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by David M. Mickelson, Lee Clayton, Robert W. Baker,
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PLEISTOCENE STRATIGRAPHIC UNITS OF WISCONSIN

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ABSTRACT

The Pleistocene deposits of Wisconsin consist of a complex sequence of deposits differing in origin, age, lithology, thickness, and aerial extent. This report presents a lithostratigraphic classification for many of these deposits and also provides guidelines for the formal definition and naming of lithostratigraphic units in Wisconsin. The classification scheme follows that of the American Code of Stratigraphic Nomenclature. Each unit definition should include a discussion of the following: source of name, type-section location and description, reference-section location and description, description of unit, nature of contacts, differentiation from other units, regional extent and thickness, origin, age, correlation, and identification of the person naming the unit.

The framework for the classification of Pleistocene units is based on till stratigraphy. However, most members and formations named in this paper include not only till, but associated fluvial and lacustrine deposits.

Many of the Pleistocene deposits in Wisconsin are classified in this paper. We here name and define 11 formations that include 28 members. Some till deposits and most fluvial, lacustrine, and alluvial deposits remain to be defined. This paper is viewed as a first step in the lithostratigraphic classification of Quaternary units in the state.

INTRODUCTION

During the past several years, a number of Pleistocene lithostratigraphic units have been informally named in published reports and in theses. This paper is the result of several years of thought and discussion by the authors and others inside and outside Wisconsin on the development of a formal lithostratigraphic classification for Quaternary units in the state. In addition to formally defining a number of units and discussing some not formally defined, we establish a framework for future lithostratigraphic classification. We hope that it will be a dynamic system and that it will change as needs arise, but we recognize the need for some fundamental decisions to be made at this time.

Although other workers in the state cannot be forced to follow the framework set up here or to formally define their units, a certain amount of uniformity of usage will result in less confusion. The standards set in this publication are those that will be followed in future publications of the Wisconsin Geological and Natural History Survey.

Although chronostratigraphic units, biostratigraphic units, and stratigraphic units based on interpreted geologic events are needed by Pleistocene geologists, we here concentrate on lithostratigraphic units because they form the foundation of any stratigraphic system. We hope that formal recognition of these other units will come later.

In addition to time-stratigraphic considerations, which are given only a mention in this paper, we have not done justice to the properties of all units. One purpose for developing a lithostratigraphic classification of Pleistocene deposits is to impose order on very complex deposits so that properties of deposits in various places can be understood. More quantitative summary of unit properties will be published in future years.

PRINCIPLES OF LITHOSTRATIGRAPHIC CLASSIFICATION IN WISCONSIN

The definitions in this report are generally in accordance with the requirements given in the Code of Stratigraphic Nomenclature (American Commission on Stratigraphic Nomenclature, 1970). In particular, we have accepted the formation as the basic mapping unit. Formations have been defined so as to be recognizable in the field. Although not all formations in the state are defined in this report, it is our intention that all materials of Quaternary age, with the possible exception of man-made deposits, eventually will be included in some formation.

Formations are subdivided into members where clear-cut stratigraphic subdivisions are present within a formation. Members are formally defined with type sections but need not be recognizable everywhere in the field. One of our ultimate goals is to interpret glacial history. Where it is clear, for example, that a certain till unit represents an ice advance of some significance, the unit should be distinguished from members above and below even though they may be indistinguishable in many outcrops in the field.

All units defined should be traceable laterally even though gradational changes occur away from the type section. In some units, in fact, the basis for recognition at the type section may not be usable in other areas. This is acceptable as long as the integrity of the unit remains. If at some point, however, it becomes indistinguishable from the unit above or below, an arbitrary vertical cutoff should be used.

In addition to the preceeding points, our definitions are based on the following considerations:

(1) Initially, at least, caution is needed in using names from adjacent regions. Admittedly, an overabundance of names may cause confusion because they are hard to remember, but the confusion resulting from incorrect correlations is probably much greater. Therefore, Illinois (Lineback, 1979) and Minnesota lithostratigraphic names are used only if they seem well established, if their relationship to units in Wisconsin seems clear, and if the units have only a limited distribution in Wisconsin. Later, when the stratigraphy becomes more firmly established, some of these new names may be abandoned in favor of previously defined equivalents.

(2) In the glaciated area the framework is built around sequences of till units (fig. 1; table 1). These units are frequently the most distinctive, most laterally extensive, and least variable. In addition, most stratigraphic studies of Pleistocene deposits undertaken in the past have been based

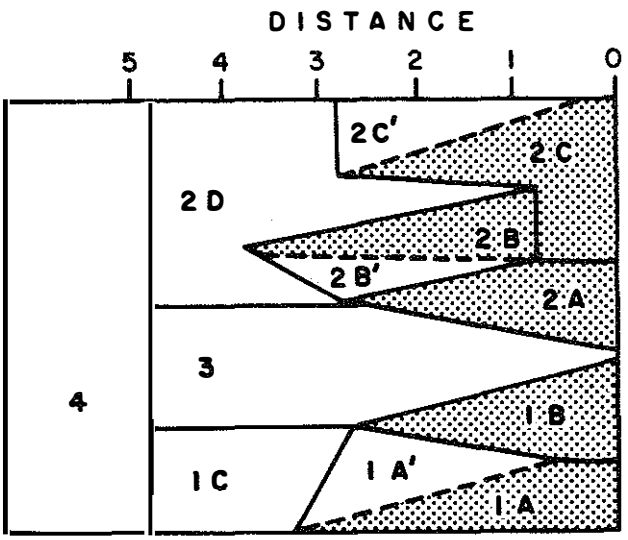


FIGURE 1.--Hypothetical depth-distance stratigraphic diagram to illustrate the subdivision of units into formations and members. Distances are arbitrary. Units with pattern are till. Others are fluvial, eolian, or lacustrine deposits. For purposes of discussion they are assumed to be gravel. See text for discussion.

on till units. In southwest Wisconsin, where most Wisconsinan and Holocene deposits are in valley bottoms physically separated by uplands, till is absent and the stratigraphic framework will be based on regionally extensive fluvial and lacustrine units.

(3) To reduce map complexity, formations should not intertongue at the field-mapping scale. However, lithologies do intertongue with each other, and an arbitrary decision is needed on the placement of lateral boundaries between formations. Tongues of different grain size might be lumped into one or the other formation on the basis of similarity in some characteristic other than grain size (color, for example), or they can be lumped on the basis of a vertical-cutoff rule (American Commission on Stratigraphic Nomenclature, 1970, Article 5e), or on some other basis, as the individual situation requires. A vertical cutoff that extends downward from the end of a tongue generally results in a less complex geologic map than one that extends upward, and we suggest that this be standard procedure unless a good reason can be found for doing otherwise.

For example, in figure 1 members 2B and 2C become indistinguishable at distance 1, and a vertical cut-off is drawn downward. This procedure prevents having a contact between identical units on a surface map as would happen if the contact were drawn upward, and it eliminates the implication that they are distinguishable to the right as would be the case if a horizontal contact were drawn.

(4) Because the stratigraphy is based primarily on till units, confusion may occur in the classification of other material such as proglacial fluvial sediment and lacustrine sediment. There are a number of different ways in which these materials can be handled, and after much discussion, we have chosen a system for units that are newly defined here that is best illustrated by discussion of figure 1.

Figure 1 shows till units and other units, which could be lacustrine or fluvial sediment. We will assume for the sake of discussion here that they are all gravel. There are four formations shown. Assume that the till of formations 1 and 2 are distinguishable by clearly recognizable field criteria (presence or absence of some rock type, major textural difference, major color difference).

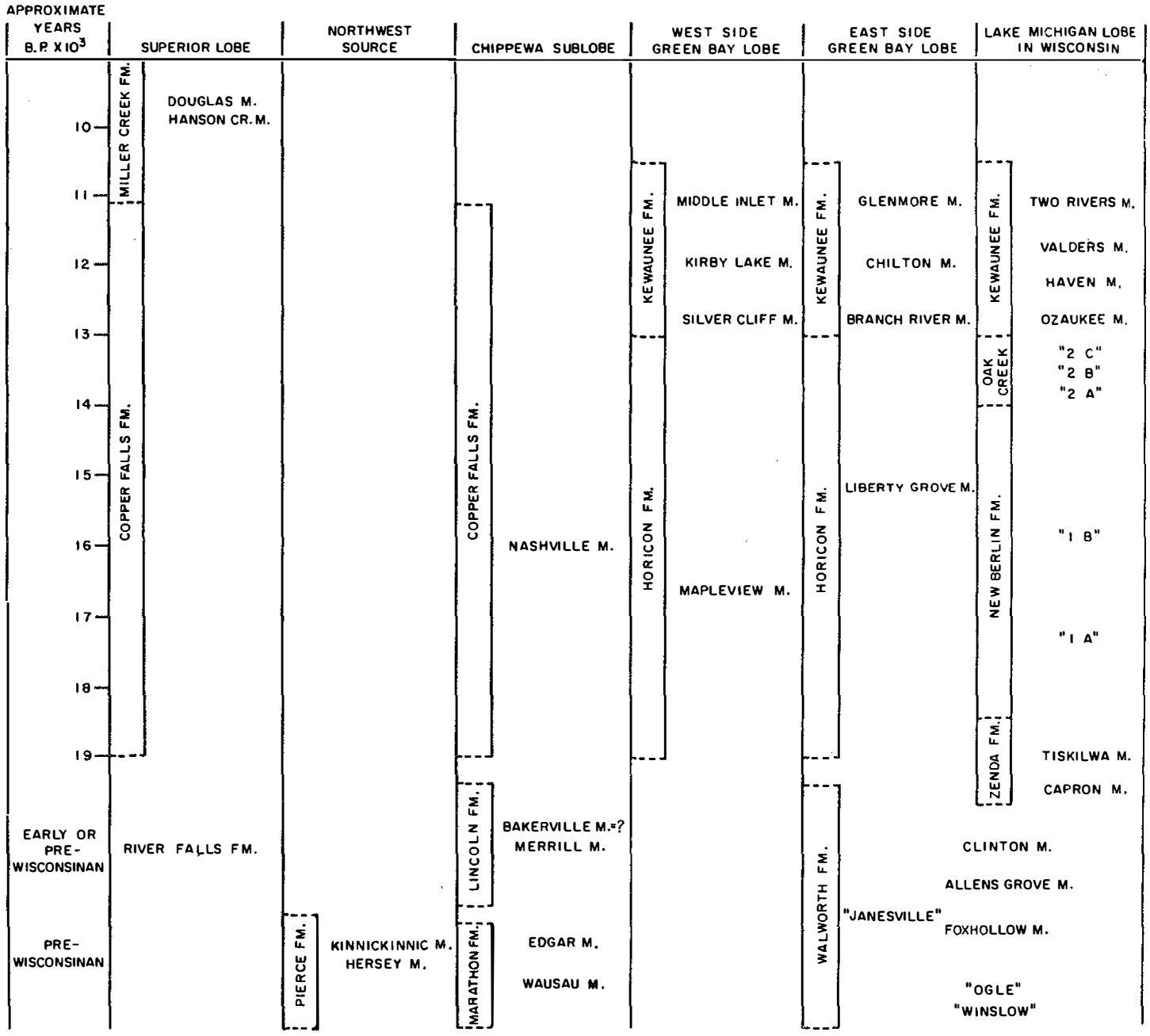
Starting at the base of the section, assume that till units 1A and 1B are distinguishable from each other throughout the area of the cross section. These are defined as separate members of formation 1. The gravel unit 1A' is clearly associated lithologically with the till of 1A. It is part of that member and is considered informally as a facies of the member (as are other associated deposits such as basal till, supraglacial till, etc.). The contact between this gravel and gravel to the left is drawn as far left as the association between the gravel 1A' and till 1A can be documented. If this contact cannot be found, an arbitrary cut-off is drawn as shown.

To the left of 1A' is gravel that is clearly associated with formation 1 but not demonstrably with either member. This is considered a third member of formation 1 (1C).

The system proposed here does not allow the intertonguing of formations but does allow intertonguing of members. In figure 1, if the gravel above member 1B and below member 2A were clearly associated with either formation, the contact would be drawn accordingly. If the interformational gravel can not be related to either formation, it is defined as a new formation (3), which is bounded above and below by formations 2 and 1. Its left boundary is an arbitrary vertical cut-off at the point where units 2D and 1C become indistinguishable from formation 3.

The gravel between till units 2A and 2B is a parallel case to that between 1A and 1B, and the same arguments hold for defining the units. The gravel between units 2B and 2C is not clearly associated with either member but is clearly associated with the formation and is therefore made part of member 2D. The gravel above the till of unit 2C is clearly associated with unit 2C and is placed in that unit. Moving to the left, as soon as the association

TABLE 1.--Organization of Pleistocene lithostratigraphic units of Wisconsin by glacial lobe (west to east) and approximate placement of units in time



with 2C is lost, a contact is drawn and the gravel is considered to be unit 2D. This may or may not coincide with the outer limit of a till sheet.

Formation 4 (actually several formations if different materials are involved) consists of all of the material not clearly associated with a formation based on till lithology. Formations with relationships similar to formation 4 are not defined in this paper but will be defined later as the need arises.

(5) "Till" should not be used in the name of a lithostratigraphic unit, even though it seems to be permitted by article 10e of the Code (American Commission on Stratigraphic Nomenclature, 1970) because lithostratigraphic units are descriptively rather than genetically defined (articles 4a and 4c), and "till" is a genetic, not a descriptive term. That is, "Douglas Clay," rather than "Douglas Till" or "Douglas Till Member," would be the correct name for a lithostratigraphic unit, if the till is composed largely of clay. However, it seems more appropriate to use a lithostratigraphic name rather than a lithologic name for a lithostratigraphic unit--Douglas Member.

