **wc.** The windblown silt is the same in both units, but in unit **wt** it overlies Pleistocene sand; in unit wc it overlies Cambrian sand or sandstone. It is roughly 1 m thick where it has been mapped (plate 1) on level upland surfaces near the Wisconsin River; where not mapped, it is roughly 0.5 m thick on level upland surfaces over the rest of the area. It has been eroded from steeper slopes, and it was never present on surfaces as young as or younger than the Love terrace, indicating that it was deposited during and before the Winegar advance of the Green Bay Lobe, the last time glacial meltwater flowed down the Wisconsin River.

Windblown sand is included in map units **ws, wn,** and **wk** on plate 1. Windblown sand overlies meltwater-stream sand in map unit **ws,** and offshore sand (or silt and clay in some places) in map units **wn** and **wk.** In map units ws and **wn,** the windblown sand is thin, averaging perhaps 0.5 m or less in thickness; the larger dunes are between about 1 and 3 m high. In map unit **wk,** the windblown sand is thick, averaging perhaps 1 to a few metres in thickness; the larger dunes are between about 3 and 20 m high. In map units **om** and **su** the windblown sand is very thin; the largest dunes are generally less than about 1 m high.

The dune sand is primarily medium to fine sand (about 0.2 to 0.5 mm), about the same size as the underlying offshore sand but finer than typical meltwater-stream sand. Much of it is probably cross-bedded, with dips to east-southeast, but it is generally unbedded in shallow exposures, because of stirring by plant roots and burrowing animals. In most places where the base of the windblown sand was observed, it overlies a paleosol. The windblown sand consists largely of well rounded quartz grains because it was derived from stream or offshore sediment that was derived from Cambrian sand and sandstone, which is predominantly well rounded medium quartz sand.

Where the windblown sand is thickest, the surface form consists of parabolic dunes as high as 20 m. The arms of the dunes are typically about 1 km long, some as long as 3 km (fig. 4). The axes of the dunes average about N. 55° W., and the ridges are steepest on the convex side of the parabola, indicating that they were formed by wind from the northwest or west-northwest.

The age of the dunes is uncertain. They probably formed after much of the permafrost melted (perhaps around 13,000 B.P.) because windblown sand has obliterated the shore-ice collapse trenches east of Adams County (plate 1), which formed when the permafrost melted. In addition, the dunes have sharp, well defined forms, in contrast to landforms that originated before about 13,000 B.P., which have subdued forms as a result of solifluction. The scarcity of dunes on the Love terrace suggests they formed before the Love terrace (before about 12,500 B.P.), but the scarcity may be due to the coarseness of the Love sediment rather than to its age. Most likely the large dunes formed during the dry period around 7000 or 6000 B.P., and some small dunes have been active since farming began.

Hillslope sediment

Material deposited by processes such as slopewash, creep, and solifluction occur at the base of hillslopes and in depressions throughout Adams County, but nowhere in large enough masses to be shown separately on plate 1. Because of the abundance of sand, most water infiltrates rather than runs off, and little soil erosion occurs today, except on steep cultivated slopes. Through most of postglacial time, the main erosive process on hillslopes was perhaps soil movement when trees were uprooted in windstorms. Up until roughly 12,500 B.P., however, deep, continuous permafrost was present, and surface water could not infiltrate. As a result, a great deal of hillslope erosion occurred then, especially in the form of slopewash and solifluction (debris flows), and most of the hillslope sediment in Adams County is probably older than about 12,500 years.

The most widespread and convincing evidence for permafrost in Adams County is contained on aerial photographs that show ice-wedge polygons (fig. 5). Each star symbol on plate 1 indicates a group of several tens or hundreds of polygons. The polygons are typically 10 to 50 m in diameter. The ice-wedge casts, which are 1 to 2 m wide, show up in cultivated fields because of slight tonal differences resulting from moisture differences in the overlying windblown sediment. They occur on a variety of surfaces older than the main Love terrace in Adams County, including the fans (map unit **sp,** plate 1) formed around the mouths of the small valleys cut back into the meltwater-stream plain west of the Johnstown moraine in southern Adams County. This suggests that the valleys were cut

