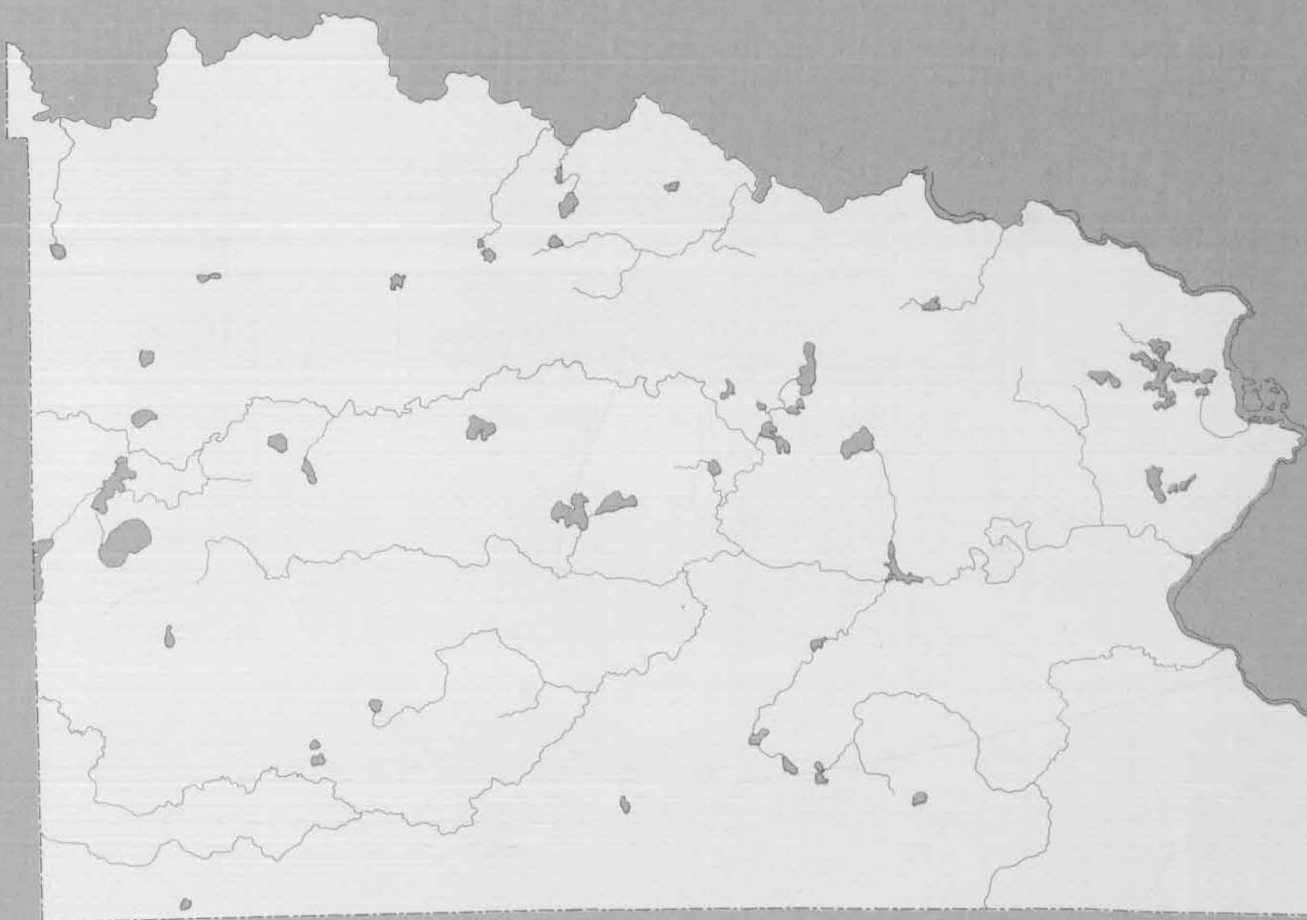
Pleistocene Geology of Florence County, Wisconsin

by Lee Clayton



University of Wisconsin—Extension

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Pleistocene Geology of Florence County, Wisconsin

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A description of the geological materials underlying the surface soil and overlying the Precambrian in one of Wisconsin's northeasternmost counties

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ABSTRACT

Florence County, in northeastern Wisconsin, is underlain by Precambrian igneous and metamorphic rock, which is overlain by 0 to 100 m of Pleistocene till and fluvial sediment. Much of the Pleistocene material was deposited during several advances of the ice sheet near the end of Wisconsin Glaciation. The Nashville Member and member W of the Copper Falls Formation were deposited over much of the county during the early Mountain Advance and earlier advances. The red clayey till of the Florence Member and member E of the Kewaunee Formation were deposited during the middle Mountain Advance. The Silver Cliff Member of the Kewaunee Formation was deposited during the late Mountain Advance and the early Athelstane Advance.

INTRODUCTION

This report is a description of the Pleistocene geology of Florence County, in northeastern Wisconsin (fig. 1). Florence County has an area of about 1270 km², and it has one of the lowest population and road densities in the state.

The county is underlain by a variety of igneous and metamorphic rock types formed during Precambrian time, which are overlain in most places by till or fluvial sediment deposited during Pleistocene time. The surface of the Precambrian rock in Florence County is irregular, with relief of at least 200 m. As a result, the thickness of the Pleistocene material is irregular, ranging from 0 to 50 m within less than 1 km in many areas. Similarly, the lithology of the Pleistocene material is irregular; the till undergoes conspicuous changes within distances of only a few kilometres, depending on the nature of the Precambrian or Pleistocene material the glacier overrode. The land surface ranges in elevation from 315 m at the eastern edge of the county to 528 m in the northwest.

Florence County was glaciated many times during the Pleistocene Epoch, but little is known about any but the last few of these events. During the last part of the Wisconsin Glaciation, the ice sheet readvanced several times, reaching Langlade County, to the southwest of Florence County, between about 20 000 and 15 000 yr ago. It then wasted back across Florence County, with several minor readvances between about 14 000 and 12 000 yr ago. During this time, the Langlade Lobe of the ice sheet deposited units of the Copper Falls Formation in western Florence County, and the Green Bay Lobe deposited units of the Kewaunee Formation in the eastern part of the county. These events are discussed in detail in the first half of this report, and the resulting deposits are described in the second half.

This report is based on several weeks of field work during the summer of 1981. Forty holes were augered

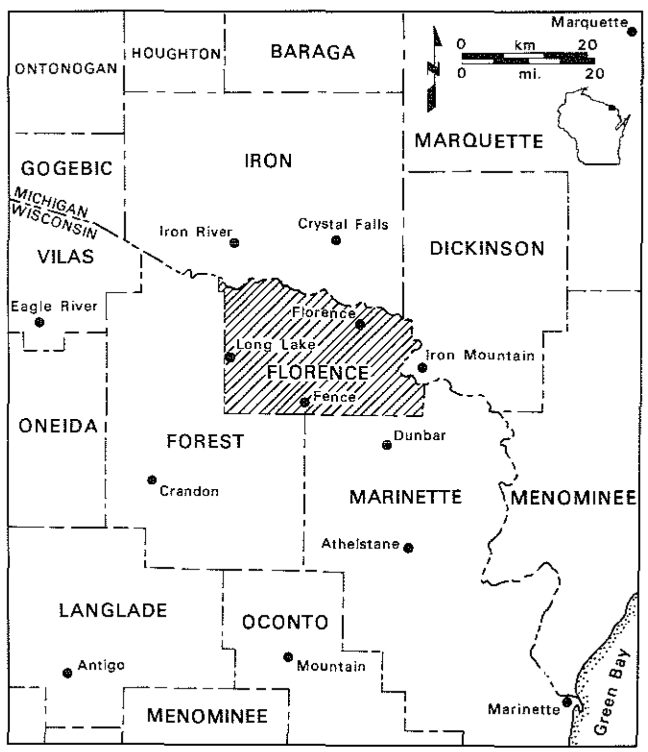


FIGURE 1.--Location of Florence County

from depths of 3 to 30 m, averaging 10 m. Samples were analyzed in the Quaternary laboratory of the Department of Geology and Geophysics of the University of Wisconsin at Madison. Contacts on plate 1 were drawn using 1:40 000 air photo stereopairs taken in 1979 and 1980 for the U.S. Department of Agriculture and 1:24 000 topographic maps (with 10-ft or 20-ft contour intervals) made by the U.S. Geological Survey. Additional lithologic information was derived from a 1:63 000 soil map of Florence County (Hole and others, 1962) and from unpublished township reports and logs of water wells in the files of the Wisconsin Geological and Natural History Survey.

I acknowledge the numerous helpful suggestions made by Tom Evans, Fred Madison, and Dave Mickelson, who reviewed the manuscript of this report.