SUMMARY OF LITHOSTRATIGRAPHIC UNITS DEFINED IN THIS PAPER

UNITS OF PROBABLE PRE-WISCONSINAN AND EARLY WISCONSINAN AGE

Older till and associated sediment of probable pre-Wisconsinan age (table 1) are present in the central, western, and southern parts of the state. No comprehensive study of all of these units has been undertaken, and units are defined locally. It seems likely that as work continues in these areas, some defined units will be combined and other units named. It seems appropriate at this time, however, to define those units that appear to have a sound basis, with the recognition that major redefinition of many of these units will take place in the future. The distribution of units is shown in figure 2.

Other units, without described type sections in Wisconsin, will be used informally. These units, not described in this report, include the Ogle, Winslow, Argyle, and Janesville tills of Bleuer (1971).

Walworth Formation

The Walworth Formation occurs in south-central Wisconsin (fig. 2). It is distinguished by sandy, generally gray to brown tills and associated deposits (Appendix 1). The Walworth Formation is subdivided into three members, stratigraphically from oldest to youngest, the Foxhollow, Allens Grove, and Clinton Members. Descriptions for these members (adapted from Fricke, 1976) are given in Appendices 1a, 1b, and 1c. The till of the Foxhollow Member is present only in drill holes (Appendix 1a) in southern Rock and southern and western Walworth Counties. It is present in exposures near Rockford, Illinois, (John Kempton, verbal communication, 1981) but has not been formally named by the Illinois State Geological Survey. However, this name will probably be used in Illinois (John Kempton, written communication, 1983).

Stratigraphically above the Foxhollow Member is the Allens Grove Member (Appendix 1b). The till of this member appears to be correlative with the Argyle Till Member of Illinois (Fricke, 1976; Richard Berg, verbal communication, 1981). In eastern Rock and Western Walworth Counties, the till is overlain by the Clinton Member, defined by Fricke (1976) near Clinton in eastern Rock County (Appendix 1c). This till unit appears to extend into Illinois (Fricke, 1976; John Kempton, verbal communication, 1981).

Marathon and Lincoln Formations

Although "drifts" were mapped in central Wisconsin by Weidman (1907), Hole (1943), and others, the units were not defined in any formal sense, and this terminology has dropped from common usage.

In Langlade, Lincoln, Marathon, Clark, Wood, and Jackson Counties two Formations (Marathon and Lincoln), each with two members, are recognized (fig. 2). The oldest member of the Marathon

FIGURE 2.--Map of Wisconsin showing the surface distribution of named lithostratigraphic units. Number and letter designations used here correspond with appendix designations for named lithostratigraphic units. (1) Walworth Formation, 1c: Clinton Member; (2) Marathon Formation, 2a: Wausau Member, 2b: Edgar Member; (3) Lincoln Formation, 3a: Merrill Member, 3b: Bakerville Member; (4) Pierce Formation, 4a: Hersey Member, 4b: Kinnickinnic Member; (5) River Falls Formation; (6) Zenda Formation, 6a: Capron Member, 6b: Tiskilwa Member; (7) New Berlin Formation; (8) Oak Creek Formation; (9) Horicon Formation, 9a: Mapleview Member, 9b: Liberty Grove Member; (10) Kewaunee Formation, 10a: Ozaukee Member, 10b: Haven Members, 10c: Valders Member, 10d: Two Rivers Member, 10e: Branch River Member, 10f: Chilton Member, 10g: Glenmore Member, 10h: Silver Cliff Member, 10i: Kirby Lake Member, 10j: Middle Inlet Member; (11) Copper Falls Formation, 11a: Nashville Member; (12) Miller Creek Formation, 12a: Hanson Creek Member, 12b: Douglas Member.

Formation (Appendix 2) is the Wausau Member (Appendix 2a), the till of which was informally named the Wausau till by LaBerge and Myers (1971) and described in detail by Stewart (1973) and Mode (1976). It is assumed to be pre-Wisconsinan in age. The till of the Edgar Member (Appendix 2b) is the only calcareous till in the area and is more silty than the till of the Wausau Member, but it is more similar to the Wausau till than to younger till units (Mode, 1976). The Marathon Formation is typified by a generally water-eroded landscape with thin till or sand and gravel over pre-Pleistocene rock. No glacial constructional topography has been recognized.

The Lincoln Formation (Appendix 3), which lies above the Marathon Formation, contains two members containing till that is sandier and redder than the till below. The till of the Merrill Member (Appendix 3b), thought to be early Wisconsinan age (Stewart, 1973; Stewart and Mickelson, 1976) has less sand and more silt and clay than till of the Nashville Member of the Copper Falls Formation to the north. In addition, it has less illite and chlorite and more vermiculite and smectite (Stewart and Mickelson, 1976).

The Bakerville Member (Appendix 3a) contains till that is in some places texturally indistinguishable from the till of the Merrill Member, although it is typically more clay rich. It was given a different name by Mode (1976) because of the considerable distance between his study area and the type area of the Merrill Member. The term is retained here because continuity between these units has not been documented. It is not included in the Merrill Member because Weidman (1907) separated the two units and it seems possible that with further work it will prove to be a different lithostratigraphic unit.

Pierce and River Falls Formations

In Pierce and adjoining counties, several pre-Late Wisconsinan till units have been recognized. These have previously been referred to on an informal basis as the Hersey and Baldwin tills (Baker and Simpson, 1981 and Baker and others, 1982).

The Pierce Formation (Appendix 4) contains two members, the Hersey Member (Appendix 4a) and the Kinnickinnic Member (Appendix 4b). The older, the Hersey Member, contains gray calcareous till and associated sand and gravel derived from a northwesterly source. The till of the Hersey Member is the "old gray" till of Chamberlin (1910) and Leverett (1932) and the basal till of Black (1959; 1965). This is locally overlain by the Kinnickinnic Member, a thinly laminated sequence of silts and clays deposited in ice-marginal lakes. Based on soil development and paleomagnetic data, the Pierce Formation appears to be pre-Illinoian age.

In northern Pierce and St. Croix Counties (fig. 2) the Pierce Formation is overlain by the River Falls Formation (Appendix 5). This formation consists of fluvial sand and gravel and reddish-brown sandy till typical of that derived from the Lake Superior basin. The till of the River Falls Formation is the "old red" till of Chamberlin (1910) and Leverett (1932), the superglacial drift of Black (1959; 1965) and the Baldwin till of Baker and Simpson (1981) and Baker and others (1982). The age of the River Falls Formation appears to be either Early Wisconsinan or Illinoian (Baker and others, in press).

UNITS OF LATE WISCONSINAN AGE

Although the glacial lobe that deposited a given till is not, in itself, considered to be part of the definition of a lithostratigraphic unit, several significant lithostratigraphic breaks occur along former lobe boundaries. In other places, however, there appears to be little difference between deposits of adjacent lobes, and in those areas a single lithostratigraphic unit is mapped for deposits of both lobes (for example, Kewaunee Formation). In the discussion that follows, glacial lobes are discussed relative to the distribution of units, but, as stated above, this is not considered part of the formal definition.

Zenda Formation

The Zenda Formation (Appendix 6) occurs in south-central Wisconsin and includes two members, the older of

which is believed to be Early Wisconsinan age and the younger Late Wisconsinan (Willman and Frye, 1970). Both contain pink, medium grained till, distinctly different from tills of the Walworth Formation below and the New Berlin Formation above. We accept the definitions of the Capron and Tiskilwa Till Members of Willman and Frye (1970) but in Wisconsin drop the word "till" from the formal name. Definitions of the members are given in Appendices 6a and 6b.

The Capron Member is present at the surface in a small area of south-western Walworth County (fig. 2) (Fricke, 1976; Johnson, 1976). Its extent in the subsurface is unknown.

The surface occurrence of the Tiskilwa Member is limited to a relatively small area in Walworth County (Alden, 1918; Johnson, 1976). It is present in the subsurface beneath the New Berlin Formation at least as far north as Milwaukee.

New Berlin Formation

Till of the New Berlin Formation (Appendix 7) is present in southeastern Wisconsin. Till of this formation has more sand than tills of the Zenda Formation below and the Oak Creek Formation above. It is typically yellowish brown where oxidized and can be distinguished from the similar Horicon Formation of the adjacent Green Bay Lobe by the greater amount of Niagaran (Silurian) dolomite in the New Berlin (Alden, 1918). The formation contains two main members, a lower sand and gravel member and an upper till member, neither of which is formally named and defined at this time. It is possible that two till units are contained in the formation (1A and 1B of Mickelson and others, 1977), but they likewise are not being defined at this time.

The till of the New Berlin Formation is lithologically most like the Haeger Till Member of the Wedron Formation in Illinois and is probably in large part correlative with it. The New Berlin Formation may be time equivalent to part or all of the Malden, Yorkville, Haeger, and Wadsworth Till Members of Illinois.

Oak Creek Formation

Overlying the New Berlin Formation in Kenosha, Racine, Waukesha, Milwaukee, and Ozaukee Counties (fig. 2) are lacustrine silt and clay, fluvial sand and gravel, and till of the Oak Creek Formation (Appendix 8). The till of this formation is generally gray (where unoxidized) and clayey, and it is distinctly different from till of underlying and overlying formations. The till was deposited by ice of the Lake Michigan Lobe, and many of the lacustrine units associated with the till were deposited during early phases of glacial Lake Chicago.

The formation contains at least three till units (2A, 2B, and 2C of Mickelson and others, 1977) and an unknown number of other members. These are not defined in this paper. This formation is largely correlative with the Wadsworth Till Member of the Wedron Formation of Illinois.

Horicon Formation

The Horicon Formation (Appendix 9) consists of till and associated deposits in much of the area covered by the Green Bay Lobe during Late Wisconsinan time (fig. 2). The till is sandy and yellowish brown where oxidized. In most places it appears to be bounded below by pre-Pleistocene bedrock, and it is overlain by redder, more clayey deposits of the Kewaunee Formation.

In any given place only one till unit has been recognized, but several names have been used in different parts of the state. On the northeast side of the area covered by the Green Bay Lobe the Liberty Grove Member is found in the Door Peninsula (Appendix 9b). Farther south the term "Wayside till" was used by McCartney and Mickelson (1982), but this unit was not studied in detail and it is premature to formalize the unit as a member of the Horicon Formation.

On the west side of the Green Bay Lobe, in Langlade and Marathon Counties, the Mapleview Member (Appendix 9a) is recognized. In this area the till is distinguished from till of the Nashville Member of the Copper Falls Formation deposited by the Langlade Lobe to

the west primarily on the basis of its greater dolomite content (Mickelson, Nelson, and Stewart, 1974). To the north in Florence County, however, it appears that this distinction can not be made. Further research in this area will probably lead to some redefinition of units.

Between Langlade County in the north and Dane and Rock Counties in the south, considerable change in grain size of the till of the Horicon Formation takes place. It seems likely that in the future additional members will be named in this formation.

Kewaunee Formation

Deposits of the Kewaunee Formation (Appendix 10) overlie various members of the New Berlin, Oak Creek, and Horicon Formations and pre-Pleistocene bedrock. The till included in this formation is typically more reddish brown in color than deposits of underlying formations, and it contains more silt and clay than till of the Horicon and New Berlin Formations. The Kewaunee Formation includes till and associated deposits of both the Lake Michigan and Green Bay Lobes (fig. 2).

Kewaunee Formation of the Lake Michigan Lobe

In the area covered by the Lake Michigan Lobe, four members are recognized (Acomb, 1978; Acomb, Mickelson, and Evenson, 1982). The stratigraphy of lake sediment and sand and gravel deposits has not been defined, and the placement of many of these units is not defined here.

The lower most member is the Ozaukee Member (Appendix 10a). Till of this member is present as the surface till along the shoreline of Lake Michigan from northern Milwaukee County to the city of Port Washington. It is presumably found northward in Manitowoc and Kewaunee Counties as well (Acomb, 1978; Dagle and others, 1980). It is distinguished from till of the overlying Haven Member by its greater clay content (Acomb, Mickelson, and Evenson, 1982). The Ozaukee Member is at least in part correlative with the Manitowoc or Shorewood Till Member of the Illinois State Geological Survey (Lineback, Gross, and Meyer, 1974) and with the Silver Cliff and Branch River Members in the Green Bay Lowland.

The till of the Haven Member (Appendix 10b) is present in the Lake Michigan bluffs from central Ozaukee County north into southern Door County (Dagle and others, 1980). The till of this member is siltier than either the Ozaukee till or the overlying Valders till. The Valders Member (Appendix 10c) has a more limited distribution and is distinguished from the overlying Two Rivers Member by its greater content of expandable clay and lower illite content. The Haven and perhaps the Valders Member is evidently correlative with the Manitowoc Till Member defined by the Illinois State Geological Survey, which was defined in cores from the bottom of Lake Michigan, Linebeck, Gross, and Meyer (1974). It appears that they correlate with the Kirby Lake and Chilton Members of the Green Bay Lowland.

The Two Rivers Member (Appendix 10d), defined by Evenson (1973), is the uppermost Lake Michigan Lobe deposit containing till. Although neither the location of the type section nor the implied definition by Evenson (1973) is changed, the definition here provides more detail.