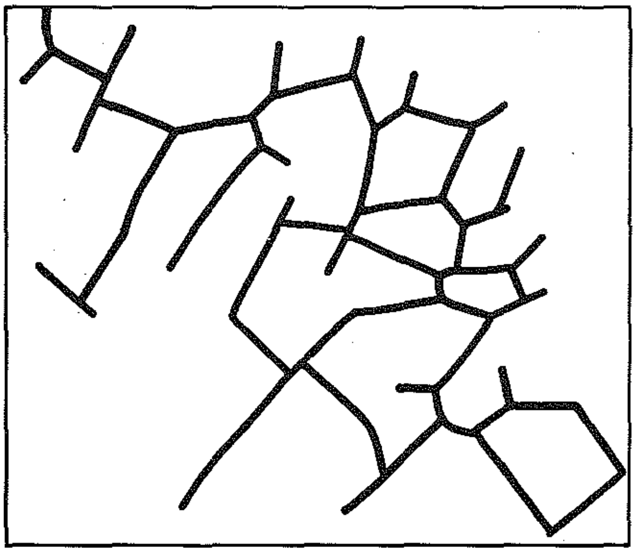


Figure 5 Ice-wedge polygons on stream sediment deposited beyond mouths of small valleys cut after Lake Wisconsin drained, in the SW1/4SW1/4SW1/4 sec. 4, T. 14 N., R. 6. E., southwestern Adams County. Traced from U.S. Department of Agriculture aerial photograph AJA-1FF-284. Area shown is 170 m wide.

before the permafrost melted, which is confirmed by the presence of shore-ice collapse trenches formed across the valley heads. These trenches formed when the permafrost melted and after the valleys formed.

Organic sediment

Muck and peat are indicated by map unit **p** on plate 1 where they are more than about 0.5 m thick. Many small or thin deposits have not been indicated on the map, especially between dunes in the northwestern half of the county. Much of the peat and muck was probably deposited since the dry period around 7000 to 6000 B.P.

PLEISTOCENE STRATIGRAPHY

The Horicon Formation was named by Mickelson and others (1984) to include brown or reddish brown, sandy, calcareous sediment of eastern Wisconsin. It consists of till, stream sediment, and associated materials deposited below or around the margin of the Green Bay Lobe of the Laurentide Ice Sheet. In Adams County the Horicon Formation includes the Mapleview and New Rome Members (fig. 2).

Mickelson and others (1984) named the Mapleview Member to include the till of the outer moraine in Langlade County and adjacent areas. In Adams County the Mapleview Member includes sandy calcareous till and associated stream and lake deposits. It is probably typically 30 to 60 m thick, although the subsurface part of the unit is poorly known. On plate 2 no attempt was made to differentiate the till, stream sediment, and offshore sand in the southeastern part of the county because they are so similar in composition that they have not been consistently differentiated on water-well logs.

The New Rome Member is included in both the Horicon and Big Flats Formations. It consists of silt and clay underlying surface sand of both the Horicon and the Big Flats Formations (plate 2). It pinches out northeastward just into Portage County and thickens south through Wood, Juneau, and Sauk Counties. It has been named by Brownell (*in* Attig and others, in press) for the former community of New Rome in sec. 10, T. 20 N., R. 5 E., in northwestern Adams County. The New Rome Member consists of offshore sediment deposited in the main basin of Lake Wisconsin. It is exposed in deep stream and road cuts in the west-central part of the county and in map unit **oe** in the southern part of the county. It is generally several metres thick.

The Big Flats Formation includes sand west of the Horicon Formation in Adams (plates 1 and 2), Portage, Wood, Juneau, and Sauk Counties. This formation was named after the community of Big Flats in secs. 17 and 20, T. 19 N., R. 6 E., in northern Adams County (Brownell *in* Attig and others, in press). The Big Flats Formation includes the offshore sand of map units **wn, wk, om,** and **oe** (plate 1) and is separated from the overlying dune sand by a paleosol in most places. In Adams County the Big Flats Formation was deposited about the same time as the Horicon Formation.

A few tens of metres of Horicon or Big Flats sand and some additional silt and clay beds occur below the New Rome Member (plate 2), but they are too poorly known to be assigned to formally named stratigraphic units. The New Rome Member and the unnamed members above and below it were deposited at the same time as the Mapleview Member of the Horicon Formation; for this reason they are shown to be the lateral equivalents of the Mapleview in figure 2.