LATE PLEISTOCENE HISTORY

In this section, late Pleistocene events in Florence County will be discussed, starting with earliest. Each event will first be briefly described, and then the evidence for the event will be discussed. These events are summarized on figures 2 and 3.

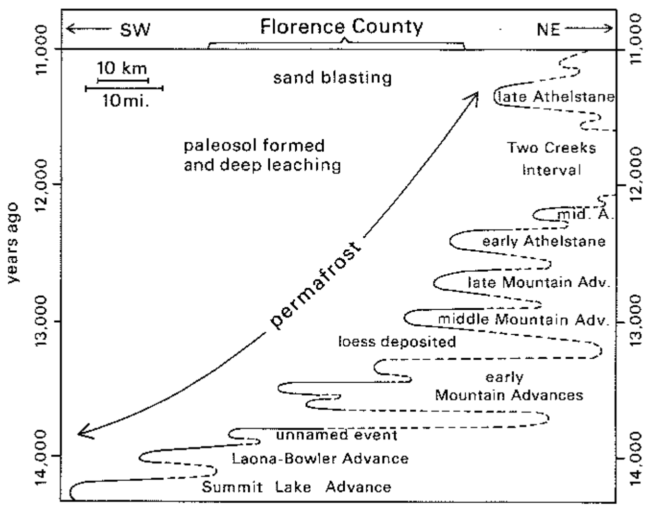


FIGURE 2.--Time-distance diagram showing fluctuations of the Langlade and Green Bay Lobes during the last part of the Wisconsin Glaciation. Except for the Two Creeks Interval, dates are rough estimates.

Early events

Perhaps about 25 000 yr ago the Laurentide Ice Sheet advanced across Florence County, and later, during the Parrish Advance, the ice sheet reached central Langlade County, to the southwest of Florence County (fig. 3). The ice sheet then melted back, and during the Summit Lake Advance (fig. 2 and 3), it again readvanced a short distance into Langlade County and again melted back to the northeast. During the Laona Advance, the ice sheet readvanced as far as central Forest County; according to Thwaites (1943), the Laona Advance was

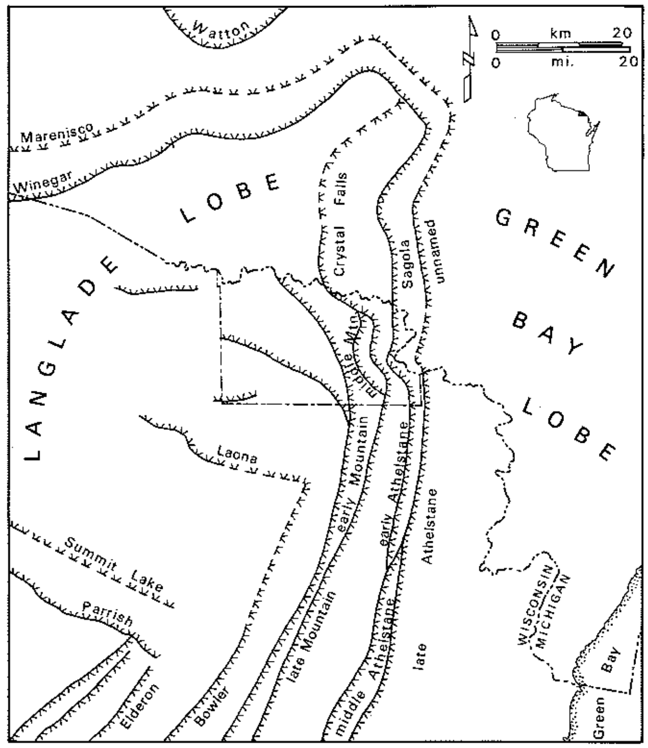


FIGURE 3.--Correlation of ice margins in northeastern Wisconsin and adjacent Michigan. Tick marks are on upglacier side of ice-margin lines. From a variety of sources, including Thwaites (1943), Peterson (1982), Simpkins (1979), McCartney (1979), and Mickelson (Langlade County; in preparation).

contemporaneous with the Bowler Advance of the Green Bay Lobe (fig. 3).

The margin of the ice sheet again melted back to the northeast and either halted at or readvanced to the southwestern edge of Florence County (fig. 3). Evidence for this unnamed minor event (fig. 2) includes a series of east-west ridges interpreted to be end moraines (shown by line symbols in map unit **gn** along the south edge of T. 38 N., R. 15 E., plate 1) and flat sand areas interpreted to be outwash plains formed in front of the ice (map unit **sun**, plate 1). These materials are all included in the Nashville Member of the Copper Falls Formation, described later in this report.

Early Mountain Advances

Following a period of general backwasting, the Green Bay Lobe advanced to the early Mountain moraine west of the community of Mountain in Oconto County. Thwaites (1943) traced the early Mountain moraine northward about 9 km into Florence County, along the easternmost of the two ice margins shown in figure 4. The position of this ice margin northward across Florence County is unclear (dashed part of the ice-margin line in fig. 4), but it might coincide with the western edge of member W of the Copper Falls Formation (map unit **gw** on plate 1), discussed in a later section of this report.

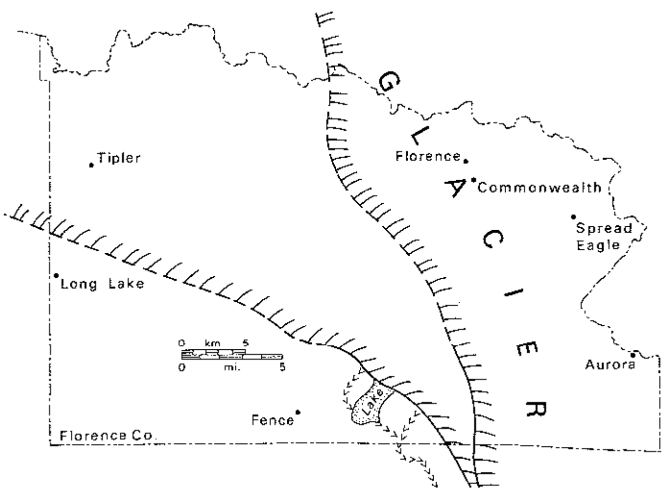


FIGURE 4.--Early Mountain Advances, showing both the eastern and western ice margins, which converge 4 km south of Florence County. Part of the Nashville Member and member W of the Copper Falls Formation were deposited at this time. Arrowheads indicate direction of melt-water flow.

About 4 km south of Florence County a slightly earlier ice margin diverged from the one just discussed (the westernmost ice margin shown in fig. 4). This ice margin was not recognized by Thwaites, nor is it marked by an obvious moraine, but it is based on the presence of the Macintire Creek spillway, shown by a line of arrowheads in figure 4. The spillway was graded to the level of the outwash plain in front of the early Mountain moraine in sec. 20, T. 37 N., R. 18 E., 4.5 km south of Florence County. It was therefore contemporaneous with the early Mountain moraine, and for this reason an early Mountain ice margin is thought to have curved northwestward, at least to an elevation of 427 m in sec. 24, T. 38 N., R. 17 E., damming the water in Lamon Tangue valley, to the level of the Macintire spillway. The position of this ice margin in western Florence County is unclear (dashed part of the ice-margin line in figure 4), but it might have coincided with the moraines shown southeast of Fay Lake on plate 1. Alternatively, these "moraines" may be eskers.

The early Mountain advances occurred during the last part of the Wisconsin Glaciation, but they have never been precisely dated. Thwaites (1943, p. 131) tentatively correlated the early Mountain moraines southward to the Waupun and Rush Lake moraines of southeastern Wisconsin, which Alden (1918) tentatively correlated with the Lake Border moraines of Illinois, which Johnson (1976) suggested were formed about 13 000 yr ago.

The till of these early Mountain Advances is included in member W and the Nashville Member of the Copper Falls Formation (discussed later in this report). The early Mountain till is lithologically distinct from that of earlier advances south of Florence County (McCartney, 1979; Simpkins, 1979), but they become similar northward and are practically indistinguishable in southern Florence County.

Middle Mountain Advance

After the early Mountain advances, the glacier wasted back, probably at least to the northeastern border of Florence County (fig. 2), and then readvanced to the position shown in figures 3 and 5. Evidence for this advance consists of the till of the Florence Member of the Kewaunee Formation, described later in this report (map unit **gf**, plate 1). This till is thought to be the result of a separate glacial readvance because it is much more clayey than most of the rest of the till in the region, it overlies sand in most areas, and its western and southwestern boundary is abrupt. The clay in the till was probably derived from lake clay, perhaps deposited in the Menominee valley at the east edge of the county between the early and middle Mountain Advances.