Kewaunee Formation of the Green Bay Lobe East of Fox River

Green Bay, the Fox River, and the steep slope of the Silurian escarpment form a discontinuity across which no detailed stratigraphy has been done. Properties of probably correlative units differ significantly, and at this time it appears most logical to have an arbitrary vertical cut-off at the Fox River (fig. 2) and use separate member names on either side. East of the Fox River three members of the Kewaunee Formation, from oldest to youngest, the Branch River, Chilton, and Glenmore Members, are defined based on till bodies within each member. The till of the Branch River Member (Appendix 10e) is redder and has more clay than the underlying till of the Horicon Formation. It is sandier than the overlying Chilton and Glenmore Members and is correlative with the Silver Cliff Mem-

ber west of the Fox River. The Chilton (Appendix 10f) and Glenmore (Appendix 10g) Members are indistinguishable in the field except by measuring depth of carbonate leaching in the till at well drained sites in the landscape (Mickelson and Evenson, 1975). The till of the Chilton Member is distinguished from the till of the Glenmore Member in the laboratory by having higher magnetic susceptibility (McCartney and Mickelson, 1982). The Chilton Member is correlative with the Kirby Lake Member, and the Glenmore Member is correlative with the Middle Inlet Member west of the Fox River.

Kewaunee Formation of
the Green Bay Lobe West of the Fox River

Informal names were given to the reddish-brown till in this area by McCartney (1978); her definitions serve as the basis of formal lithostratigraphic definitions presented here. The oldest member of the Kewaunee Formation west of the Fox River is the Silver Cliff Member (Appendix 10h). The till contains less sand than the underlying Mapleview Member of the Horicon Formation and more sand than till of the overlying Kirby Lake Member. The till of the Kirby Lake Member (Appendix 10i) is typically thinner, redder, and finer grained than the till of the overlying Middle Inlet Member and correlates with the fine grained Chilton till east of the Fox River.

The Middle Inlet Member (Appendix 10j) is the youngest lithostratigraphic unit containing till deposited by the western part of the Green Bay Lobe in Wisconsin. In the south (Brown and Outagamie Counties) the till is fine grained like the correlative Glenmore till east of the Fox River. To the north in Oconto, Marinette, and Florence Counties it is progressively more sandy (McCartney, 1978).

The Two Creeks Bed is here given informal lithostratigraphic recognition. It consists of organic material accumulated as forest floor litter or in shallow ponds and is dated about 12,100 to 11,600 B.P. It is present throughout much of the area covered by Two Rivers, Glenmore, and Middle Inlet Members.

Copper Falls Formation

The Copper Falls Formation occurs across a broad area of northern Wisconsin. Because the boundaries of this formation have not been clearly defined to date, the Copper Falls Formation (Appendix 11) will be used to include till that is generally sandy and reddish brown, with a small proportion of Paleozoic sedimentary clasts. This till is derived from the Lake Superior basin and is generally distinctly different than deposits of the Lake Michigan and Green Bay Lobes. In some places, particularly in Florence County where the lobes overrode similar bedrock, the distinction between the Copper Falls Formation and the adjacent Horicon Formation is not clear.

The formation includes one member that is recognized here, but several more will be defined in the future. The type section of the Nashville Member (Appendix 11a) is in southern Forest County, and the unit is recognizable in northern Langlade, most of Forest, and Oneida Counties (fig. 2). Its extent toward the east and northeast is not clear at this time. The till of the member is reddish brown and sandy. It is distinguished from till of the underlying Marathon and Lincoln Formations by its greater sand content and by its lesser amounts of vermiculite and expandable clay. It is distinguished in Langlade and southern Forest Counties from the Mapleview Member of the Horicon Formation by its lesser content of dolomite and other Paleozoic sedimentary clasts. It is probably time correlative with all or part of the Horicon Formation. In eastern Langlade and southern Forest Counties, the Nashville Member overlies the Mapleview Member. Although detailed work to the northeast has not been completed, it seems likely that an unnamed member of the Horicon Formation lies above the Nashville Member. We recognize that this results in intertonguing of formations, but this seems unavoidable for practical classification of the units.

Miller Creek Formation

The Miller Creek Formation (Appendix 12) is present as the surface unit in parts of Douglas, Bayfield, Ashland,

and Iron Counties (fig. 2) in northwestern Wisconsin. Deposits of lacustrine silt and clay and till in the formation have a distinctly red color. All of the till in the formation is distinctly more clayey than that in the underlying Copper Falls Formation.

Two members are defined within the formation. The older, the Hanson Creek Member, consists of laminated silt and clay and till that is typically 5YR 3/4 in color (Need, 1980). Color is the main distinction between it and the overlying Douglas Member, which has till that is typically 2.5YR 4/4. The till of the Douglas Member has two distinct facies: a clay facies that has textural properties similar to the till of the Hanson Creek Member and a more sandy facies. The Douglas Member was deposited after 9900 B.P. (Clayton, in press).

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APPENDIX 1

WALWORTH FORMATION

Source of name.--Walworth County, in southern Wisconsin.

Type section.--Same as Clinton Member, Appendix 1c.

Reference sections.--Type sections and reference sections of Foxhollow, Allens Grove, and Clinton Members serve as reference sections for this formation (Appendix 1 a,b,c).

Description of unit.--The Walworth Formation includes till and associated sand and gravel which is generally sandy and gray (unoxidized) to brown (oxidized). At present, three members are recognized. The oldest is the Foxhollow Member, which contains gray (unoxidized), silty, clayey till (mean is 44 percent sand, 37 percent silt, 19 percent clay). This is overlain by the Allens Grove Member, which contains somewhat sandier till (mean 53 percent sand, 35 percent silt, 12 percent clay). The uppermost unit now recognised in the formation is the Clinton Member, which contains sandier till (mean 61 percent sand, 27 percent silt and 12 percent clay) Fricke (1976). Sand and gravel within the formation has not been described in detail.

Nature of contacts.--This formation is the surficial unit in eastern Rock and western Walworth Counties. In eastern Walworth County it is overlain by the Zenda Formation that contains more silt and clay and is distinctly red or pink in outcrop. The basal contact is generally not known except where various members lie on pre-Pleistocene rock.

Differentiation from other units.--Till of this formation can be distinguished from till of the overlying Zenda Formation, by the greater sand content and lack of reddish color of the Zenda Formation (Fricke, 1976; Johnson, 1976). The extent to the west and differentiation from older units described by Bleuer (1971) are not known at this time.

Regional extent and thickness.--The formation ranges in thickness from only a few metres on top of bedrock highs in eastern Rock County to approximately 80 m in the Rock River valley in western Rock County. Its extent eastward beneath the Zenda Formation (fig. 2) and northward beneath the Horicon Formation (fig. 2) is unknown. It extends as a surficial deposit from western Walworth County to the valley of the Rock River where it is abutted by sand and gravel of the Horicon Formation. It probably extends at least into western Rock County but the western edge of the formation is not mapped.

Age and correlation.--The age of the Walworth Formation is unknown. Correlative deposits in Illinois were assumed to be Early Wisconsinan (Altonian) age (Willman and Frye, 1970) but recent studies (Leon Follmer, personal communication, 1981) suggest that the deposits may be older. The Foxhollow Member probably has an unnamed correlative in Illinois but correlatives in Wisconsin are unknown. The Allens Grove Member is evidently equivalent to the Argyle Till Member of Illinois. The Clinton Member extends as the surficial unit into Illinois but it has not been formally named there. Clinton till has been correlated with the Argyle Till Member of Illinois in the past but this correlation is evidently in error (R. Berg, J. Kempton, personal communication, 1981).

Person naming unit.--David M. Mickelson. This is the first use of this unit name.

APPENDIX 1a

FOXHOLLOW MEMBER OF THE WALWORTH FORMATION

Source of name.--The rural locality of Foxhollow, Rock County, located on the Shopiere 7.5-minute quadrangle.

Type section.--Test hole drilled approximately 3 miles (5 km) east of Beloit on the east side of a county road, north of old Highway 15; center NE¼SE¼NE¼ sec. 33, T. 1 N., R. 13 E., shown on the Shopiere 7.5-minute quadrangle (fig. 3).

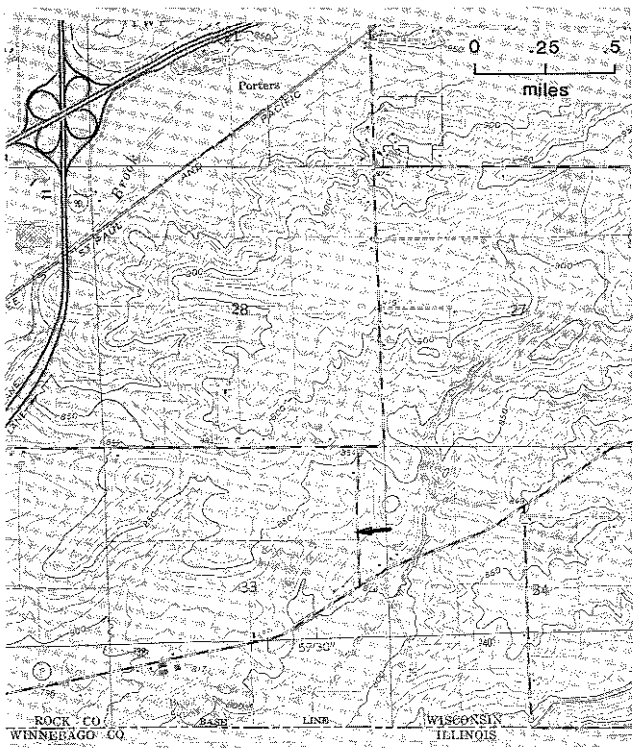

FIGURE 3.--Part of the Shopiere 7.5-minute quadrangle showing the location of the type section (drill hole) of Foxhollow Member.

Description of unit.--The Foxhollow Member contains a pebbly, silty and clayey till. Its overall color is gray, ranging from silver to brownish gray and purplish gray. In the type section test hole, the upper 0.6 m of the Foxhollow till is oxidized and red in color. The till also contains wood fragments. Numerous dolomite pebbles and igneous stones are found in the till. The ratio of light-colored to dark-colored dolomite in the very coarse sand (1 to 2 mm) size range is equal to or less than 0.8:1. Semiquantitative analysis of selected clay minerals shows an average montmorillonite:illite:chlorite plus kaolinite ratio of 28:53:19.

Nature of contacts.--The upper contact with the Allens Grove Member is sharp and easily recognized.

Differentiation from other units.--The Foxhollow Member can easily be distinguished from other tills in the area (the Allens Grove, Clinton, and Capron tills and tills of the Horicon and New Berlin Formation) by its lower sand and higher silt and clay content, low light to dark dolomite ratio, low illite content, and gray color.

Regional extent and thickness.--The Foxhollow Member is known to underlie most of Wisconsin east of the Rock River, south of Turtle Creek, in and west of the buried Troy Valley (fig. 2), and part of northern Illinois. The till is known to exceed 3.6 m in thickness.

Origin.--The Foxhollow Member consists largely of till, most likely deposited by glacial ice that advanced from the Lake Michigan basin.

Age.--The Foxhollow Member was deposited in mid-Wisconsinan time or earlier (earlier than 40,000 B.P.).

Correlation.--Stratigraphically, the Foxhollow Member lies below the Allens Grove Member. The till extends into Illinois.

Description of type section.--The type section is test hole 671 of Fricke (1976). Here the Foxhollow Member is overlain by 4.3 m of till of the Clinton Member at the surface, then 5.5 m of Allens Grove Member. The boring penetrated 3.0 m of gray till of the Foxhollow Member before refusal. The Foxhollow Member here contains abundant wood chips.

Person naming unit.--Carl Fricke and David Mickelson. First used informally as a unit name by Fricke (1976). This is the first formal use of the name.

APPENDIX 1b

ALLENS GROVE MEMBER OF THE WALWORTH FORMATION

Source of name.--The rural locality of Allens Grove, Walworth County, located on the Clinton 7.5-minute quadrangle.

Type section.--Base of west wall of borrow pit NW¼SE¼SW¼ sec. 32, T. 2 N., R. 15 E., 0.5 miles (0.8 km) east of Allens Grove, approximately 2.5 miles (4 km) west of the Capron Ridge, and just north of old Highway 15 (fig. 4), shown on the Sharon and Clinton 7.5-minute quadrangles.

Description of unit.--The Allens Grove Member contains a light brown to yellowish brown (7.5YR to 10YR 5/4 to 6/4), sandy, pebbly till and associated deposits. The till is hard and compact, both when dry and wet, and commonly has a pinkish tint. Numerous dolomite and igneous pebbles are present in the till. The till contains a mean of 53 percent sand, 35 percent silt, and 12 percent clay. Semiquantitative analysis of selected clay minerals shows two groups of montmorillonite:illite:chlorite plus kaolinite ratios--one averaging 26:61:13 and the other 39:47:14.

Nature of contacts.--The upper contact (with the Clinton Member) ranges from sharp to diffuse. The lower contact (with the Foxhollow Member) is sharp.

Differentiation from other units.--The Allens Grove Member is less sandy than the Clinton Member and till in the Horicon and New Berlin Formations, but is more sandy than the Foxhollow Member and the Capron Member. The Allens Grove Member has a light-to-dark-dolomite ratio of between 0.8:1 and 1.3:1, intermediate between the Clinton Member and the Foxhollow Member. Its salmon-pink color can sometimes be used as a distinguishing feature.

Regional extent and thickness.--The Allens Grove Member underlies the Clinton Member in Rock County, Wisconsin, east of the Rock River, south of the Johnstown moraine and west of the Capron Ridge. The till extends south into northern Illinois. The till is up to 3.9 m thick.