The Kewaunee Formation was named by Mickelson and others (1984) to include reddish brown clayey material of east-central Wisconsin. In southeastern Adams County, it consists of an unnamed member containing the silt and clay of map unit **oy.**

PLEISTOCENE HISTORY

Before the first glacier reached Wisconsin, probably in late Pliocene or early Pleistocene time, Adams County resembled present-day western Juneau County (fig. 1); Cambrian sand and sandstone was at the surface in most places. The Wisconsin River did not yet exist in central Wisconsin. Rivers flowed southeast

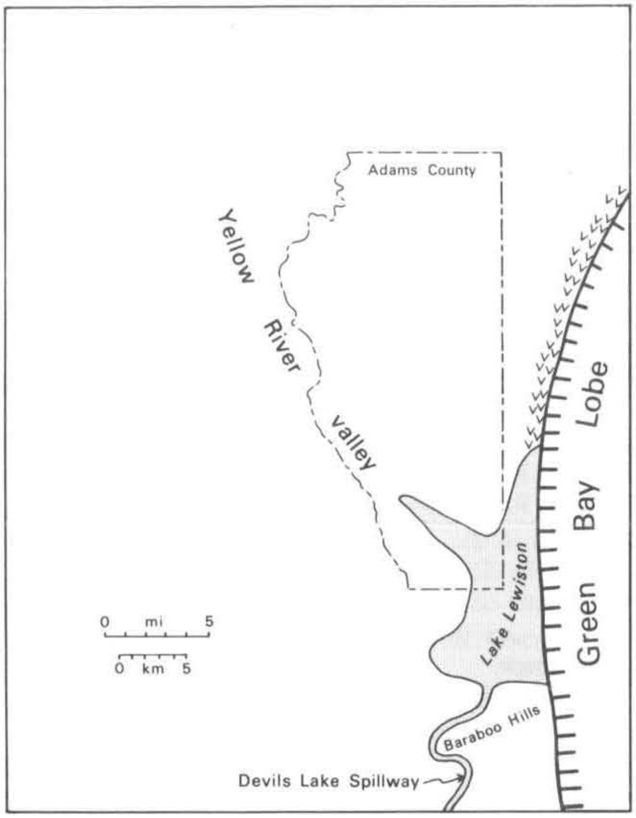


Figure 6 Adams County during an early glaciation, probably before the Arnott Glaciation. Arrowheads indicate direction of meltwater flow; shaded area indicates lake water.

from the drainage divide in Monroe and Jackson Counties to the eastern Wisconsin lowlands. The ancestral Yellow and Lemonweir Rivers probably joined in southern Adams County and continued southeastward, probably through southwestern Marquette County.

Little evidence is available in central Wisconsin for the glaciations that are known to have occurred elsewhere in North America through the early and middle part of Pleistocene time. Any glaciers that reached the east end of the Baraboo Hills before late Pleistocene time formed Lake Lewiston, with its outlet through the Devils Lake gorge (fig. 6). Any glaciers that reached as far west as Devils Nose, a quartzite ridge southeast of Devils Lake (figs. 7 and 8), blocked the Devils Lake outlet. This created Lake Wisconsin, with its outlet to the northwest, through East Fork Black River (fig. 8). The most extensive glaciations, perhaps including the Arnott Glaciation (figs. 7 and 8), may have clogged Devils Lake gorge with till above an elevation of 295 m; this would have caused Lake Wisconsin to refill whenever later glaciations reached the east end of the Baraboo Hills. The layers of offshore sand, silt, and clay beneath the New Rome Member (plate 2) were deposited in early versions of Lake Wisconsin, during the Arnott or early glaciations, or perhaps also during the early part of the Wisconsin Glaciation (fig. 7).

The last major resurgence of the Wisconsin Glaciation began around 25,000 B.P. (fig. 7). Lake Wisconsin again filled and spilled into the East Fork Black River when the ice reached the east end of the Baraboo Hills. At this time offshore silt and clay of the New Rome Member was probably being deposited in the main basin of Lake Wisconsin. Meltwater from the glacier deposited sand in the Lewiston basin between the glacier and the higher area to the west (fig. 9).