A relatively long period of time is thought to have separated the early and middle Mountain Advances because there seems to be an abrupt change in loess thickness near the middle Mountain ice margin. The older till and fluvial sand in the western part of Florence County is typically covered with 0.5 to 1.0 m of loess, whereas the middle Mountain and younger materials generally are covered with less than about 0.3 m of loess. This period could not have been of very great length, however, because most middle Mountain and younger outwash west of the middle Mountain ice margin has been collapsed, indicating a period too short for all the buried stagnant ice of the early Mountain Advance to melt.

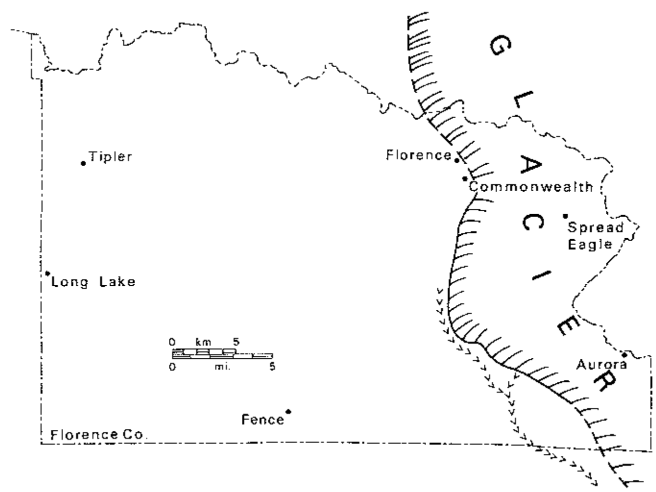


FIGURE 5.-- Middle Mountain Advance. The Florence Member and member E of the Kewaunee Formation were deposited at this time. Arrowheads indicate direction of melt-water flow.

The middle Mountain till is exposed in numerous roadcuts and is described in several water-well logs in east-central Florence County. In the southeastern part of the county it is covered by younger deposits; it has been recognized in the subsurface as far southeast as the late Mountain moraine but is unknown beyond that. In northeastern Florence County the middle Mountain Advance was probably responsible for the till of member E of the Kewaunee Formation (described later in this report), which is sandier than the till of the Florence Member, but otherwise lithologically similar. The till of unit W has the same color and has nearly the same grain-size distribution as the till of unit E, but it is thought to be the result of an earlier glacial advance because it is mineralogically different from both the Florence Member and member E, it extends well to the west of the western boundary of the Florence Member, and it apparently grades laterally into the Nashville Member. However, neither member E nor the Florence Member have been seen stratigraphically above member W. No occurrences of middle Mountain till are known north of Florence County.

Late Mountain Advance

Following a short period of backwasting, the Green Bay Lobe readvanced to the late Mountain moraine, near the community of Mountain, in Oconto County (fig. 2). Thwaites (1943) traced the late Mountain moraine northward to near Dunbar and then correlated it northeastward across a 6-km gap to the moraine in southeastern Florence County that is here considered to be the early Athelstane moraine. Judging by the modern topographic maps, it is more likely that the late Mountain moraine correlates northward from near Dunbar as a nearly continuous ridge to the southern border of Florence County, 6 km west of the early Athelstane moraine, as shown in figures 3 and 6. From the southern border it can

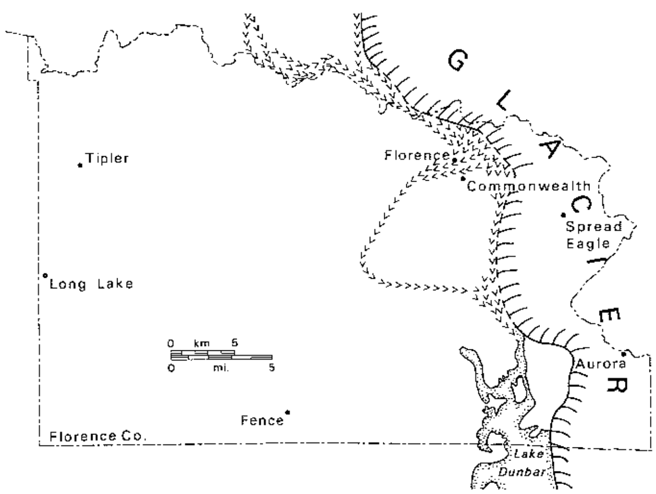


FIGURE 6.-- Late Mountain Advance. Part of the Silver Cliff Member of the Kewaunee Formation was deposited at this time. Arrowheads indicate direction of melt-water flow.

be traced northward for several kilometres as a discontinuous ridge to near the Little Popple River, in sec. 1, T. 38 N., R. 18 E. (plate 1). After a several-kilometre gap, where it is absent or covered with fluvial sediment in Pine valley, it is tentatively correlated northwestward to the Crystal Falls moraine in Michigan (Peterson, 1982). Alternatively, the late Mountain moraine might correlate with the Sagola moraine (fig. 3) in Michigan (Peterson, 1982).

The till of the late Mountain Advance has been included in the Silver Cliff Member of the Kewaunee Formation (described in a later part of this report; map unit **gm**, plate 1) by McCartney (1979). It is distinctly sandier than the middle Mountain till in central and northeastern Florence County, and it is sandier than the early Mountain till in the north-central part of the county (member W), but it is similar to the early Mountain till in the southeastern part of the county (Nashville Member).

During the late Mountain Advance, ice-marginal drainage was blocked by the east end of McCaslin Mountain, producing Lake Dunbar, which extended from 32 km south of Florence County northward to sec. 1, T. 38 N., R. 18 E. (plate 1, fig. 6). The lake shore is marked by a low bluff at an elevation of about 373 m (just above the 1220-ft contour). The lake sediment (map unit **oum**, plate 1) consists of near-shore and off-shore sand, silt, and clay, which in places are overlain by wind-blown sand, especially south of Florence County. Thwaites (1943, fig. 17) showed Lake Dunbar extending northeastward into Pine valley, but there appears to be no evidence for it northeast of the late Mountain moraine.

A slightly earlier ice margin than the one indicated in figure 6 is marked by the end moraine 1 km west of Tyran (northwest of Florence; plate 1). This moraine is here considered to have formed during an early phase of the late Mountain Advance. Alternatively, this may be a middle Mountain moraine, but the till more closely resembles that of the Silver Cliff Member than of member E.

Early Athelstane Advance

After a brief retreat, the ice margin readvanced to the early Athelstane moraine west of the community of Athelstane in Marinette County, probably about 12 300 yr ago. Thwaites (1943) traced the moraine northward only to within 9 km of Florence County, but, judging from modern topographic maps, it can be traced fairly continuously northward to a moraine in the southeast corner of Florence County (fig. 3 and 7). From there it can be traced nearly continuously northwest to Aurora

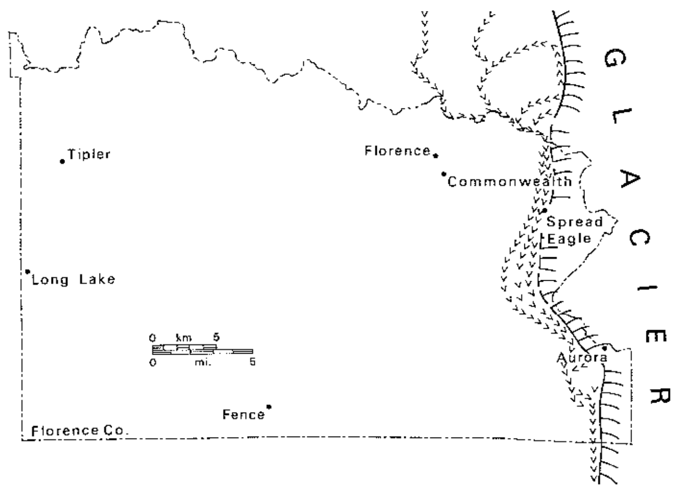


FIGURE 7.--Early Athelstane Advance. Part of the Silver Cliff Member of the Kewaunee Formation was deposited at this time, about 12 300 yr ago. Arrowheads indicate direction of melt-water flow.

and discontinuously to the Sagola moraine of Michigan (Peterson, 1982).

The till of the early Athelstane Advance is included in the Silver Cliff Member of the Kewaunee Formation (map unit **ga**, plate 1). In Florence County, the till of the late Mountain Advance, which is also included in the Silver Cliff Member, and the till of the early Athelstane Advance are practically indistinguishable.

Two Creeks Interval

During the Two Creeks Interval, the Green Bay and Lake Michigan Lobes wasted northward, and during the subsequent readvance the ice buried trees that had grown during that interval. Several dozen of these trees have been radiocarbon dated, mostly in east-central Wisconsin, indicating that the Two Creeks Interval lasted from about 12 200 to 11 500 yr ago. This was a period of intense soil leaching, and, according to Mickelson and Evenson (1975), McCartney (1979), and McCartney and Mickelson (1982), calcareous sandy-loam till deposited in northeastern Wisconsin just before the Two Creeks Interval is typically leached of carbonates to a depth of about 1 to 1.5 m, whereas calcareous sandy-loam till deposited after the interval is typically leached to a depth of less than about 0.15 m. That is, about 1 m of leaching occurred during roughly 700 yr of Two Creeks time, whereas less than 0.15 m occurred in the 11 500 yr since then.