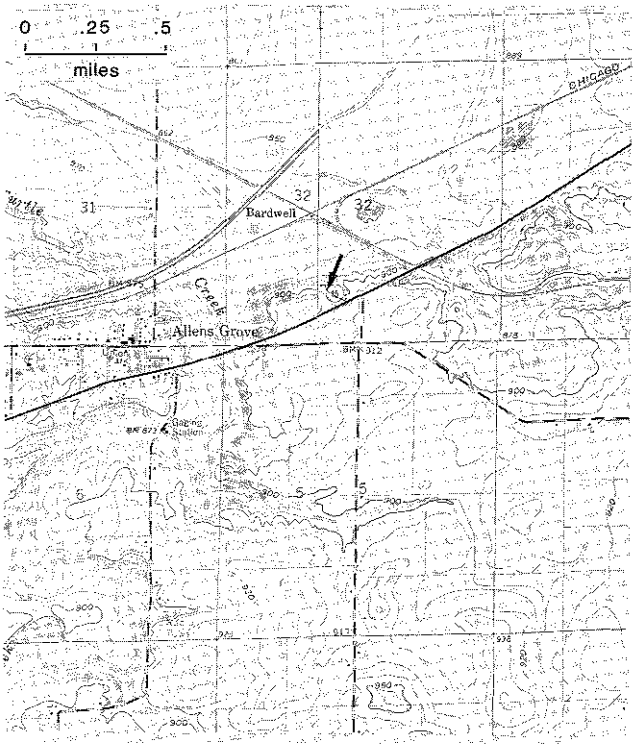

FIGURE 4.--Part of Sharon and Clinton 7.5-minute quadrangles showing the location of the type section of the Allens Grove Member.

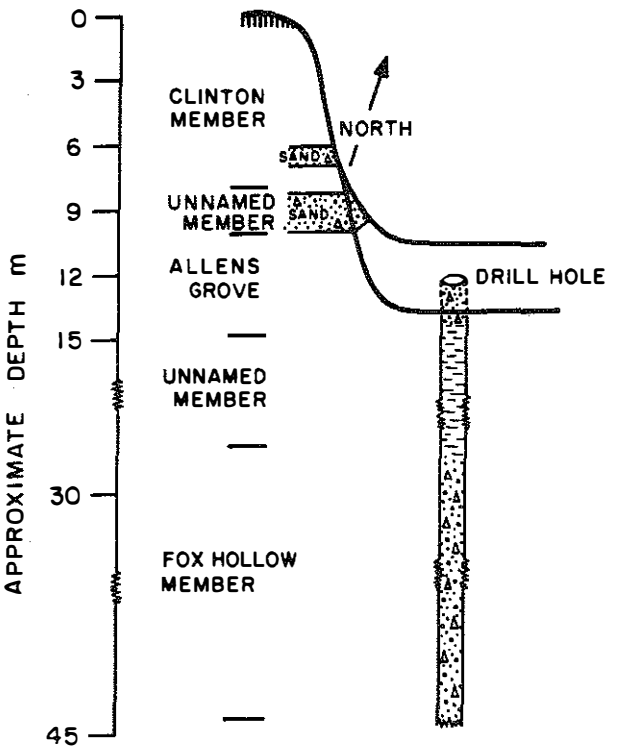

FIGURE 5.--Sketch of stratigraphy in borehole at type section of the Allens Grove Member.

Origin.--Glacial till deposited by ice from the Lake Michigan basin.

Age.--The Allens Grove Member was deposited earlier than 40,000 B.P.

Correlation.--The Allens Grove Member is equivalent to the Argyle Till Member in Illinois.

Description of type section.--The top of the section (fig. 5) contains 0.6 m of red brown (5YR 4/6) truncated B horizon developed on 8 m of Clinton till and sand. An unnamed sand separates the Clinton Member from the underlying Allens Grove Member that here consists of compact, grayish till oxidized at the surface (Fricke, 1976, p. 22). A drill hole adjacent to the section penetrates Clinton till (2 m), gray lacustrine silt (14 m), and 7 m of what is presumably Foxhollow Member.

Person naming unit.--Carl Fricke and David Mickelson. First used as an informal unit name by Fricke (1976), and used formally for the first time in this paper.

APPENDIX 1c

CLINTON MEMBER OF THE WALWORTH FORMATION

Source of name.--The village of Clinton, Rock County, located on the Clinton 7.5-minute quadrangle.

Type section.--Road cut and test hole along new Highway 15 (the Beloit-Milwaukee Road), 2 miles (3.2 km) northeast of Clinton; NE¼SW¼ sec. 3, T. 1 N., R.

14 E., located on the Clinton 7.5-minute quadrangle, (fig. 6).

Reference section. Turtle Town Quarry; NW¼SW¼NW¼ sec. 22, T. 1 N., R. 13 E., located on the Shopiere 7.5-minute quadrangle (fig. 7). Described by Bleuer (1971) and briefly by Fricke (1976).

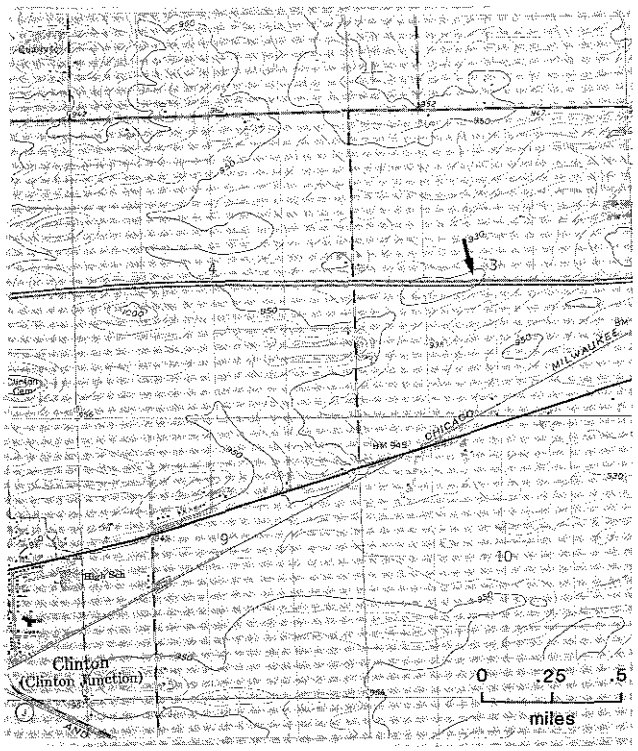

FIGURE 6.--Part of the Clinton 7.5-minute quadrangle showing the location of the type section of the Clinton Member.

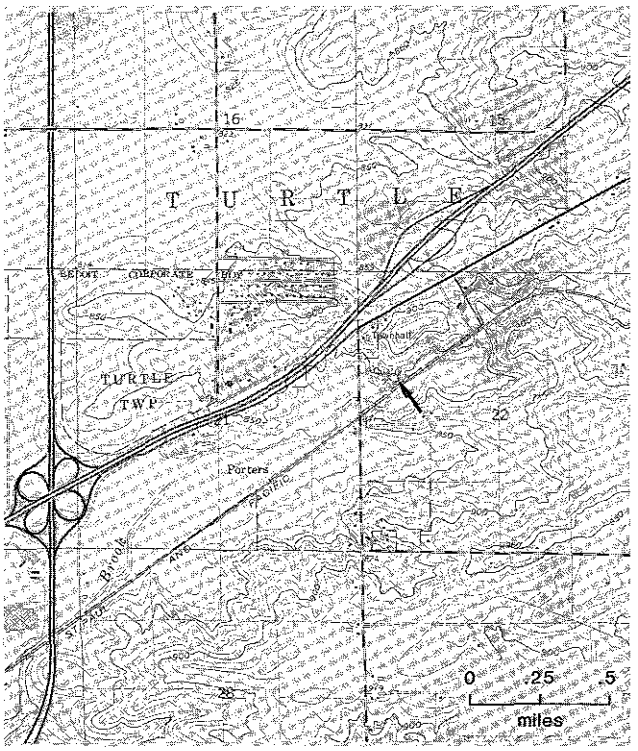

FIGURE 7.--Part of the Shopiere 7.5-minute quadrangle showing the location of the reference section of the Clinton Member.

Description of unit.--The Clinton Member contains a pebbly, sandy, till containing little clay. In outcrops, its color most often is light yellowish brown (10YR 6/4), although at times it has a pink tint. When dry, the till is hard and crumbly.

Numerous dolomite pebbles and a few cobbles are found in the till, along with smaller amounts of igneous-rock clasts. In the very-coarse-sand fraction (1 to 2 mm) the ratio of light-to-dark dolomite is greater than 1.3:1. The unit is composed of about 61 percent sand, 27 percent silt, and 12 percent clay. Semiquantitative analysis of selected clay minerals most often shows an average content of 26 percent montmorillonite (expandables), 60 percent illite, and 14 percent chlorite plus kaolinite. However, a second group of samples averages 45 percent montmorillonite, 45 percent illite, and 10 percent chlorite plus kaolinite (Fricke, 1976).

Nature of contacts.--The contacts between the Capron Member (above) and Allens Grove Member (below) are generally sharp, although the contact with the Allens Grove Member is diffuse in places.

Differentiation from other units.--The Clinton Member can be distinguished from the Capron Member, the Allens Grove Member, and the Foxhollow Member by

its very sandy texture, buff color, clay mineralogy, and its ratio of light-to-dark dolomite in the sand fraction. It is nearly indistinguishable from till in the Johnstown moraine (Horicon Formation) except possibly for the Clinton Member's lower content of weathered minerals.

Regional extent and thickness.--South and west of the Darien and Johnstown moraines, the Clinton Member is the uppermost (surficial) till in eastern Rock County and western Walworth County. Its extends westward at least as far as 2.9 miles (4.8 km) west of the Rock River in Rock County, Wisconsin, with the possible exception of the upland west of Janesville, north of Bass Creek, and south of the Johnstown moraine. It extends south into northern Illinois and east beneath the Capron Ridge. The till ranges in thickness from less than 1 m along the Rock River and in the shallow bedrock uplands north of Turtle Creek to over 12.6 m south of Turtle Creek.

Origin.--Till and associated deposits deposited by ice that advanced westward from the Lake Michigan basin.

Age.--No precise age can be given to the Clinton till, but it was probably deposited during mid-Wisconsinan time, or before 40,000 B.P.

Correlation.--The Clinton Member was formerly correlated with the Argyle Till Member of the Winnebago Formation in northern Illinois. It can now be demonstrated that it is a separate, distinct unit that lies above the Allens Grove Member (the Argyle Till Member in Illinois) and below the Capron Member.

Description of type section.--Loess 2.1 m thick overlies a truncated B horizon 1.5 m thick developed in Clinton till. Clinton till extends to the bottom of the cut 8 m below the surface. A drill hole penetrates Clinton till to a depth of 14.6 m below the top of the cut.

Person naming unit.--Carl Fricke and David Mickelson. First used as an informal unit name by Fricke (1976), and used formally for the first time in this paper.

APPENDIX 2

MARATHON FORMATION

Source of name.--Marathon County.

Type section.--Same as Wausau Member, Appendix 2a.

Reference section.--Type and reference section of the Edgar and Wausau Members serve as reference sections for this formation (Appendix 2a,b).

Description of unit.--The Marathon Formation contains till and associated sand and gravel that are generally light gray, pale yellow, or pale brown depending on the amount of oxidation. Two members are recognized. The lower is the Wausau Member, which contains brown loam till (mean 43 percent sand, 34 percent silt, and 23 percent clay). Overlying the Wausau Member is the Edgar Member, which contains somewhat siltier, brown loam till (mean 33 percent sand, 43 percent silt, and 24 percent clay). Sand and gravel units within the formation have not been described in detail.

Nature of contacts.--The Marathon Formation overlies Precambrian bedrock in most of Marathon County. The bedrock is sometimes unweathered, but generally it is decomposed to depths of several metres. This formation is the surficial unit in most of Marathon County, except in the far northern and western parts, where it is overlain by the redder and sandier Lincoln Formation (Appendix 3), and in the far eastern part, where it is presumably overlain by the Horicon Formation (Appendix 9).

Differentiation from other units.--Till of the Marathon Formation is finer textured and yellower in color than till of the overlying Lincoln Formation. Lithologically, the till of this formation contains more smectite and less illite as components of the clay-mineral assemblage than does till of the Lincoln Formation.

Regional-extent and thickness.--The thickness of the Marathon Formation ranges from zero to as much as 20 m. It is thinnest at its southern limit in Marathon, Wood, and Clark Counties. The formation is thickest where it fills buried valleys (Bell and Sherrill, 1974). It generally thickens northward and extends beneath the Lincoln Formation to the north. The extent of this formation beneath the Copper Falls Formation (further north) and the Horicon Formation (to the east) is not known.

Age and correlation.--There are no dates on the Marathon Formation. Lithology, position in sequence, and mapped distribution suggest it could be correlative with the Pierce Formation of western Wisconsin. The lower member of the Pierce Formation is reversely magnetized, suggesting a pre-Illinoian age (Appendix 4, Pierce Formation) but paleomagnetism has not been measured for the Marathon Formation. It may be that the Wausau Member of the Marathon Formation is correlative with the River Falls Formation of western Wisconsin. If this correlation is correct, the Wausau Member (and presumably the entire Marathon Formation) may be Illinoian or Early Wisconsinan age.

Person naming unit.--William N. Mode. First use as a unit name is in this paper.

APPENDIX 2a

WAUSAU MEMBER OF THE MARATHON FORMATION

Source of name.--The city of Wausau, Marathon County.

Type section.--Gravel pit off west side of Ryan Street, 1½ miles south of Highway 29, SW¼SW¼NE¼ sec. 27, T. 28 N., R. 8 E., Marathon County, on Wausau 15-minute quadrangle (fig. 8).