As the glacier advanced to its outermost position, the Lewiston basin was overrun, and the meltwater was able to sweep sand well out into the main basin--the sand was no longer trapped by the Lewiston basin (fig. 10). This event probably marked the change from deposition of silt and clay of the New Rome Member to deposition of the overlying sand in the main basin (figs. 2, 7, and 10). As the glacier stood at the Johnstown position, the sand was built up above lake level, forming a broad meltwater-stream plain between the glacier and the lake (fig. 10). When the ice melted back after the Johnstown Phase (fig. 7), the Lewiston basin was again exposed (fig. 11). Lewiston Bay was almost completely isolated from the main basin by the Johnstown moraine and its outwash plain. As a result, the meltwater-transported silt and clay, as well as sand, was largely trapped in the Lewiston basin; little reached the main basin at this time.

Lake Wisconsin drained when the ice again melted back to the east end of the Baraboo Hills, probably between two of the Elderon subphases (fig. 7). The water of the Lewiston Bay quickly drained through the Alloa outlet into Lake Merrimac (Bretz, 1950) and then down the Wisconsin River, forming the sand plain now occupied by Sauk City (fig. 12). Water spilling from the main basin of Lake Wisconsin cut the sandstone gorges of the Wisconsin Dells.

The Wisconsin River assumed nearly its present course at this time, flowing across the former courses of the Yellow and Lemonweir Rivers. It was no longer able to flow down to the eastern Wisconsin lowlands because its former route was dammed by glacial material.

When the water of Lake Wisconsin drained and cut the Wisconsin Dells, much of the sediment of Lake Wisconsin also was eroded from southwestern Adams County, creating a steep slope at the west side of the meltwater-stream plain. Small valleys (map units **oe** and **se**, plate 1) were cut back into this steep slope, and fans of sand were deposited around the mouths of these valleys. Permafrost formed in the sand and across the rest of the former lake bed.