McCartney measured the depth of leaching on till that is much more calcareous than the till of Florence County, so a direct comparison is not possible, but all the till of Florence County seems too deeply leached to have been deposited after Two Creeks time. The sandy-loam till in the western part of the county is typically leached to a depth of about 3 to 5 m. Few exposures of sandy-loam till were seen in the eastern part of the county, but none are leached less than 1 m; 2 to 5 m seems most typical.

A paleosol, perhaps formed during this period of intense leaching, has been observed under eolian sand and over late Mountain fluvial gravel at two places in Florence County (fig. 8, table 1). The gravel has been leached of carbonates to a depth of about 7 m below the

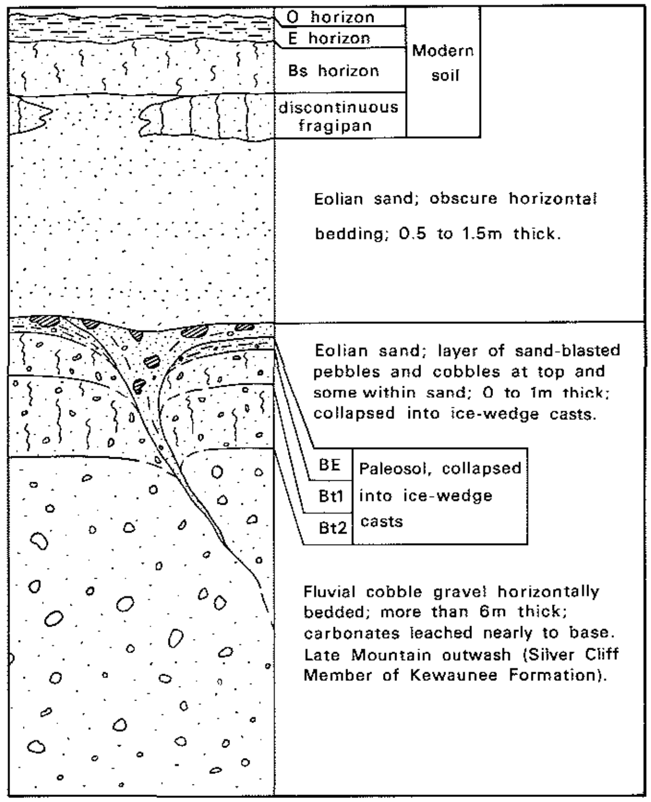


FIGURE 8.--Paleosol formed after the late Mountain Advance and before the last permafrost melted, probably during the Two Creeks Interval (fig. 2); composite of several sections in gravel pits in SE¼NW¼NW¼ sec. 28 and E½NW¼SE¼ sec. 20, T. 40 N., R. 18 E.; see table 1.

present land surface. The unconformity above the paleosol is marked by abundant sand-blasted stones, indicating that the soil-forming period was followed by a period of eolian activity after the late Mountain Advance, perhaps during a cold, dry period associated with the late Athelstane Advance following the Two Creeks Interval. Etched grooves on the stones indicate wind from N. 50° to 55° W. Ice-wedge casts occur below the unconformity at

TABLE 1.--Description of Two Creeks (?) paleosol by Fred W. Madison. Gravel pit at edge of terrace in SE1/4NW1/4NW1/4 sec. 28, T. 40 N., R. 18 E., on the southwest side of the community of Florence.

Horizon	Thickness	Description
BE	7 cm	Yellowish red (5YR 4/6) loamy sand; weak, coarse platy structure; clear, smooth boundary.
Bt1	17 cm	Dark reddish brown (2.5YR 3/4) sandy loam; weak to moderate, medium subangular blocky structure; few, very thin, discontinuous clay skins on vertical ped faces; clear, smooth boundary.
Bt2	12 cm	Dark reddish brown (5YR 3/4) light sandy loam; weak, fine subangular blocky structure; gradual, smooth boundary.

both sites, and some sand-blasted stones occur in the ice-wedge fillings, indicating that permafrost existed after the soil-forming episode and during the first part of the period of sand blasting.

Similar ice-wedge casts and sand-blasted stones have been observed on late Mountain outwash and under fluvial sand in a gravel pit a few kilometres north of Florence County (SW¼ sec. 29, T. 42 N., R. 32 W.; Warren Peterson, 1981, verbal communication). Sand-blast grooves of unknown age on Precambrian rock in the SE¼SE¼SW¼ sec. 28, T. 38 N., R. 19 E., in southern Florence County indicate wind from N. 65° to 70° W. or from S. 65° to 70° E. Cross bedding in dunes of unknown age on the plain of Lake Dunbar, just south of Florence County, indicates wind from the northwest.

Late Athelstane Advance

Following the Two Creeks Interval, the Green Bay Lobe advanced to the late Athelstane moraine east of the community of Athelstane in Marinette County. Thwaites (1943) traced the moraine northward to the Michigan border, 2 km east of Florence County. Judging from topographic maps, it most likely correlates northward to the unnamed moraine east of the Sagola, mapped by Peterson (1982), as shown in figures 3 and 9.

The till of the late Athelstane moraine has been included in the Middle Inlet Member of the Kewaunee Formation and has been correlated with till deposited after the Two Creeks Interval by McCartney (1979).

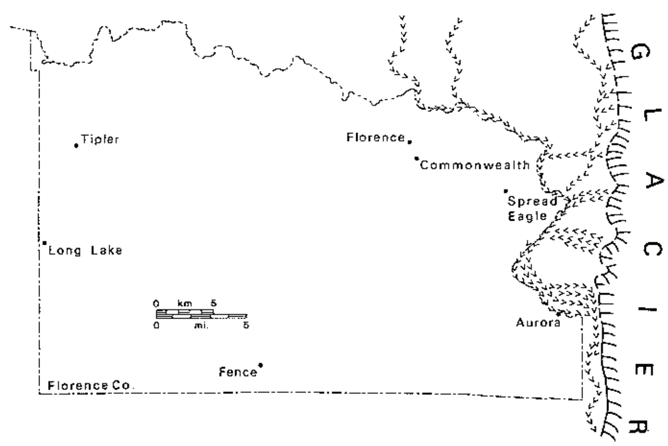


FIGURE 9.--Late Athelstane Advance. Part of the Middle Inlet Member of the Kewaunee Formation was deposited at this time, about 11 400 yr ago. Arrowheads indicate direction of melt-water flow.

Postglacial events

Following glaciation, the landscape was modified, largely by hillslope processes. Much of this modification occurred immediately after the last ice melted because hillslopes were still steep and poorly vegetated. Where permafrost was present, shallow flows of debris occurred frequently. Where permafrost or winter soil ice was present, spring melt water was prevented from infiltrating, causing slopewash erosion. However, through much of Holocene time, the climate and vegetation were similar to those of today, and the more gentle slopes existing at that time were more stable than slopes immediately following deglaciation. Little runoff occurred during summer rains on the permeable soil over most of the county, and deep snow prevented deep soil frost, resulting in little runoff during spring melt. The dominant hillslope process during the Holocene was probably creep resulting from trees blowing over and ripping up soil with their roots.

Following glaciation, the material eroded from the hillslopes filled low areas, causing the flatness of most modern wetlands. During the Holocene most of the flats were modified only by the accumulation of a few metres of peat.

Soil-creep debris continued to accumulate at the base of the steeper slopes, some sediment was deposited in lake bottoms, and sand and silt accumulated on floodplains of modern rivers.

LITHOSTRATIGRAPHIC UNITS

Several Precambrian lithostratigraphic units occur beneath the Pleistocene units in Florence County. These units contain a variety of metamorphic and igneous rock types, which have been described by Dutton (1971) and Bayley, Dutton, and Lamey (1966). Iron ore, which was mined between 1880 and 1960, occurs in the northeastern part of the county, as well as in adjacent parts of Michigan.

Small areas of Cambrian sandstone are probably present in the county (Dutton, 1971, p. 34). Outliers of early Paleozoic sandstone and dolomite occur within a few kilometres of the eastern and northeastern border of the county, and continuous Paleozoic rock occurs 25 km east of the county (Dutton and Linebaugh, 1967).

The Pleistocene lithostratigraphic units of Florence County and adjacent areas are shown in figure 10. The earliest known Pleistocene unit is the Nashville Member of the Copper Falls Formation, but earlier, unknown units probably occur in the subsurface.