Reference section.--Road cut on west side of North 57th Street, about 50 m north of its intersection with East Butternut Road, SE¼SE¼SE¼ sec. 4, T. 29 N., R. 8 E., Marathon County, on the Merrill 15-minute quadrangle (fig. 9). The reference section is in a roadside ditch exposure which contains about 1 m of till of the Wausau Member capped by 10 to 20 cm of loess.

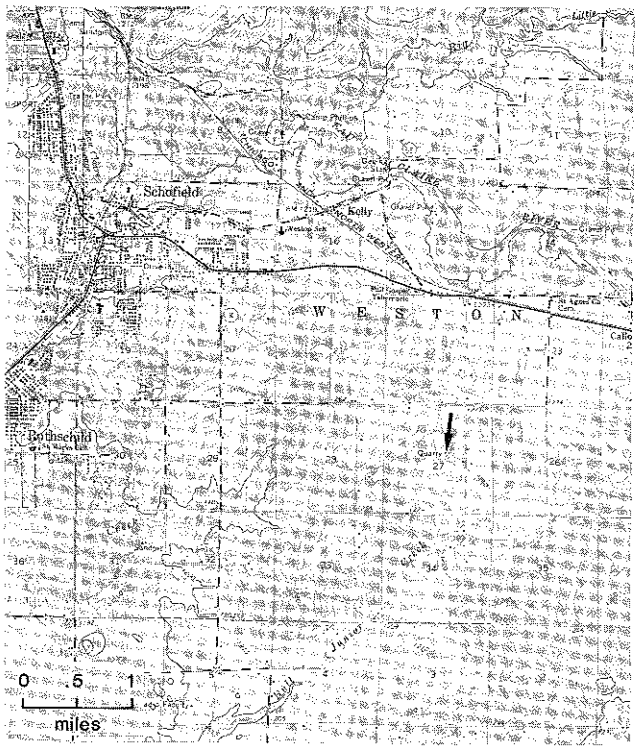

FIGURE 8.--Part of the Wausau 15-minute quadrangle showing the location of the type locality of the Wausau Member.

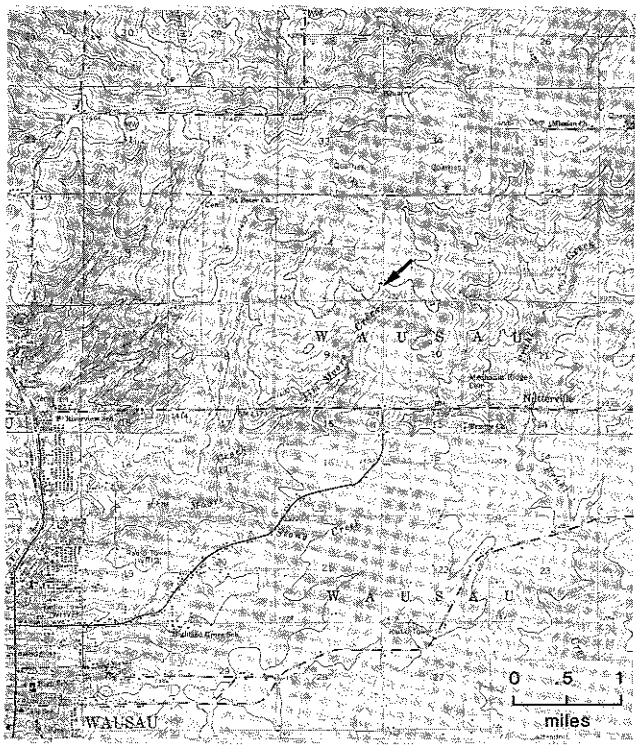

FIGURE 9.--Part of the Merrill 15-minute quadrangle showing the location of the reference section of the Wausau Member.

Description of unit.--The Wausau Member typically contains a pebbly loam to clay loam till in which the less-than-2-mm-fraction averages 43 percent sand, 34 percent silt, and 23 percent clay (15 samples). A high proportion (greater than 30 percent) of the clasts are partially to totally rotted, and many of the intact clasts appear to have been mixed upward into the till from the underlying bedrock by frost action and tree throw. The field color of the till is predominantly brown (7.5YR 4/4). Coarse-sand fraction components are 75 percent igneous, 6 percent metamorphic, and 19 percent sedimentary. The clay minerals average 44 percent illite, 5 percent kaolinite-chlorite, 18 percent vermiculite, and 32 percent smectite (Mode, 1976).

Nature of contacts.--The Wausau Member is frequently thin (less than 10 m) and found directly overlying bedrock, grussified bedrock, or saprolitic bedrock-weathering residuum. These contacts are usually sharp, though some upward mixing of local bedrock into the till is usually apparent. No exposures of upper contacts of the Wausau Member with another unit are known.

Differentiation from other units.--The Wausau Member is texturally distinct

from the Merrill Member of the Lincoln Formation and the Nashville Member of the Copper Falls Formation because it is finer grained, from the Edgar Member because its modal grain size is not silt, and from the Bakerville Member of the Lincoln Formation because it is less red in color.

Regional extent and thickness.--The Wausau Member is the surficial material over much of central Marathon and northern Wood Counties, and it is also present in the subsurface in western and north-central Marathon County. The till generally thins toward the south and toward the Wisconsin River.

Origin.--Till of the Wausau Member was deposited by southeastward flowing ice of the Chippewa Sublobe. The till has subsequently been altered considerably by weathering and erosion. The member also includes slopewash sediment and related sediments, but these may be recognized as a separate member in the future.

Age.--The Wausau Member is older than 40,800 ± 2000 radiocarbon years (ISGS-256). This date is from organic deposits on top of the Merrill Member that overlies the Wausau Member. Clay mineral studies by Stewart and Mickelson (1976) and Mode (1976) suggest a pre-Wisconsinan age.

Correlation.--The patchy distribution of till and lack of constructional topography makes correlation very difficult. It can be tentatively correlated with the Hersey Member of western Wisconsin based only on its basal position in the sequence.

Description of the type section.--The type section is located about 100 m west of Ryan Street in a gravel pit. In the west wall of the pit, about 1 to 2 m of till of the Wausau Member overlies deeply weathered granitic saprolite.

Person naming unit.--William N. Mode. First used as an informal unit name by LaBerge and Myers (1971) and subsequently by several writers including Stewart (1973) and Mode (1976). Formalized in this publication.

APPENDIX 2b

EDGAR MEMBER OF THE MARATHON FORMATION

Source of name.--Named for the village of Edgar, Marathon County, which is located in the west-central part of the Edgar 7.5-minute quadrangle.

Type section.--Railroad cut (Chicago and Northwestern) on south side of Highway N; NW¼NE¼NW¼ sec. 24, T. 28 N., R. 4 E., Marathon County, on the Edgar 7.5-minute quadrangle (fig. 10).

Reference section.--Railroad cut (Minneapolis, St. Paul, and Sault Ste. Marie) on north side of Yellowstone Drive, about 0.3 miles (0.5 km) west of its intersection with Day Road, and about 0.6 miles (0.9 km) east of the village of Hewitt; SE¼SW¼SE¼ sec. 13, T. 25 N., R. 3 E., Wood County, on the Hewitt-7.5-minute quadrangle (fig. 11). The reference section is well-vegetated but contains at least 2 to 3 m of till of the Edgar Member at about the level of the track.

Description of unit.--Till of the Edgar Member is typically pebbly loam to clay loam to silt loam; the less than 2 mm fraction averages 33 percent sand, 43 percent silt, and 24 percent clay (17 samples). The field color of the till is variable, ranging from yellowish brown (10YR 5/6) to reddish brown (5YR 4/4). Unweathered till of the Edgar Member is calcareous, with up to 10 percent dolomite pebbles. The coarse sand fraction components are 72 percent igneous, 7 percent metamorphic, and 21 percent sedimentary. Average clay

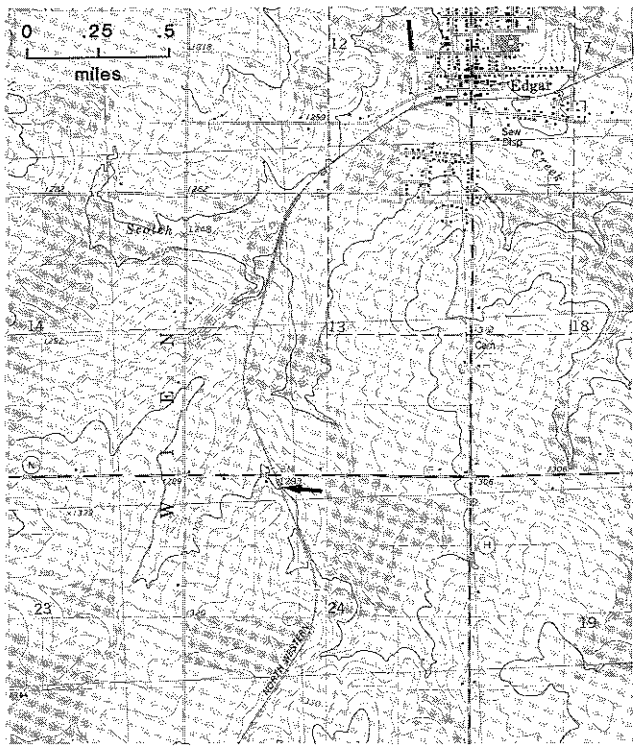

FIGURE 10.--Part of Edgar 7.5-minute quadrangle showing the location of the type section of the Edgar Member.

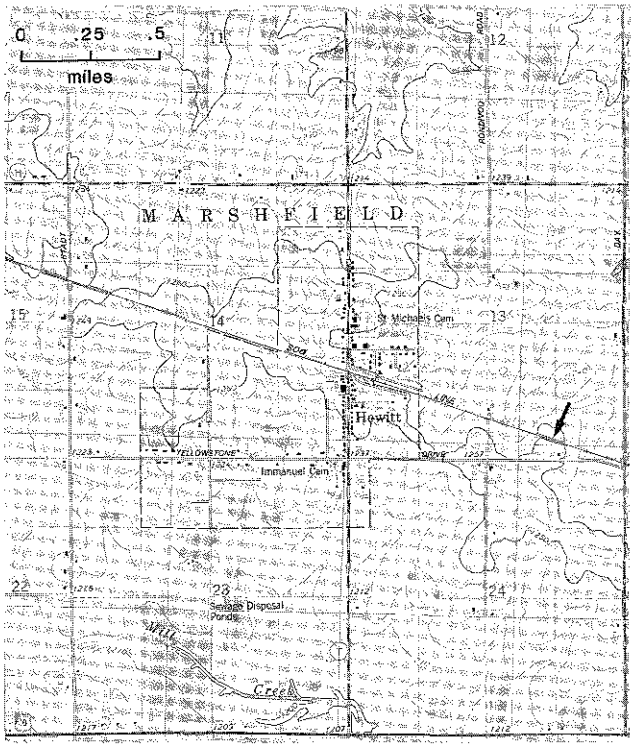

FIGURE 11.--Part of the Hewitt 15-minute quandrangle showing the location of the reference section of the Edgar Member.

mineralogy is 44 percent illite, 6 percent kaolinite plus chlorite, 17 percent vermiculite, and 33 percent smectite (Mode, 1976).

Nature of contacts.--The Edgar Member is generally thin (less than 10 m), and its lower contacts have never been observed in outcrop. In auger holes, it has a sharp upper contact with sandier materials overlying it and a sharp lower contact with bedrock, organic-rich sediment, or the Wausau Member.

Differentiation from other units.--The Edgar Member is distinguished by two characteristics: (1) it is calcareous (where unweathered) and (2) it is silty. No other silt-rich calcareous till is known in this area.

Regional extent and thickness.--The Edgar Member has only been found in northern Wood, southwestern Marthon, and eastern Clark Counties, an area centered around the city of Marshfield. North and west of Marshfield, the Edgar Member is generally buried by the Bakerville Member of the Lincoln Formation; south and east of Marshfield it is exposed at the surface. The Edgar Member is generally less than 3 or 4 m thick except atop a low divide that extends east-southeastward from Marshfield, where it thickens to as much as 10 m.

Origin.--Southward-flowing ice of the Chippewa Sublobe deposited the till of the Edgar Member (Mode, 1976), though the source of carbonate along this flow line is unknown.

Age.--The Edgar Member underlies the Bakerville Member of the Lincoln Formation which in turn is older than or equivalent to the Merrill Member of the Lincoln Formation. The Merrill Member is overlain by material radiocarbon dated at 40,800 ± 2000 (ISGS-256); therefore, the Edgar Member is beyond

radiocarbon range, presumably pre- or Early Wisconsinan.

Correlation.--There are no known correlatives of the Edgar Member.

Description of type section.--The deepest part of the Chicago and Northwestern Railroad cut is about 200 m south of Highway N. The cut is thoroughly covered with vegetation so that a large exposure has never been examined. Samples for laboratory analysis and till fabric determination were obtained from a pit dug into the wall of the cut. An auger borehole just west of the type section revealed that the Edgar Member overlies more than 4 m of organic colluvium or till (?) of an unnamed member.

Person naming unit.--William M. Mode. First used as an informal unit name by Mode (1976), and formalized in this paper.

APPENDIX 3

LINCOLN FORMATION

Source of name.--Lincoln County.

Type section.--Same as the Bakerville Member, Appendix 3a.

Reference sections.--Type and reference sections of the Merrill and Bakerville Members serve as reference sections for this formation (Appendix 3a,b).