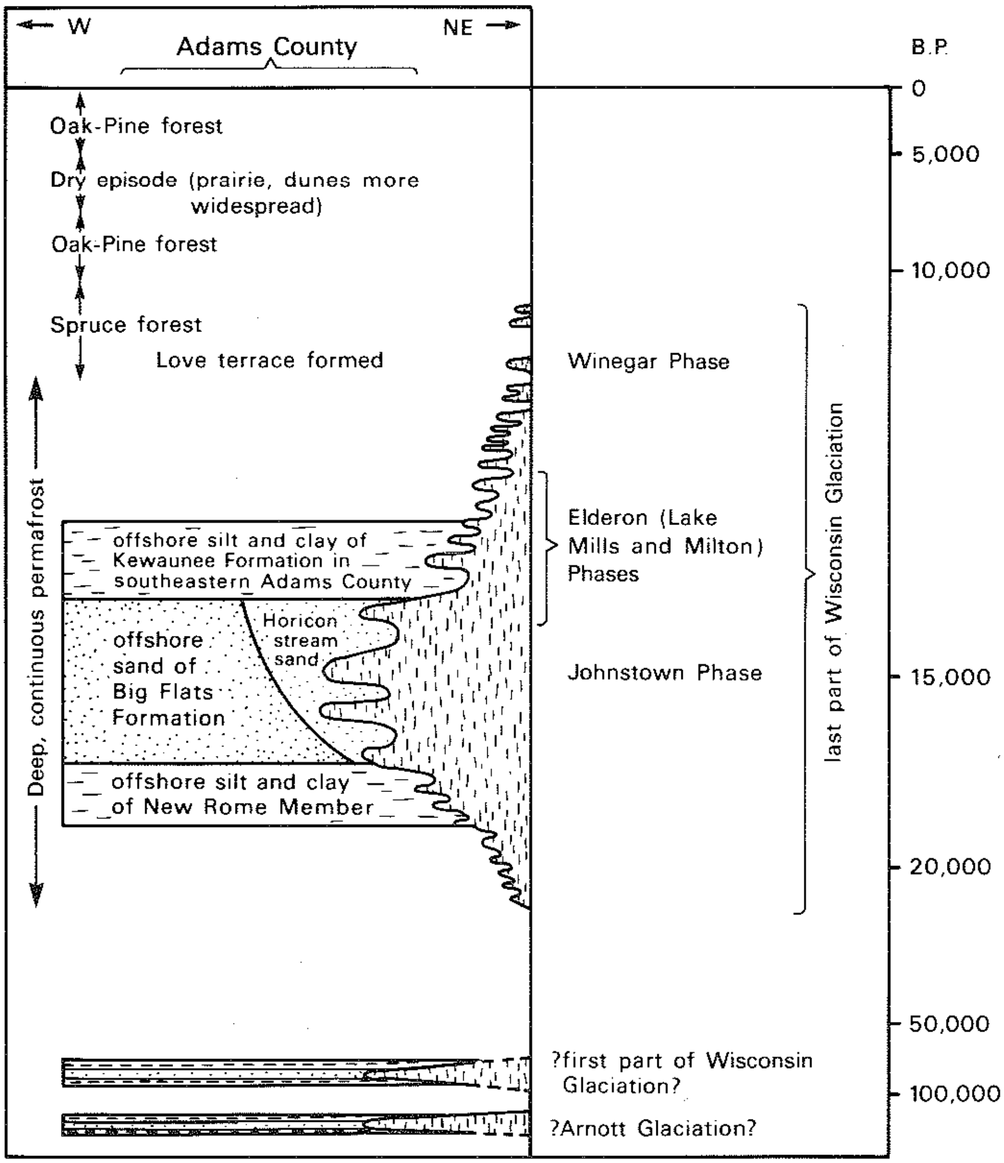


Figure 7 Chronology of late Pleistocene events in Adams County. Vertical axis shows time, with date in years before present (B.P.); horizontal axis is distance parallel to a glacial flowline, from somewhere west of Adams County, northeast to Lake Superior (the distance northeast of the county is condensed). Vertical dashes indicate presence of glacier; horizontal dashes indicate episodes of silt and clay deposition in Lake Wisconsin; dots indicate major episodes of sand deposition.

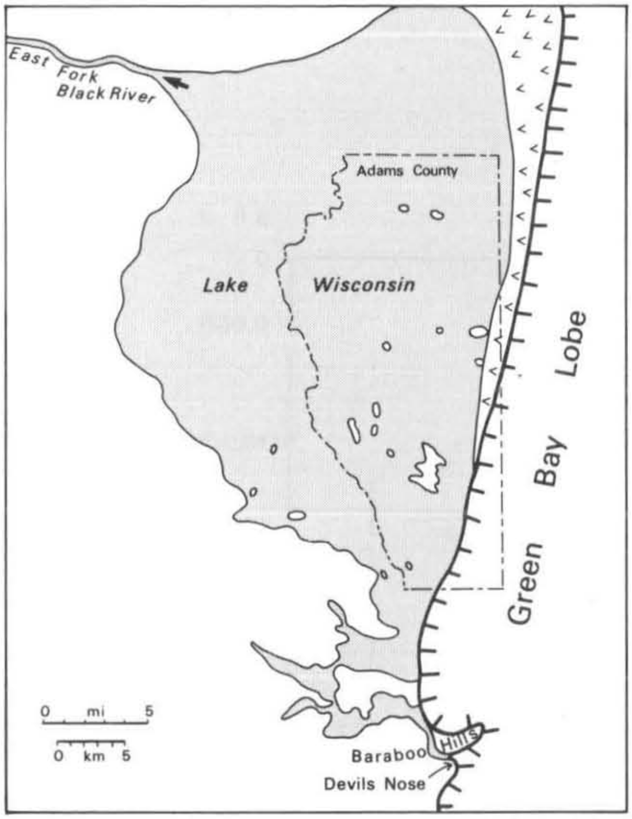


Figure 8 Adams County during an early glaciation, perhaps during the Arnott Glaciation.