Copper Falls Formation

The Copper Falls Formation is the surface lithostratigraphic unit over much of northern Wisconsin (Mickelson and others, 1984). It consists largely of two types of material: sand and reddish-brown, gravelly sandy loam (using U.S. Department of Agriculture grain-size terminology).

The Copper Falls Formation is at least in part the same age as the Horicon Formation of eastern Wisconsin (Mickelson and others, 1984). It is distinguished from the Horicon by the scarcity of dolomite fragments in the Copper Falls Formation. The exact distinction between the Copper Falls Formation and the Horicon Formation, however, has never been specified. In northwest

Wisconsin, the Copper Falls Formation contains few dolomite fragments, typically no more than a hundredth of any sample (Clayton, in press). In Forest County, the Copper Falls Formation is generally slightly calcareous, and about a twentieth of the pebbles in the till consist of sedimentary rock types (largely dolomite), whereas the Horicon Formation is calcareous, and about a quarter of the pebbles are sedimentary rock types (Simpkins, 1979). In Marinette County, about a third of both the sand and clay fraction and the very-coarse-sand fraction of the till in the Horicon Formation (as well as in the Kewaunee Formation) consists of carbonates (McCartney, 1979). Northward, in Florence County, the Copper Falls and Horicon Formations become nearly indistinguishable. The Copper Falls Formation here has more than typical dolomite because the source areas, to the northeast, are closer: dolomite of the Precambrian Saunders and Randville Formations occur in northeastern Florence County and in adjacent Michigan, and outliers of Paleozoic dolomite occur within a few kilometres northeast of the county (Dutton and Linebaugh, 1967). The Horicon Formation here has less than typical dolomite because the source areas, to the east, are farther away than in Marinette County. For this reason, an arbitrary vertical cutoff is required somewhere in the broad zone of gradation between the two formations. That cutoff is here placed at the boundary between Florence and Marinette Counties (fig. 10 and 11).

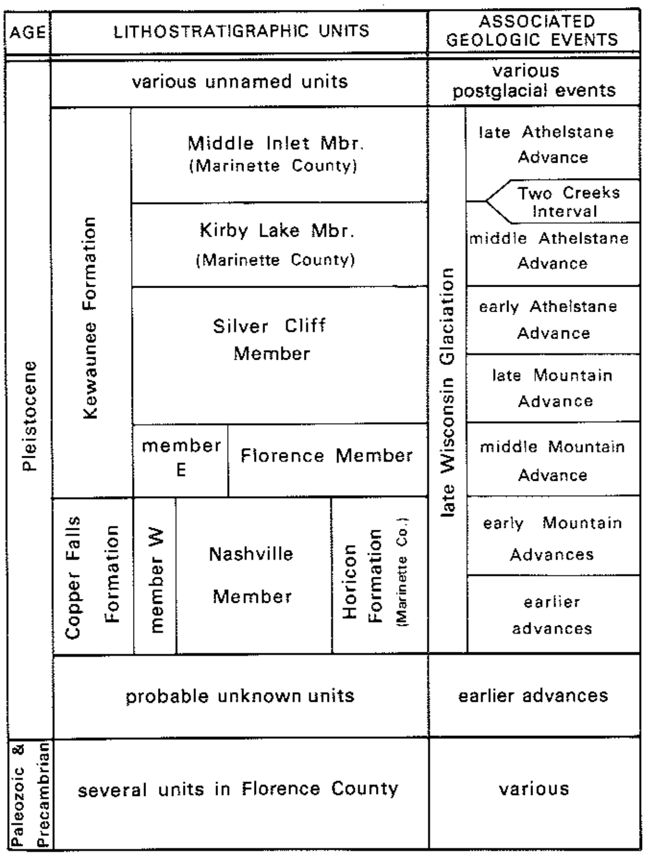


FIGURE 10.--Late Pleistocene lithostratigraphic units in Florence County and adjacent areas and the associated geologic events.

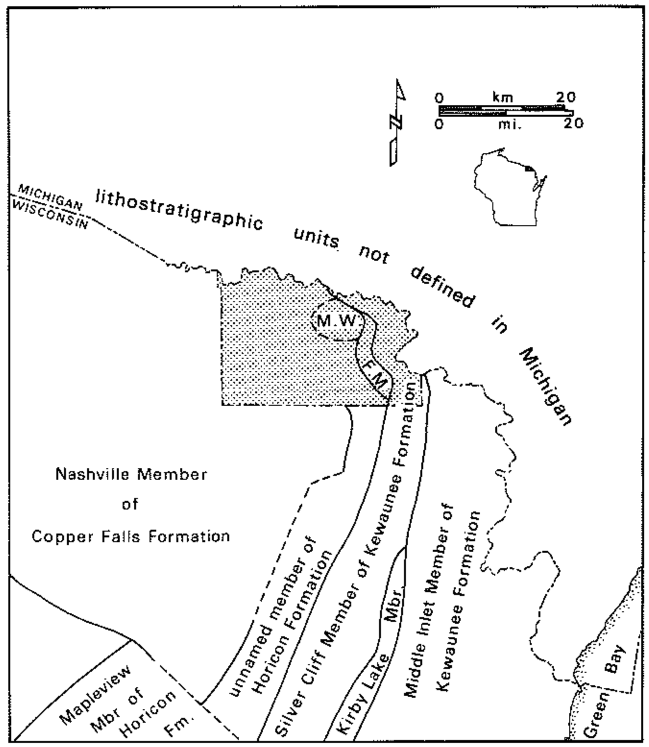


FIGURE 11.-- Distribution of till of late Pleistocene lithostratigraphic units in northeastern Wisconsin. FM = Florence Member of Kewaunee Formation. MW = member W of the Copper Falls Formation. From Mickelson and others (1984) and McCartney (1979). Florence County is dotted area.

In much of northeastern Wisconsin (fig. 11), the surface unit in the Copper Falls Formation is the Nashville Member, but in north-central Florence County the Nashville grades laterally into member W, described below.

Nashville Member

The Nashville Member (plate 1) was named for Nashville Township in Forest County (Simpkins, 1979; Mickelson and others, 1984). In Florence County, the Nashville Member consists of two main sediment types: till and fluvial sediment. The till is generally gravelly sandy loam, with between about 5 and 25 percent gravel; the matrix consists of about 60 to 80 percent sand, 15 to 30 percent silt, and 4 to 13 percent clay in the western and south-central part of the county, and it consists of about 45 to 60 percent sand, 30 to 40 percent silt, and 10 to 16 percent clay in the north-central part of the county where the Nashville is transitional with member W (fig. 12; table 2). It is generally dark brown (7.5YR 3 to 4/3 to 4) but is redder (5YR) where it is transitional with member W.

The Nashville till consists largely of Precambrian rock fragments derived from the northeast. Dark-colored igneous and metamorphic rock fragments are more

TABLE 2.--Till analyses (Quarternary laboratory, geology department, University of Wisconsin, Madison). A = auger hole. P = borrow pit. R = roadcut. Lab colors are Munsell designations for matrix dispersed in water; hues are generally 0 to 2.5 units yellower, values are about 2 units lighter, and chromas are about 2 units brighter than moist field colors. Gravel (larger than 2 mm) values are percentage of total sample, and sand, silt (0.002 to 0.063 mm), and clay values are percentage of matrix (smaller than 2 mm). Values of magnetic susceptibility of matrix are dimensionless. Carbonate percentages in the 0.037-to-0.063-mm fraction were determined with a Chittick apparatus.