Description of unit.--The Lincoln Formation includes till and associated sand and gravel that are generally reddish brown. Two members are distinguished: the lower Bakerville Member contains reddish-brown, sandy loam till (62 percent sand, 25 percent silt, and 13 percent clay); and, the upper, Merrill Member contains dark reddish-brown, sandy loam till (62 percent sand, 28 percent silt, and 10 percent clay). Sand and gravel units within the formation have not been described in detail.

Nature of contacts.--The formation can be seen in sharp contact with the underlying Marathon Formation in roadcuts and drill holes throughout northern and western Marathon County and in southern Lincoln and Langlade Counties. In a few places, it overlies fresh or weathered bedrock. Throughout these areas, this formation is the surficial unit. Further north and east, where the formation is presumably overlain by younger units, its upper contacts are poorly known.

Differentiation from other units.--Lincoln Formation till is darker reddish brown than till of the underlying Marathon Formation and till of the overlying Copper Falls Formation. Lincoln till is sandier than the underlying till but less sandy than the overlying till. The till of the Lincoln Formation contains more illite and less smectite than till of the Marathon Formation; it contains more vermiculite and less kaolinite-chlorite and illite than tills of the Copper Falls and Horicon Formations (Stewart and Mickelson, 1976).

Regional extent and thickness.--With the exception of the Marshfield moraine, this formation is usually thinnest at its southern limit. Like the Marathon Formation, it reaches about 20 m thickness where it fills bedrock valleys (Bell and Sherrill, 1974). It also becomes thicker beneath end moraines located near Marshfield and Merrill. The thickness and extent of this formation beneath younger formations to the north and east is unknown.

Age and correlation.--The age of this formation is greater than 40,800 $\pm$ 2000 years (ISGS-256), which is a date on organic material overlying the Merrill Member, the uppermost member of the formation (Stewart and Mickelson, 1976). It probably correlates with the River Falls Formation in western Wisconsin, based on lithologic and stratigraphic similarities. Baker suggests an Illinoian age for the River Falls Formation (Appendix 5), but an Early or Middle Wisconsinan age cannot be ruled out (Mode, 1976; Stewart and Mickelson, 1976).

Person naming unit.--William N. Mode. The first use of this name is in this paper.

APPENDIX 3a

BAKERVILLE MEMBER OF THE LINCOLN FORMATION

Source of name.--The rural locality of Bakerville, located at the intersection of Highways B and BB, northwestern Wood County, in the southwestern corner of the Marshfield 7.5-minute quadrangle.

Type section.--Gravel pit on the east side of Robin Road, about 200 m south of its intersection with Highway B, 1 mile (1.7 km) west of Bakerville, SE¼NW¼NW¼ sec. 26, T. 25 N., R. 2 E., Wood County, on the Marshfield 15-minute quadrangle (fig. 12).

Reference section.--Road cut on the northwest side of the junction of Grant York Road and Romadka Road, about 0.6 miles (1 km) north of the village of Granton, SE¼SE¼SE¼ sec. 35, T. 25 N., R. 1 W., Clark County, on the Granton 7.5-minute quadrangle (fig. 13). The reference section is a roadside ditch exposure which contains about 2 m of till of the Bakerville Member, capped by up to 10 cm of loess, and overlying sandstone.

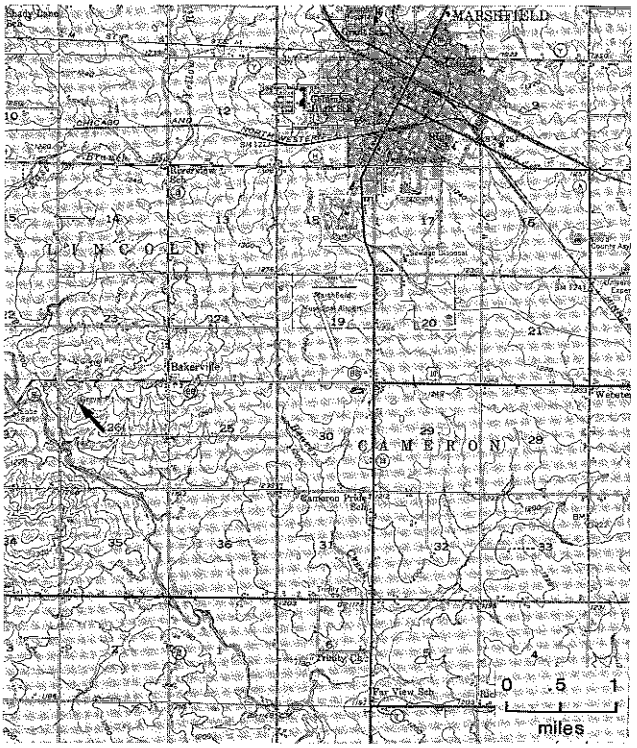

FIGURE 12.--Part of the Marshfield 15-minute quadrangle showing the location of the type section of the Bakerville Member.

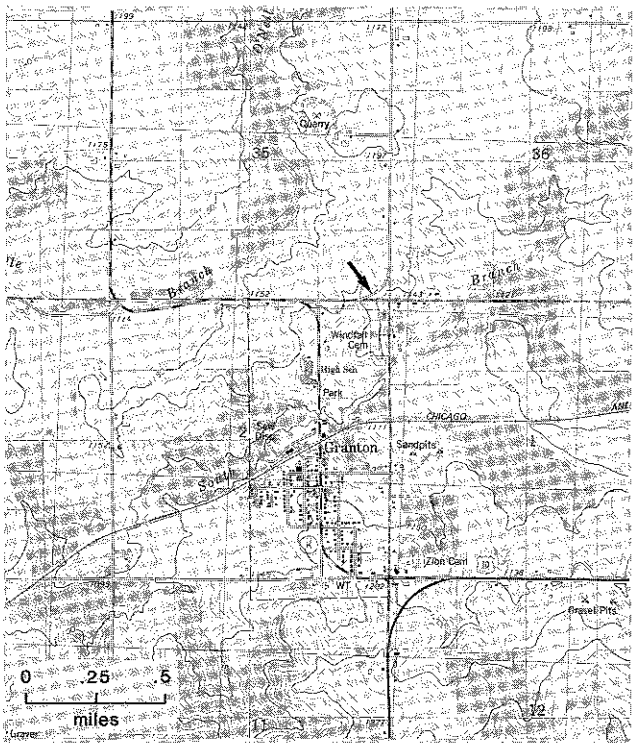

FIGURE 13.--Part of the Granton 7.5-minute quadrangle showing the location of the reference section of the Bakerville Member.

Description of unit.--The till of the Bakerville Member is a cobbly, pebbly sandy loam; the less-than-2-mm fraction averages 62 percent sand, 25 percent silt, and 13 percent clay (15 samples). Its field color is typically reddish brown (5YR 4/4). The coarse-sand fraction averages 60 percent igneous, 11 percent metamorphic, and 28 percent sedimentary rock types. Clay minerals average 53 percent illite, 8 percent kaolinite-chlorite, 14 percent vermiculite, and 25 percent smectite (Mode, 1976).

Nature of contacts.--No multiple till exposures including the Bakerville Member have been found, but the lower contact of this unit over bedrock has been observed to be abrupt. In boreholes, its lower contact with the Edgar Member of the Marathon Formation is sharp.

Differentiation from other units.--The Bakerville Member is typically redder and sandier than either the Wausau or Edgar Member. It is quite similar to the Merrill Member, and may be equivalent to it, except that it has more than

20 percent sandstone and siltstone clasts, whereas the Merrill Member has less than 10 percent. The clay mineralogy of the Bakerville Member is intermediate between that of the Wausau and Edgar Members (which are similar) and the Merrill Member.

Regional extent and thickness.--The Bakerville Member is the surface unit and reaches its greatest thickness (about 10 m) in the Marshfield moraine of southwestern Marathon, northwestern Wood, and southeastern Clark Counties. Behind this moraine, the Bakerville Member is considerably thinner (usually less than 5 m) or absent, making it very difficult to map its distribution. Complicating matters is influence of local substrates on the till composition. Near the Marshfield moraine, the Bakerville Member commonly overlies Cambrian sandstone, whereas behind the moraine it generally overlies Precambrian rock. This difference is reflected in the texture of the Bakerville Member because samples from the sandstone area are generally sandy loam whereas samples from the Precambrian bedrock area tend toward loam and sandy loam textures and are also more yellow (less red) in color.

Origin.--The till of the Bakerville Member was deposited by the southward flowing Chippewa Sublobe, which terminated at the Marshfield moraine.

Age.--The Bakerville Member, whether it underlies or is equivalent to the Merrill Member, is more than 40,800 $\pm$ 2000 (ISGS-256) radiocarbon years old; thus, it is at least mid-Wisconsinan in age.

Correlation.--Its position in sequence and its mapped distribution suggest that the Bakerville Member may be equivalent to the River Falls Formation of western Wisconsin; however, the difficulty in demonstrating the age relationship of the Bakerville and Merrill Members, which are adjacent to one another, is a caution against such a long-distance correlation.

Description of type section.--The type section is located in a gravel pit about 200 m to the east of Robin Road, about 500 m south of Highway B, Wood County. The quarry is an active one and at various times up to 10 m of subglacial till and the same amount of supraglacial till have been exposed in different faces. The gravel is intimately associated with the supraglacial till. Also exposed under the Bakerville Member is stratified, calcareous silt and sand, which has been thrust faulted and drag folded. Underlying this stratified material, but not exposed (auger hole), is calcareous till of the Edgar Member.

Person naming unit.--William N. Mode. First used as an informal unit name by Mode (1976), and the name is formalized in this report.

APPENDIX 3b

MERRILL MEMBER OF THE LINCOLN FORMATION

Source of name.--City of Merrill, south-central Lincoln County. Located in the northwestern part of the Merrill 15-minute quadrangle.

Type of section.--Northwest corner of gravel pit located north of Duginski Road, about 500 m west of the intersection of Duginski Road with old Highway 51. It is just north of the town of Merrill, SE¼SE¼NW¼ sec. 1, T. 31 N., R. 6 E., Lincoln County, Wisconsin, on the Merrill 15-minute quadrangle (fig. 14).

Reference section.--Road cut on east side of Highway S, about 100 m south of its intersection with Lincoln Drive, NW¼NW¼NW¼ sec. 29, T. 30 N., R. 5 E., Marathon County, on the Hamburg 7.5-minute quadrangle (fig. 15). The refer-

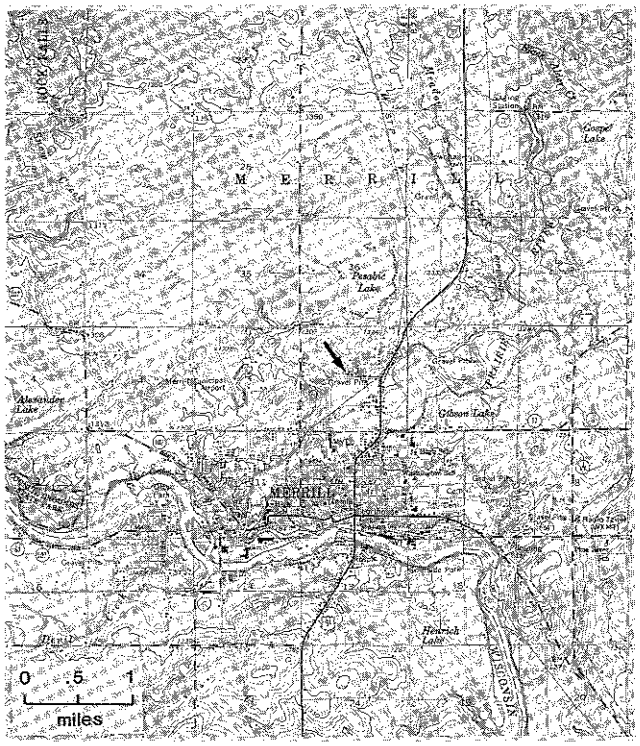

FIGURE 14.--Part of the Merrill 15-minute quadrangle showing the location of the type section of the Merrill Member.

FIGURE 15.--Part of the Hamburg 15-minute quadrangle showing the location of the reference section of the Merrill Member.

ence section is in a roadside ditch exposure, which contains about 1.5 metres of till of the Merrill Member, capped with about 20 cm of loess, and overlying Precambrian bedrock.

Description of unit.--The till of the Merrill Member is a cobbly, pebbly, sandy loam in which the less-than-2-mm fraction averages 62 percent sand, 28 percent silt, and 10 percent clay (21 samples). It is generally dark reddish brown (5YR 3/4 to 2.5YR 3/4), and the coarse sand lithology averages 71 percent igneous, 14 percent metamorphic and 14 percent sedimentary rock types. The average clay mineralogy is 53 percent illite, 9 percent kaolinite plus chlorite, 22 percent vermiculite, and 16 percent smectite (Stewart, 1973; Mode, 1976).

Nature of contacts.--Near the southern limit of the Merrill Member, in northern Marathon County, it is quite thin and can be seen in roadcuts to be in relatively sharp contact with the underlying Wausau Member. No exposures of the upper contact of the Merrill Member with the overlying Nashville Member of the Copper Falls Formation are known.

Differentiation from other units.--The Merrill Member has finer texture than the Nashville Member of the Copper Falls Formation, and coarser texture than the tills of the Wausau and Edgar Members of the Marathon Formation. It is also redder than any of these. The color and texture of the Merrill Member are quite similar to those of the Bakerville Member, and the distinctions between these members are a greater content of sandstone and siltstone clasts and more smectite in the Bakerville Member. It is possible that these two

members are equivalent, but there is a large gap between their mapped distributions.