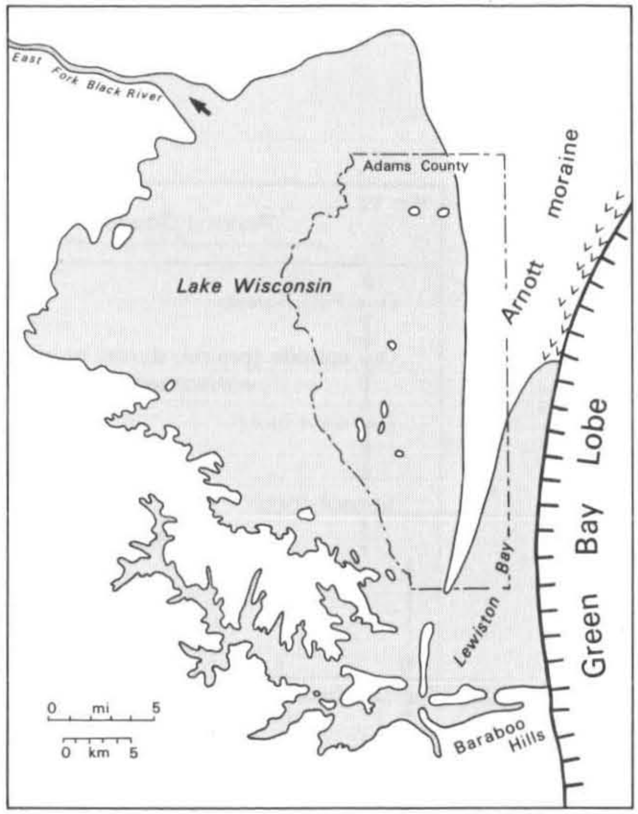


Figure 9 Adams County during an early part of the last episode of the Wisconsin Glaciation.

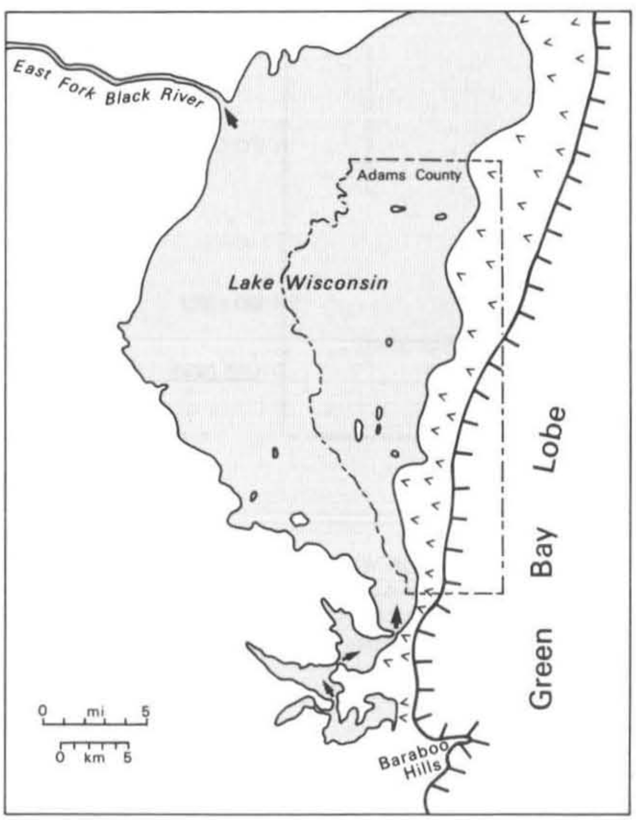


Figure 10 Adams County during the Johnstown Phase of the Wisconsin Glaciation.

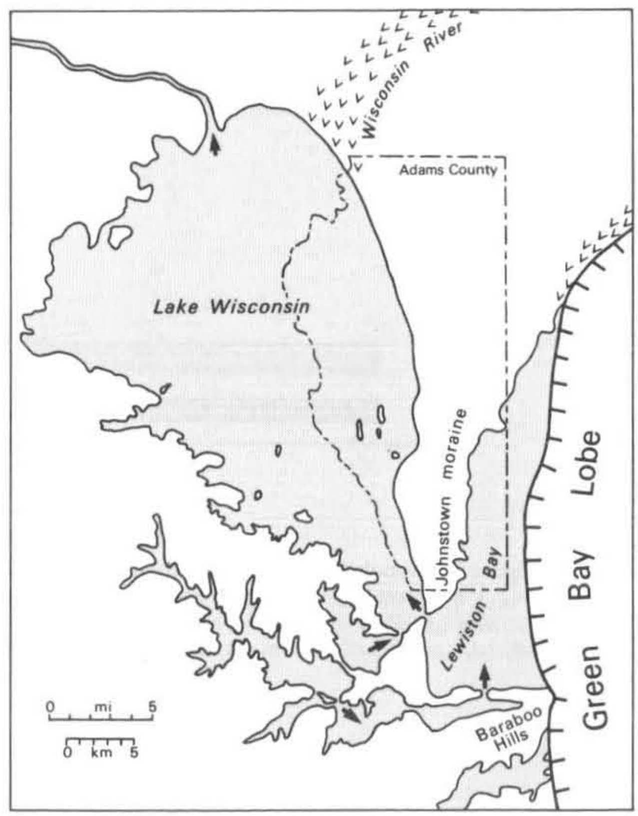


Figure 11 Adams County during an early part of the Elderon Phase of the Wisconsin Glaciation.