Sample number	Location	Exposure	Depth (m)	Lab color	% gravel	% sand	% silt	% clay	% calcite	% dolomite
	Till of Nashville Member									
Fe-351-82	NE¼SE¼NW¼ sec. 5, T.40N., R.15E.	A	3	7.5YR6/6	12	73	13	14	--	--
Fe-341-82	SW¼NE¼NE¼ sec. 5, T.40N., R.15E	A	3	7.5YR5/6	25	75	17	9	--	--
Fe-10:30-25-7-81	SW¼SW¼NW¼ sec. 5, T.40N., R.15E.	P	2.1	7.5YR5/6	16	71	20	9	--	--
Fe-5:01-23-7-81	SE¼SW¼SE¼ sec. 11, T.40N., R.15E.	R	1.7	7.5YR5/3	8	67	22	11	--	--
Fe-5:02-23-7-81	SE¼SW¼SE¼ sec. 11, T.40N., R.15E.	R	3.5	7.5YR4/6	16	73	19	8	--	--
Fe-311-82	NW¼SW¼SW¼ sec. 24, T.40N., R.15E.	A	4	7.5YR5/6	16	72	17	11	--	--
Fe-312-82	NW¼SW¼SW¼ sec. 24, T.40N., R.15E.	A	6	7.5YR5/6	13	70	17	12	0	5
Fe-421-82	SW¼SW¼SE¼ sec. 19, T.38N., R.17E.	A	3	7.5YR5/6	19	70	22	8	--	--
Fe-10:15-15-10-81	NW¼SW¼SE¼ sec. 19, T.38N., R.17E.	R	3	10YR5/6	16	64	29	7	<1	<1
Fe-2:00-28-7-81	SE¼NE¼SW¼ sec. 32, T.38N., R.18E.	P	2	10YR6/4	8	84	13	3	--	--
Fe-10:30-15-8-81	SW¼SE¼SE¼ sec. 16, T.38N., R.18E.	R	1.8	10YR6/4	9	74	22	4	--	--
Fe-5:00-15-8-81	SE¼SE¼NW¼ sec. 24, T.38N., R.18E.	R	3	7.5YR6/4	11	73	22	5	--	--
Fe-391-82	SE¼SW¼NW¼ sec. 32, T.39N., R.17E.	A	2	7.5YR5/6	6	52	35	13	--	--
Fe-392-82	SE¼SW¼NW¼ sec. 32, T.39N., R.17E.	A	5	7.5YR5/6	36	59	29	13	--	--
Fe-10:00-27-7-81	SW¼SE¼SW¼ sec. 36, T.39N., R.16E.	R	2	7.5YR5/6	15	71	19	10	--	--
Fe-12:02-26-7-81	NW¼NW¼SW¼ sec. 18, T.39N., R.17E.	P	1.5	7.5YR5/6	20	68	27	5	--	--
Fe-12:03-26-7-81	NW¼NW¼SW¼ sec. 18, T.39N., R.17E.	P	3	7.5YR5/6	4	56	35	9	--	--
Fe-12:04-26-7-81	NW¼NW¼SW¼ sec. 18, T.39N., R.17E.	P	3	7.5YR5/6	10	65	31	4	--	--
Fe-10:00-26-7-81	SE¼SW¼NE¼ sec. 19, T.39N., R.17E.	R	1.7	7.5YR5/7	11	69	25	6	--	--
Fe-12:00-20-10-81	NW¼NW¼NW¼ sec. 27, T.40N., R.16E.	R	1.5	7.5YR5/6	14	76	17	6	--	--
Fe-12:30-20-10-81	NE¼NE¼SE¼ sec. 25, T.40N., R.16E.	R	1.5	7.5YR6/6	9	75	21	4	--	--
Fe-12:00-19-10-81	NW¼SW¼SW¼ sec. 5, T.40N., R.17E.	R	1.3	7.5YR5/6	9	57	31	12	--	--
Fe-251-82	NW¼SE¼SE¼ sec. 5, T.40N., R.17E.	A	3	7.5YR5/6	6	53	34	13	--	--
Fe-1:00-20-10-81	SW¼SE¼NE¼ sec. 30, T.40N., R.17E.	R	1.5	10YR4/6	11	58	32	9	--	--
Fe-381-82	NE¼NW¼SW¼ sec. 20, T.39N., R.17E.	A	4	10YR5/5	22	54	32	13	--	--
Fe-371-82	NW¼NE¼NE¼ sec. 21, T.39N., R.17E.	A	4	7.5YR5/6	39	60	30	10	--	--
Fe-291-82	SE¼SW¼NE¼ sec. 29, T.40N., R.17E.	A	3	7.5YR5/6	8	47	36	17	--	--
Fe-292-82	SE¼SW¼NE¼ sec. 29, T.40N., R.17E.	A	10	5YR5/6	25	48	35	16	--	--
Fe-293-82	SE¼SW¼NE¼ sec. 29, T.40N., R.17E.	A	13	5YR5/6	25	52	34	14	--	--
Fe-11:00-25-7-81	NW¼SE¼SE¼ sec. 29, T.40N., R.17E.	R	1.7	5YR5/6	7	45	40	15	--	--
Fe-361-82	SW¼SE¼SE¼ sec. 14, T.39N., R.17E.	A	3	7.5YR5/6	13	51	38	10	--	--
Fe-362-82	SW¼SE¼SE¼ sec. 14, T.39N., R.17E.	A	6	5YR5/6	35	57	32	11	--	--
	Till of Member W									
Fe-5:00-19-10-81	SW¼SE¼SW¼ sec. 28, T.40N., R.17E.	R	1	5YR5/8	20	33	47	20	<1	0
Fe-12:00-30-7-81	SW¼SW¼NE¼ sec. 22, T.40N., R.17E.	R	1	5YR5/8	11	30	53	17	--	--
Fe-261-82	SE¼SW¼SW¼ sec. 14, T.40N., R.17E.	A	1	7.5YR5/6	15	42	44	14	--	--
Fe-262-82	SE¼SW¼SW¼ sec. 14, T.40N., R.17E.	A	2	5YR5/6	13	31	47	22	--	--
Fe-263-82	SE¼SW¼SW¼ sec. 14, T.40N., R.17E.	A	16	5YR5/6	9	34	43	24	0	4
Fe-10:00-30-7-81	SW¼NW¼NW¼ sec. 35, T.40N., R.17E.	R	1	5YR5/8	17	33	48	19	--	--

TABLE 2.-Continued.

Sample number	Location	Exposure	Depth (m)	Lab color	% gravel	% sand	% silt	% clay	% calcite	% dolomite
	Till of Member E									
Fe-131-82	SW¼NW¼SW¼ sec. 26, T.40N., R.18E.	A	3	5YR6/6	4	34	46	19	0	10
Fe-1:00-13-8-81	SW¼SE¼SW¼ sec. 24, T.40N., R.18E.	R	1.5	5YR5/6	7	31	45	23	0	0
Fe-101-82	SE¼SE¼SW¼ sec. 23, T.40N., R.18E.	A	6	5YR6/6	18	42	38	20	--	--
Fe-102-82	SE¼SE¼SW¼ sec. 23, T.40N., R.18E.	A	8	5YR6/6	9	36	43	21	--	--
	Till of Florence Member									
Fe-61-82	SW¼SW¼SW¼ sec. 2, T.38N., R.18E.	A	2	5YR5/6	3	17	49	34	0	10
Fe-62-82	SW¼SW¼SW¼ sec. 2, T.38N., R.18E.	A	4	5YR6/6	1	19	43	39	--	--
Fe-63-82	SW¼SW¼SW¼ sec. 2, T.38N., R.18E.	A	5	5YR6/6	<1	17	45	38	0	13
Fe-64-82	SW¼SW¼SW¼ sec. 2, T.38N., R.18E.	A	6	5YR5/6	1	16	50	35	--	--
Fe-65-82	SW¼SW¼SW¼ sec. 2, T.38N., R.18E.	A	8	5YR6/6	<1	16	47	38	0	13
Fe-66-82	SW¼SW¼SW¼ sec. 2, T.38N., R.18E.	A	9	5YR6/6	<1	11	41	48	--	--
Fe-67-82	SW¼SW¼SW¼ sec. 2, T.38N., R.18E.	A	10	5YR6/6	<1	17	39	44	0	7
Fe-1:00-17-10-81	SW¼SE¼NW¼ sec. 2, T.38N., R.18E.	R	1.2	5YR6/6	1	14	59	27	<1	7
Fe-72-82	SE¼NW¼SE¼ sec. 1, T.38N., R.18E.	A	7	5YR5/6	3	21	32	47	--	--
Fe-12:00-14-8-81	NW¼NE¼NW¼ sec. 15, T.39N., R.18E.	R	1	5YR6/6	1	14	51	14	0	<1
	Till of Silver Cliff Member									
Fe-4:00-16-8-81	SE¼SW¼SW¼ sec. 27, T.38N., R.19E.	R	1	10YR4/6	3	56	42	3	--	--
Fe-4:00-16-10-81	NE¼SW¼SW¼ sec. 9, T.38N., R.19E.	R	1.5	7.5YR6/6	3	65	31	4	--	--
Fe-10:00-19-8-81	NE¼SW¼NW¼ sec. 9, T.38N., R.19E.	P	1	5YR5/6	2	49	36	15	--	--
Fe-11:00-19-8-81	NE¼NW¼NE¼ sec. 14, T.38N., R.19E.	P	1.5	7.5YR6/6	4	77	19	4	0	0
Fe-5:00-16-8-81	SW¼SE¼SE¼ sec. 23, T.38N., R.19E.	R	1.6	7.5YR6/6	4	80	17	3	--	--
Fe-9:00-19-8-81	SW¼SW¼NW¼ sec. 11, T.38N., R.19E.	R	2	7.5YR5/6	1	68	29	3	--	--
Fe-461-82	NE¼NE¼SE¼ sec. 10, T.38N., R.19E.	A	2	5YR6/6	3	71	23	7	--	--
Fe-462-82	NE¼NE¼SE¼ sec. 10, T.38N., R.19E.	A	3	10YR5/4	42	80	14	6	0	29
Fe-431-82	SE¼NW¼SW¼ sec. 4, T.39N., R.19E.	A	5	7.5YR6/2	16	77	19	4	0	12
Fe-9:00-14-8-81	NW¼NE¼SW¼ sec. 4, T.39N., R.19E.	R	2	7.5YR5/6	14	77	18	5	--	--
Fe-181-82	NW¼NE¼NW¼ sec. 16, T.40N., R.18E.	A	4	5YR5/8	6	45	36	19	0	3
Fe-231-82	SE¼NE¼NW¼ sec. 14, T.40N., R.17E.	A	3	10YR5/6	3	51	44	6	--	--
Fe-191-82	NE¼NE¼SW¼ sec. 9, T.40N., R.18E.	A	4	7.5YR5/6	11	46	48	7	0	0
Fe-192-82	NE¼NE¼SW¼ sec. 9, T.40N., R.18E.	A	8	7.5YR6/6	22	72	22	6	0	3
Fe-171-82	NE¼NE¼SW¼ sec. 15, T.40N., R.18E.	A	5	7.5YR5/6	8	71	26	4	0	0
Fe-111-82	NW¼SW¼SW¼ sec. 24, T.40N., R.18E.	A	4	5YR6/6	16	65	27	9	--	--