Regional extent and thickness.--The Merrill Member contains the surficial till outside of the outermost moraines of Late Wisconsinan age in Langlade, Lincoln, and eastern Marathon Counties. It is generally less than 10 m, thick, is thickest in several, discontinuous, hummocky moraines (Weidman, 1907; Stewart, 1973), and is thinnest toward its southern boundary.

Origin.--Subglacial and supraglacial till of the Merrill Member was deposited by the St. Croix Sublobe, which flowed south-southeastward in the area where the Merrill Member is mapped.

Age.--A radiocarbon date of 40,800 ± 2000 (ISGS-256) was obtained from organic silt and clay overlying the Merrill Member at Schelke Bog (Stewart and Mickelson, 1976). Therefore, the Merrill Member is mid-Wisconsinan in age or older.

Correlation.--Because the River Falls Formation of western Wisconsin is found in a position similar to that of the Merrill Member, it is hypothesized that these members are correlative.

Description of type section.--The gravel pit, located north of Duginski Road about 500 m west of its intersection with old Highway 51, contains till of the Merrill Member in several stratigraphic settings. The northwestern corner of the pit exposes two till layers, each 2 to 3 m thick separated by a thin bed (fig. 16). Two till fabrics were measured here (Stewart, 1973), and their strength and uniformity suggest subglacial deposition even though the gravel pit is located in an area of hummocky terrain.

Person naming unit.--William N. Mode. First used as an informal unit name by LaBerge and Myers (1971). Subsequently used by Stewart (1973), Mode (1976) and others.

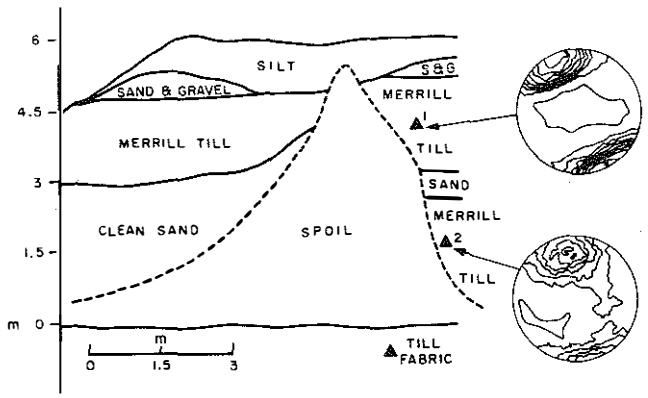

FIGURE 16.--Type section of the Merrill Member (from Stewart, 1973). Fabric diagrams are lower hemisphere, equal-area stereo net plots of till-clast fabric. First contour is 1 sigma; contour interval is 2 sigma.

APPENDIX 4

PIERCE FORMATION

Source of name.--Pierce County, in west-central Wisconsin.

Type section.--Same as the Hersey Member, Appendix 4a.

Reference section.--Type sections and reference sections of the Hersey and Kinnickinnic Members serve as reference sections for this formation (Appendix 4a and b).

Description of unit.--The Pierce Formation includes gray calcareous till and associated yellowish brown sand and gravel as well as laminated silt and clay of glacial lacustrine origin. At the present time, two members are recognized. The older, the Hersey Member, contains gray calcareous till of western origin that averages 42 percent sand, 33 percent silt, and 25 percent clay. This is overlain by the Kinnickinnic Member, a laminated lacustrine sediment deposited in ice-marginal lakes, which averages 14 percent sand, 66 percent silt, and 20 percent clay. To date, the sand and gravel in this formation has not been studied carefully.

Nature of contacts.--This formation is the surficial unit in southern Pierce and western Dunn, Pepin, and Buffalo Counties. In northern Pierce and most of St. Croix County it is overlain by the River Falls Formation, which contains reddish-brown till and associated sand and gravel from the Lake Superior area. This contact is everywhere sharp and is commonly erosional in nature. The basal contact is unknown except where the Hersey Member lies on Paleozoic bedrock.

Differentiation from other units.--Till of this formation is distinguished from till of the overlying River Falls Formation primarily on the basis of its gray color. Secondary differentiation can be made by the much higher sand content of the River Falls Formation and by the distinctive clay mineralogy of the Hersey Member.

Regional extent and thickness.--The thickness of the Pierce Formation ranges from less than a metre on the tops of some bedrock highs to at least 55 m in southern Pierce County. The Hersey Member extends to the east as the surface deposit into western Buffalo, Pepin, and Dunn Counties (fig. 2). The northern extent of the Hersey Member beneath the River Falls Formation is unknown at this time. However, exposures of what appears to be the Hersey Member have been found in southwestern Barron and west-central Polk Counties. Thus, it appears that the Hersey Member was deposited by the eastern edge of a large glacial lobe. The Kinnickinnic Member is confined to the present valleys of the Kinnickinnic, Rush, Trimbelle, Chippewa, and Buffalo Rivers (fig. 2). It is found at altitudes below about 366 m and was deposited in ice-marginal lakes on the east side of the glacier that deposited the Hersey Member.

Age and correlation.--Five radiocarbon dates have been obtained from wood and peat from within the Hersey Member. Three of the dates are infinite, ranging from greater than 38,000 to greater than 45,000 B.P., and two are finite dates of about 30,000 B.P. (Black, 1959; 1974 and Baker and Simpson, 1981). Recent paleomagnetic investigations, however, suggest that the finite radiocarbon dates are erroneous. Results of alternating-field demagnetization show that both the lower Hersey and Kinnickinnic Members are reversely magnetized, whereas the upper portions of these members have normal remanent magnetization. The possible ages of this unit are discussed in Baker and others (in press). It probably was deposited before the Illinoian.

Person naming unit.--Robert W. Baker. This is the first use of this unit name.

APPENDIX 4a

HERSEY MEMBER OF THE PIERCE FORMATION

Source of name.--The rural locality of Hersey, eastern St. Croix County, in the northwest quadrant of the Wilson 7.5-minute quadrangle.

Type of section.--On the west side of an abandoned gravel pit, north of Highway 12, and approximately 0.6 miles (1 km) southwest of Hersey, SW¼SE¼SE¼ sec. 29, T. 29 N, R 15 W, located on the Wilson 7.5-minute quadrangle (fig. 17).

Reference section.--Lower till in Northwestern Railroad cut in the town of Woodville, SE¼NW¼NW¼ sec. 35, T. 29 N., R. 16 E., located on the Baldwin East 7.5-minute quadrangle (fig. 18).

Description of unit.--The till of the Hersey Member is predominantly structureless and in the unweathered state, strongly calcareous. Its color ranges vertically within the weathering profile from yellowish brown (10YR 5/4 to 6) in the oxidized zone to dark gray (10YR 4/1) in the unoxidized zone. The Hersey Member is deeply weathered, with a solum of up to 2.9 m thick and leaching to a depth of up to 3.5 m. The unweathered Hersey Member is loam averaging 42 percent sand, 33 percent silt, and 25 percent clay rather consistently throughout Pierce and St. Croix Counties. The weathered Hersey Member is typically a clay loam with the particle-size distribution depending on the position in the solum. Pebble lithologies average 43 percent igneous, 16 percent metamorphic, and 41 percent sedimentary rock types (samples counted at eight sites). The clay mineralogy of the Hersey Member is quite distinctive. In all profiles, vermiculite drops to either 5 percent or 0 in the lower portion of the B horizon and is totally absent from the C horizon. Other clay minerals average 50 to 60 percent montmorillonite, 25 to 30 percent kaolinite, 15 percent mica (illite), 5 to 10 percent quartz, and 0 to 5 percent chlorite.

Nature of contacts.--Because it is thick and deeply buried in northern Pierce and St. Croix Counties, the lower contact of the Hersey Member is unknown except where the member overlies Paleozoic bedrock. The upper contact, where it is buried by the River Falls Formation, is always sharp, with a truncated paleosol in the Hersey Member frequently observable. In the major river valleys of west-central Wisconsin, the Hersey Member is overlain by the Kinnickinnic Member, a glaciolacustrine deposit (fig. 2). The boundary between these members is commonly of a gradational, interfingering type. However, in several exposures in southern Pierce County, the boundary is quite sharp.

Differentiation from other units.--The till of the Hersey Member is similar to gray till of Late Wisconsinan age deposited by the Grantsburg Sublobe in western Wisconsin. However, the two are easily distinguishable on the basis of stratigraphic position, shale content, and by vastly different sola thicknesses; they are everywhere separated by one or more red till units and the solum thickness of the Hersey Member is on the average five times thicker than the Wisconsinan till. The Hersey Member can be distinguished from the overlying River Falls Formation on the basis of its dark gray color, its lower sand but higher silt content, and its lower vermiculite and higher montmorillonite content.

Regional extent and thickness.--The Hersey Member is the surface unit in southern Pierce and western Buffalo, Pepin, and Dunn Counties. Its northern extent is unknown due to burial by the River Falls Formation and several units of Late Wisconsinan age in the St. Croix moraine complex. However, deep exposures of what appears to be the Hersey Member have been found in southwestern Barron and western Polk Counties. The thickness of the Hersey Member is variable, ranging from less than a metre over uplands to greater than 55 m

in southern Pierce County. In many areas, however, its exact thickness is unknown.

Origin.--The calcareous nature, color, texture, and clay mineralogy and pebble content of the Hersey Member are typical of glacial deposits in Iowa and Minnesota that have northwestern sources (Manitoba area). This is further supported by till fabric measurements and the distribution of the member, which suggest that it was deposited by the eastern edge of a large glacial lobe that advanced into Wisconsin from the northwest.

Age and correlation.--The Hersey Member may have been deposited before the Illinoian. See Appendix 4, the Pierce Formation, for details on age determination. The Hersey Member correlates with the "old gray drift", mapped by Ruhe and Gould (1954) in southeastern Minnesota as Kansan in age. In addition, its color, particle-size distribution, pebble, and clay mineralogy and degree of soil development are nearly identical to the pre-Illinoian Wolf Creek Formation (Hallberg, 1980) in eastern Iowa (Baker and others, in press).

Description of type section.--The type section is located about 200 m north of Highway 12, in a 10 m-high exposure on the west side of an abandoned gravel quarry. The soil profile description of the type section is given below.

	Depth (m)	Horizon	Description
WISCONSINAN Loess	0-0.20	Ap	Very dark grayish brown (10YR 3/2) silt loam; weak granular structure; very friable; abrupt smooth boundary.
	0.20-0.31	Bt1	Dark yellowish brown (10YR 4/4) clay loam to silty clay loam; moderate subangular blocky structure; friable, clear wavy boundary.
TILL OF THE HERSEY MEMBER	0.31-0.92	2Bt2	Brown to dark brown (7.5YR 4/4) clay loam; moderate prismatic breaking to strong subangular blocky structure; gradual wavy boundary.
	0.92-1.13	2Bt3	Brown to dark brown (7.5YR 4/4) clay loam; strong subangular blocky structure; friable; clear, wavy boundary.
	1.13-1.38	2Bt4	Yellowish brown (10YR 5/6) clay loam; strong subangular blocky structure; friable; gradual wavy boundary.
	1.38-1.93	2BCK1	Yellowish brown (10YR 5/6) loam; strong angular blocky structure; firm; strongly calcareous; gradual wavy boundary.
	1.93-2.32	2BCK2	Yellowish brown (10YR 5/4) loam; moderate, angular blocky structure; firm; strongly calcareous gradual wavy boundary.
	2.32-2.80	2C1	Yellowish brown (10YR 5/4) loam; structureless; firm; calcareous; gradual wavy boundary.
	2.80-3.18	2C2	Yellowish brown (10YR 5/4) loam; structureless, massive; very firm; strongly calcareous; abrupt wavy boundary.
	3.18+	2C3	Dark gray (10YR 4/1) loam; structureless; massive; very firm; strongly calcareous.

Description of reference section.--The reference section is located at the base of a 20 m high railraod cut in the town of Woodville. The soil profile description of the reference section is given below.

	Depth (m)	Horizon	Description
WISCONSINAN Loess	0-0.28	A	Very dark grayish brown (10YR 3/2) silt loam; moderate granular structure; very friable; clear smooth boundary.
	0.28-0.40	E	Brown (7.5YR 5/4) silt loam; weak and fine subangular blocky structure; friable; clear smooth boundary.
RIVER FALLS FORMATION Till	0.40-0.53	2Bt1	Yellowish red (5YR 4/6) light sandy clay loam; fine and moderate subangular blocky structure; friable; slightly sticky and slightly plastic; gradual smooth boundary.
	0.53-0.73	2Bt2	Yellowish red (5YR 4/6) sandy loam; medium and moderate subangular blocky structure; friable; slightly sticky and slightly plastic; gradual smooth boundary.
	0.73-1.20	2Bt3	Yellowish red (5YR 4/6) heavy sandy clay loam; moderate subangular blocky structure; friable; sticky and plastic; common, distinct light brown (7.5YR 6/4) ped face coatings; gradual smooth boundary.
	1.20-1.78	2Bt4	Yellowish red (5YR 4/6) sandy clay loam; weak subangular blocky structure; friable to firm; sticky and plastic; common; prominant light brownish gray (10YR 6/2) and (7.5 YR 6/4) mottles.
	1.78-3.45	2C1	Yellowish red (5YR 4/6) sandy clay loam; structureless massive; friable; sticky and plastic; few prominant (7.5YR 6/4) mottles.
	3.45-5.15	2C2	Yellowish red (5YR 4/6) sandy clay loam; structureless massive; friable; sticky and plastic.
	5.15-12.27	3C3	Yellowish brown (10YR 5/8) sands, coarse sands and gravels; structureless; single grain; non-calcareous, and brownish yellow sands and gravels; structureless; single grain.
	12.27-13.50	3C4	Pale brown (10YR 6/3) sands and gravels; structureless; single grain; calcareous.
PIERCE FORMATION Hersey Member Till	13.50-13.80	4Btb1	Dark yellowish brown (10YR 4/4) clay loam; structureless massive; very firm sticky and plastic; non-calcareous.
	13.80-14.00	4Btb2	Yellowish brown (10YR 5/4) clay loam; structureless massive; very firm; sticky and plastic; non-calcareous.
	14.00+	4C	Dark gray (10YR 4/1) loam; structureless massive; very firm; calcareous.