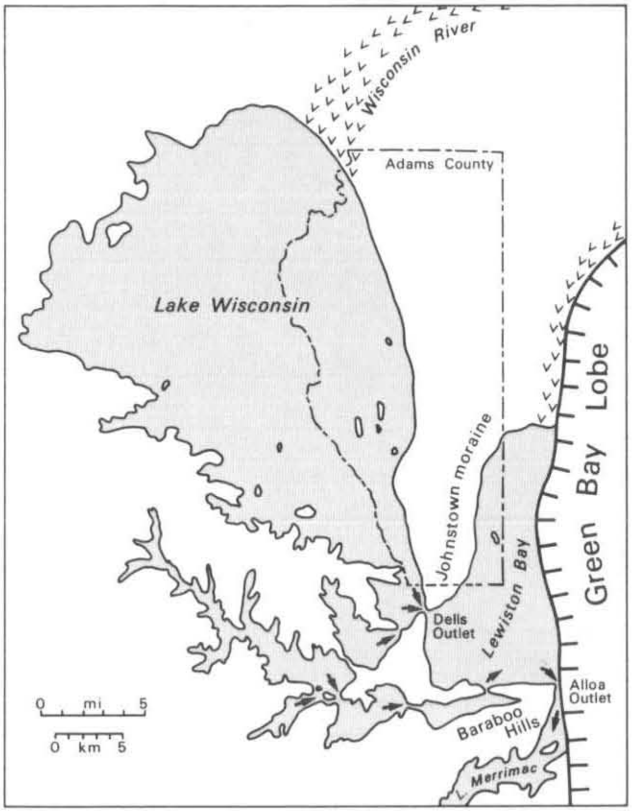


Figure 12 Adams County during a later part of the Elderon Phase of the Wisconsin Glaciation.

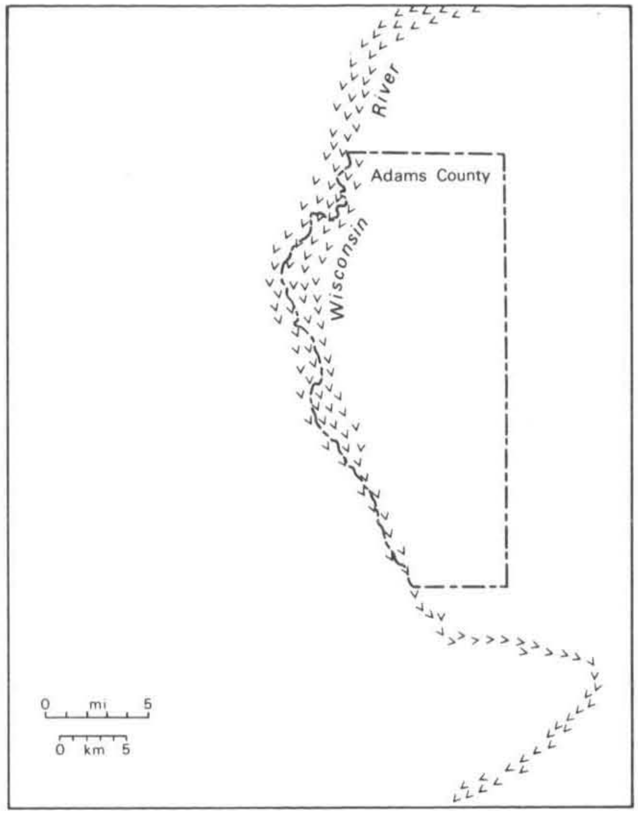


Figure 13 Adams County during the Love Phase of aggradation along the Wisconsin River.

The Wisconsin River was again entrenched, and then the river underwent a major episode of aggradation during the Love Phase (fig. 13), which may have coincided with the Winegar Phase of glaciation in northern Wisconsin (fig. 7). By this time, most of the permafrost had melted, and spruce forest had spread across Wisconsin.

At the end of the Love Phase, the Wisconsin River changed from a braided river carrying abundant sand to a meandering river, much like the present river. Sometime after the last permafrost melted sand dunes were active in much of Adams County, perhaps during the Love Phase, but also probably during the dry period around 7000 or 6000 B.P.

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