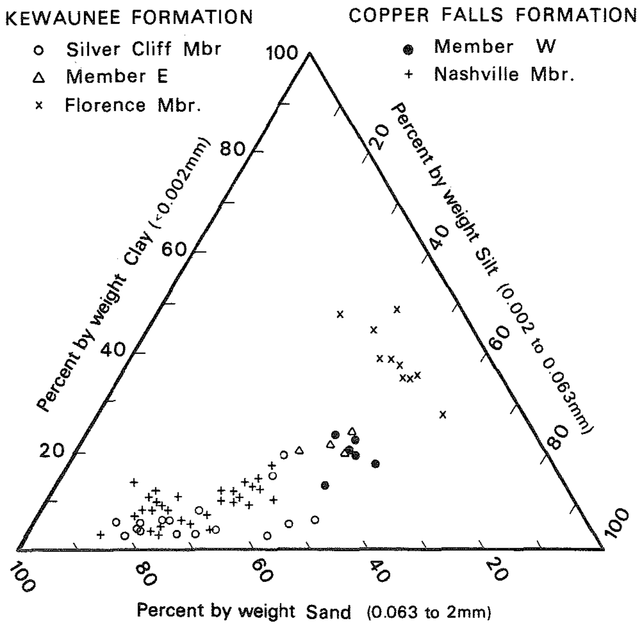


FIGURE 12.-- Ratio of sand, silt, and clay in till of lithostratigraphic units in Florence County.

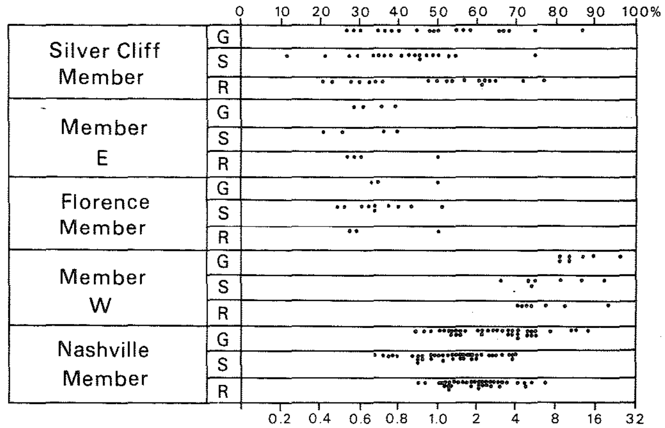
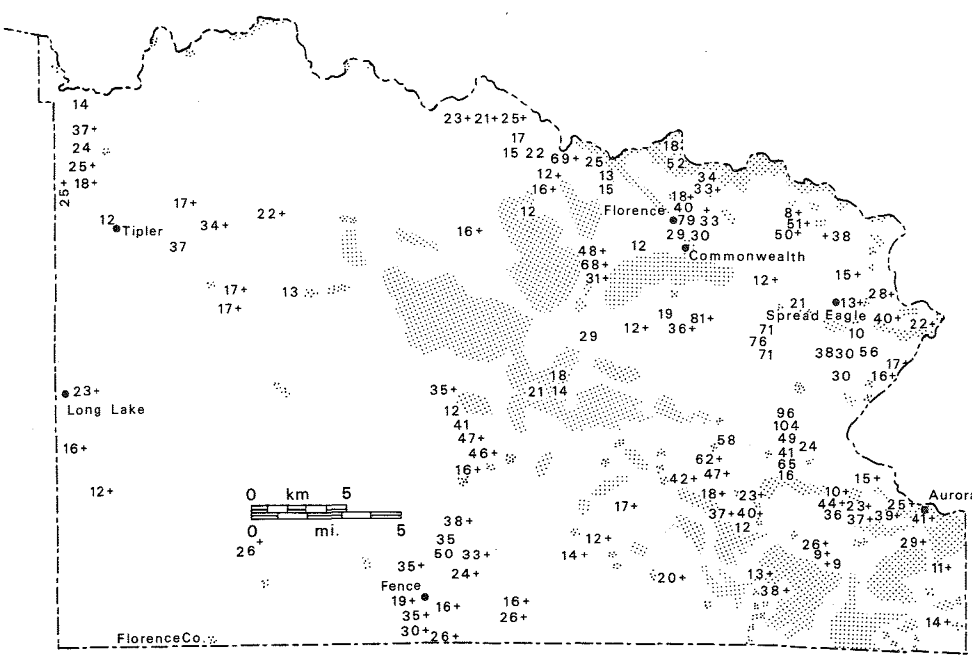


FIGURE 13.-- Percentages of dark igneous and metamorphic rock in gravel (larger than 2 mm) fraction (G; upper scale), percentages of dark igneous and metamorphic rock in very-coarse-sand (1 to 2 mm) fraction (S; upper scale), and ratios of dark-to-light igneous and metamorphic rock in gravel fraction (R; lower scale) in till in lithostratigraphic units in Florence County.

abundant to the northeast where it is transitional with member W (fig. 13). A few percent of the sand fraction consists of well-rounded quartz grains, probably derived from Cambrian units to the northeast. The till is typically leached of carbonates to depths of about 3 to 5 m. Where unleached, the carbonates, consisting largely of Precambrian and Paleozoic dolomite, constitute about 5 to 10 percent of the silt, very-coarse-sand, and gravel fractions; rarely the large-pebble fraction (16 to 64 mm) consists of more than 20 percent dolomite.

About half the fluvial sediment in the Nashville consists of pebbly and slightly pebbly sand, and much of the rest is sandy gravel. Coarse gravel occurs in some places, especially in eskers. Petrographically, the fluvial sediment is similar to the sand and gravel fraction of the till, but it is commonly leached of carbonates to greater depths than the till.

Only a few water wells have penetrated the full sequence of Pleistocene deposits in the western and south-central part of the county (fig. 14). They indicate that the Nashville Member, which probably makes up most



of this sequence, ranges from 0 to perhaps more than 50 m in thickness. The Nashville has not been identified in the eastern part of the county.

Member W

In north-central Florence County, the till of the Nashville Member grades laterally into the till of a unit here called member W. It is slightly more clayey and redder (2.5YR 3 to 4/4) than the adjacent Nashville till (fig. 12), and it contains more dark rock fragments (fig. 13), but there seems to be no sharp distinction between the two units. The contact between the units could have been drawn anywhere within a transition zone that is several kilometres wide; it was arbitrarily placed (plate 1) where sand constitutes about 40 percent of the till.

Member W (west of the community of Florence) is similar to member E (east of Florence) of the Kewaunee Formation. Both consist of reddish brown to dark reddish brown gravelly loam (fig. 12). However, they have distinctive petrographies. Member W contains many more dark rock fragments (fig. 13). Like the Nashville Member, it generally contains fewer than 10 percent dolomite fragments.

Member W is more than 16 m thick at an auger site in the NE¼NW¼NW¼ sec. 20, T. 17 E., R. 40 W., but in most places it is much thinner, and outcrops of Precambrian rock are abundant.

Kewaunee Formation

The Kewaunee Formation is the surface unit over much of northeastern Wisconsin (Mickelson and others, 1984). It is younger than the Horicon and Copper Falls Formations (fig. 10). Kewaunee till generally differs from Horicon and Copper Falls till in being finer grained and redder. However, the Copper Falls and Kewaunee Formations become more similar northward, and in Florence County they are nearly indistinguishable. Although the Florence Member of the Kewaunee Formation is finer and redder than the Nashville Member of the Copper Falls Formation, member W of the Copper Falls Formation is finer and redder than the Silver Cliff Member of the Kewaunee Formation.

South of Florence County, the Kewaunee and Copper Falls Formations can generally be distinguished by dolomite content. However, the dolomite content of the Kewaunee decreases northwestward away from source areas, and the dolomite content of the Copper Falls increases northeastward toward source areas; as a result, this distinction is less obvious in Florence County than to the south. In Florence County, the Copper Falls Formation generally has less than about a tenth dolomite in the silt, very-coarse-sand, and gravel fractions, whereas the Kewaunee Formation, where unleached, commonly has more than that amount.

In Florence County, the Kewaunee Formation consists of the Florence Member, member W, and the Silver Cliff Member.

Florence Member (new)

A reddish clayey unit in eastern Florence County is here named the Florence Member. It consists of slightly gravelly clay, silty clay, and silty clay loam (fig. 12). Gravel content is typically about 1 percent, and surface boulders are less common than on other till units in the area. Everywhere it was observed, the unit is unbedded. It is generally reddish brown (2.5YR 4/4). It is typically leached of carbonates to a depth of about 1 m, and, where unleached, it contains 7 to 13 percent carbonates (largely dolomite) in the silt fraction, 7 to 17 percent dolomite in the very-coarse-sand fraction, and about 10 percent dolomite in the gravel fraction.

In most areas (plate 1), the Florence Member is between 8 and 12 m thick and overlies sand (fig. 15). Its western and southwestern extent is fairly sharply defined. Just east of its southeastern-most mapped location (plate 1), it appears in several water-well logs, beneath Silver Cliff (late Mountain) outwash. It has been observed under 3 m of Silver Cliff till of the late Mountain moraine in an auger hole in the SE¼NW¼SE¼ sec. 1, T. 38 N., R. 18 E., and it has been seen in roadcuts behind the late Mountain moraine in the SE¼SE¼ sec. 5 and SW¼SW¼ sec. 4, T. 38 N., R. 19 E.

FIGURE 14.--Areas where Precambrian rock is at or near the surface (dotted pattern); isolated patches of Pleistocene sediment more than 15 m thick are present in these areas. Pleistocene sediment is generally 5 to 100 m thick in unpatterned areas. The numbers indicate thickness of Pleistocene sediment in metres; these values are mostly from water-well-drillers' logs (a plus sign indicates that the thickness is greater than value given).

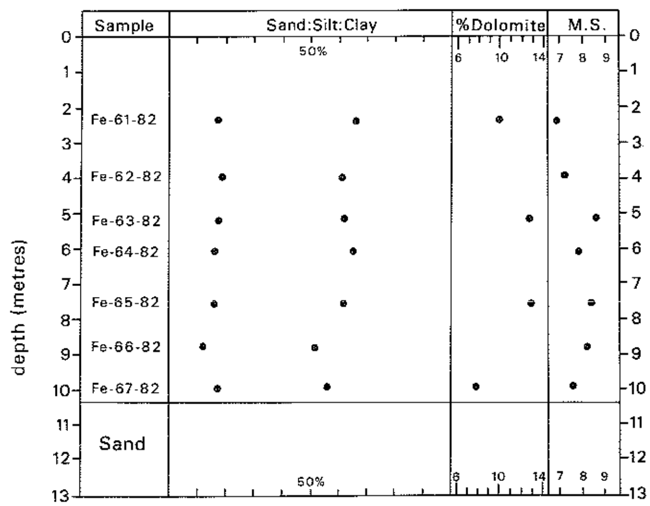


FIGURE 15.--Type section of the Florence Member (an auger hole at the southwest corner of sec. 2, T. 38 N., R. 18 E.), showing grain-size distribution, percentage of dolomite in silt fraction, and magnetic susceptibility (m.s.).

Because of its grain-size distribution, the lack of bedding, and the presence of surface boulders, it is interpreted to be till, and it is the basis for recognition of the middle Mountain glacial advance, discussed earlier (fig. 2 and 5). The topography of the till is gently undulating, and vague northeast-southwest lineations, which may be small drumlins, can be seen on air photos. Middle Mountain outwash presumably occurs southwest of the till, but it has not been recognized, and no sand and gravel is here included in the Florence Member.

The Florence Member is easily distinguished from most other units in the area by its grain size (fig. 12). It most closely resembles member E, with which it is apparently laterally gradational, and member W, but the Florence Member is noticeably finer grained. It differs from the lake sediment included in the younger Silver Cliff Member (map unit **oum**, plate 1) by the absence of bedding and the presence of surface boulders.

Correlation outside Florence County is uncertain. The Florence Member resembles the Kirby Lake Member of east-central Wisconsin, but it is above rather than below the Silver Cliff Member (Mickelson and others, 1984). No member has been previously defined below the Silver Cliff Member in the Kewaunee Formation, but the Silver Cliff has been tentatively correlated with two units, the Ozaukee and Haven Members of southeastern Wisconsin (Mickelson and others, 1984); the Florence might correlate with the lower of the two--the Ozaukee. A unit, apparently part of the Kewaunee Formation, occurs below the Silver Cliff Member in the Kirby Lake type section in Marinette County; it is redder and more clayey than the Silver Cliff and might correlate with the Florence (Mickelson and others, 1984, fig. 60).

Member E

Member E resembles member W, to the west; the till of the two units has the same grain-size distribution (fig. 12) and color. However, member E contains far fewer dark rock fragments (fig. 13). Member W generally contains less than 10 percent dolomite and has therefore been included in the Copper Falls Formation, whereas member E generally contains more than 10 percent dolomite and therefore has been included in the Kewaunee Formation.

Member E is apparently everywhere overlain by the Silver Cliff Member. It has been seen in outcrop at the following sites: (1) Shallow road cut in SW¼SE¼SW¼ sec. 24 T. 40 N., R. 18 E.; overlain by less than 1 m of Silver Cliff Member. (2) Shallow roadcut in SE¼SW¼SE¼ sec. 25, T. 40 N., R. 18 E.; overlain by less than 1 m of Silver Cliff Member. (3) Shallow roadcut in SW¼SW¼SW¼ sec. 24 T. 40 N., R. 18 E.; overlain by about 1.5 m of Silver Cliff Member. (4) Shallow roadcut in NW¼SW¼SW¼ sec. 24, T. 40 N., R. 18 E.; overlain by 1 m of Silver Cliff Member. Alternatively, the material observed at these four sites may be blocks of member E that have been incorporated in the Silver Cliff Member by glacial thrusting, or member E may be the surface unit in this area, as suggested by Hole and others (1962), who mapped the Hibbing and associated soil series in this area. However, unit E probably underlies the Silver Cliff Member in auger holes at the following sites: (1) SE¼SE¼SW¼ sec. 23, T. 40 N., R. 18 E.; 5 m Silver Cliff sand over 6 m unit E over sand. (2) SW¼NW¼SW¼ sec. 26, T. 40 N., R. 18 E.; 1 m Silver Cliff sand over 3 m unit E over sand. (3) NE¼SW¼SE¼ sec. 27, T. 40 N., R. 18 E.; 4 m Silver Cliff sand over 1.5 m unit E over sand.

The actual stratigraphic relationships between members E and W and the Florence Member have nowhere been observed in the field, however. An alternative to the correlation suggested in figure 10 is that member E correlates with member W; they differ in grain petrography because the glacier that deposited the till of both units picked up a large amount of dark rock fragments where it overrode the rock ridge trending southeast-northwest on either side of the community of Florence.

Silver Cliff Member

The Silver Cliff Member is at the surface over the eastern edge of the county (plate 1). It was named for Silver Cliff Township in Marinette County (McCartney, 1979; Mickelson and others, 1984).

In Florence County, the Silver Cliff Member consists of till, fluvial sediment, and lake sediment. The till is generally gravelly sandy loam, with between about 3 and 20 percent gravel; the matrix consists of about 50 to 80 percent sand, 15 to 45 percent silt, and 3 to 15 percent clay (fig. 12). It is generally reddish brown or dark brown (5YR to 7.5YR, 4/3 to 4). The till consists largely of Precambrian rock fragments derived from the east (fig. 13). It is typically leached of carbonates to depths of about 2 to 5 m. Where unleached, the carbonates, consisting largely of Paleozoic dolomite, constitute about a tenth to a fifth of the silt, very-coarse-sand, and gravel fractions. The till of the Silver Cliff Member is less than 1 m thick in much of eastern Florence County (units **ga** and **gm**, plate 1) but is several metres thick in the late Mountain and early Athelstane moraines.

More than half the Silver Cliff Member in Florence County consists of fluvial sediment, much of it outwash. It consists largely of slightly pebbly sand, with smaller amounts of pebbly sand and sandy gravel. Petrographically, it is similar to the sand and gravel fraction of the till, but it has been leached of carbonates to greater depths.

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