Person naming unit.--Robert W. Baker. This name was first used for this unit by Baker and Simpson (1981), and is formalized here.

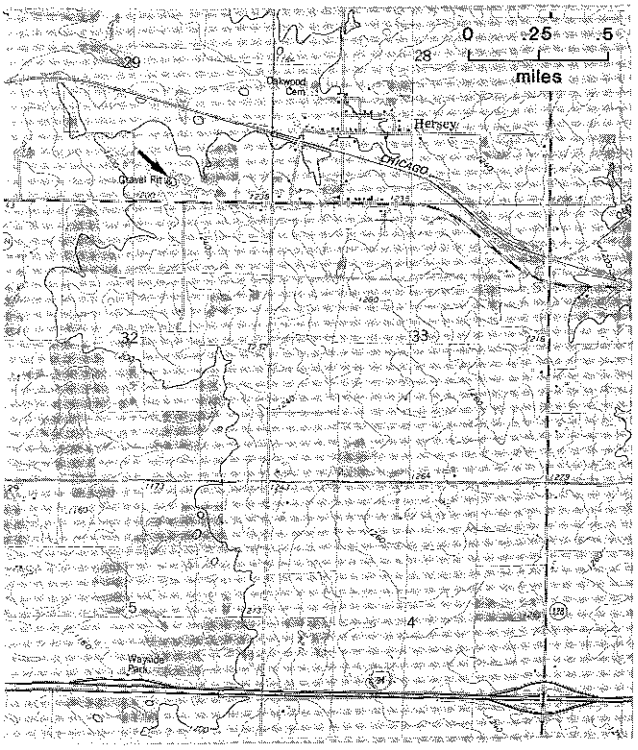

FIGURE 17.--Part of the Wilson 7.5-minute quadrangle showing the location of the type section of the Hersey Member.

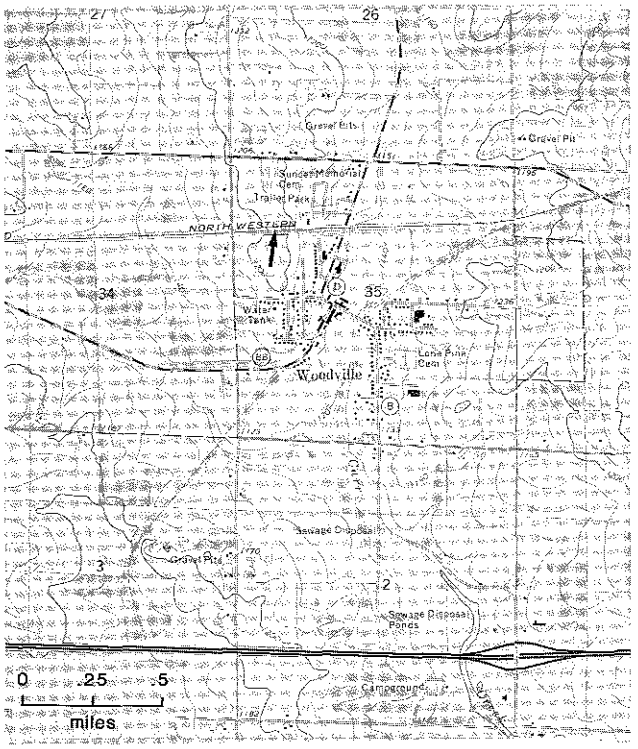

FIGURE 18.--Part of the Baldwin East 7.5-minute quadrangle showing the location of the reference section of the Hersey Member.

APPENDIX 4c

KINNICKINNIC MEMBER OF THE PIERCE FORMATION

Source of name.--The Kinnickinnic River located in western St. Croix and Pierce Counties, terminating in the St. Croix River about 6 miles (10 km) north of the town of Prescott.

Type of section.--Stream embankment about 400 m north of Highway FF, Pierce County, SE¼SW¼SW¼ sec. 12, T. 27 N., R. 19 W., located on the River Falls West 7.5-minute quadrangle (fig. 19).

Reference section.--Stream embankment about 500 m north of Highway FF, Pierce County, SW¼NW¼ sec. 15, T. 27 N., R. 19 W., located on the River Falls West 7.5-minute quadrangle (fig. 20).

Description of unit.--The Kinnickinnic Member consists of thinly laminated calcareous glacial lacustrine sediment. Its color ranges vertically within the weathering profile from very dark grayish brown (10YR 3/2) in the oxidized zone to dark gray (10YR 4/1) in the unoxidized zone. The Kinnickinnic Member is silt loam, averaging 14 percent sand, 66 percent silt, and 20 percent clay. Because of its high silt and clay content, the Kinnickinnic Member has a low permeability and consequently has undergone rather limited soil development; the solum has a thickness of generally less than 2 m and leaching rarely occurs to depths in excess of 2.8 m. The Kinnickinnic Member averages 50

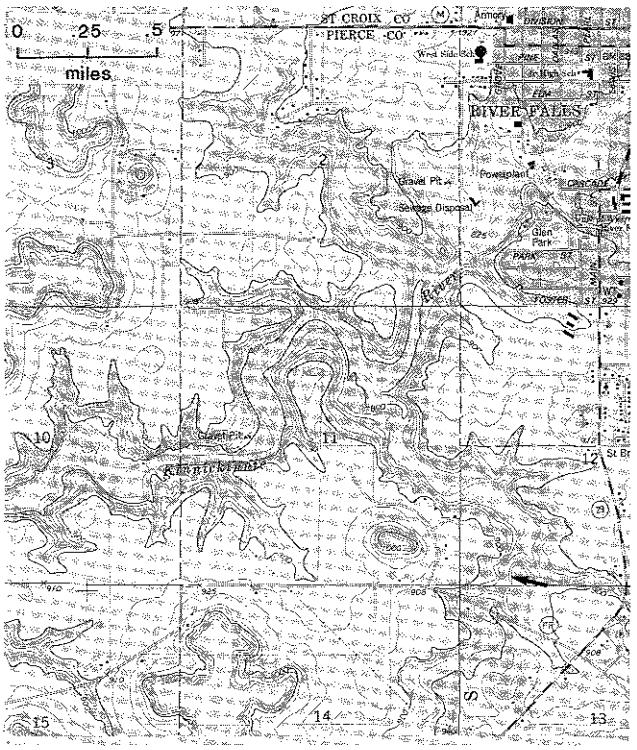

FIGURE 19.--Part of the River Falls West 7.5-minute quadrangle showing the location of the type section of the Kinnickinnic Member.

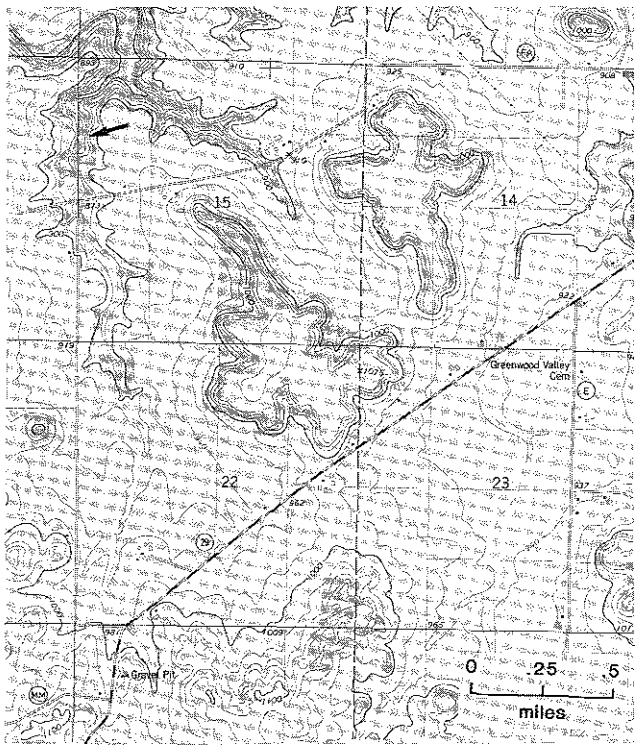

FIGURE 20.--Part of the River Falls West 7.5-minute quadrangle showing the location of the reference section of the Kinnickinnic Member.

percent montmorillonite, 25 percent kaolinite, 15 percent mica (illite), and 10 to 15 percent vermiculite.

Nature of contacts.--The lower contact between the Kinnickinnic Member and the Hersey Member, where visible, is variable, ranging from sharp to interfingering. In areas where it is buried by the River Falls Formation, the upper contact of the Kinnickinnic Member is abrupt and sharp.

Differentiation from other units.--The Kinnickinnic Member is readily distinguishable from other units in western Wisconsin largely on the basis of its distinctive, thinly laminated nature. It can also be differentiated on the basis of its high silt and clay content (more than 80 percent) and its dark gray color.

Regional extent and thickness.--The Kinnickinnic Member is at elevations below about 1200 feet (366 m) in the valleys of the Kinnickinnic, Trimbelle, Rush, Chippewa, and Buffalo Rivers. Its distribution in these valleys is not uniform due to episodes of cutting and filling that have occurred subsequent to its deposition. In the Kinnickinnic, and upper Trimbelle and Rush River valleys, the Kinnickinnic Member is buried beneath the River Falls Formation. Because the lower contact of the Kinnickinnic Member is frequently not observable, its maximum thickness is unknown. Based on measurements made in vertical exposures and from hand augering, its thickness is known to be over 21 m.

Origin.--The Kinnickinnic Member was deposited in an extensive, interconnecting network of glacially dammed lakes. The glacial advance that deposited the Hersey Member also blocked the drainage of the Kinnickinnic, Trimbelle, Rush,

Chippewa, and Buffalo Rivers, forming a series of proglacial lakes. As the glacier retreated from its maximum position, these lakes lengthened to the southwest. Based on the distribution of the Kinnickinnic Member in these valleys, the lake complex covered an area of over 5800 km^2. Estimates of sedimentation rates by counting varves indicate that these lakes existed for a minimum of 1200 years.

Age.--The deposition of the Kinnickinnic Member probably took place in pre-Illinoian time. See Appendix 4, the Pierce formation, for details on age determination.

Correlation.--No correlative is known to exist in either Wisconsin or Minnesota at this time.

Description of type section. The type section is located about 400 m north of Road FF in a 11 m-high stream embankment. The soil profile description of the type section is given below.

	Depth (m)	Horizon	Description
	0.08-0		Very dark grayish brown (10YR 3/2) loamy sand; weak granular structure; very friable.
Colluvial Material	0-0.16	A	Black (10YR 2/1) loamy sand; weak subangular blocky structure; very friable; clear wavy boundary.
	0.16-0.24	C1	Yellowish brown (10YR 5/6) loamy sand; weak subangular blocky structure; very friable; clear wavy boundary.
	0.24-0.46	2C2	Brown (10YR 5/3) sandy loam with many distinct mottles; platy structure; wavy boundary.
	0.46-0.69	2C3	Yellowish brown (10YR 5/6) silt loam; platy structure; clear, smooth boundary.
Kinnickinnic Member	0.69-1.20	2C4	Yellowish brown (10YR 5/4) silt loam with many faint 10YR 5/6 mottles; platy structure; abrupt boundary.
	1.20+	2C5	Dark gray (5YR 4/1) silty clay loam with dark yellowish brown (10YR 4/6) sandy laminae; platy structure.

Description of reference section.--The reference section is located about 500 m north of Road FF, in a 17 m high exposure on the east bank of an intermittent tributary to the Kinnickinnic River. The soil profile description of the reference section is given below.

	Depth (m)	Horizon	Description
	0-0.08	A	Dark grayish brown (10YR 4/2) sandy loam; moderate granular structure; very friable; clear, wavy boundary.
Colluvial Material	0.08-0.20	AB	Dark grayish brown (10YR 4/2) sandy loam; weak subangular blocky structure very friable; clear, wavy boundary.
	0.20-0.33	BA	Dark yellowish brown (10YR 4/4) sandy loam, weak subangular blocky structure; friable; wavy boundary.
	0.33-0.51	BW	Strong brown (7.5YR 5/6) sandy loam; weak subangular blocky structure; friable, abrupt boundary.
	0.51-1.38	2C1	Yellowish brown (10YR 6/8) silt loam; strong angular blocky structure; wavy boundary.
Kinnickinnic Member	1.38-7.84	2C2	Dark gray (5YR 4/1) silty clay loam with dark yellowish brown (10YR 4/6) lamina; platy structure.
	7.84+	3C	Olive yellow (2.5Y 6/8) sand.

Person naming unit.--Robert W. Baker. This is the first use of this unit name.

APPENDIX 5

RIVER FALLS FORMATION

Source of name.--The city of River Falls, in the northwest quadrant of the River Falls West 7.5-minute quadrangle, southern Pierce County.

Type section.--On the south side of an abandoned gravel quarry 300 m south of Road E, approximately 2.5 miles (4 km) northeast of Baldwin, SE¼NE¼NE¼ sec. 18, T. 29 N., R. 16 W., located on the Emerald 7.5-minute quadrangle, St. Croix County (fig. 21).

Reference section.--On the west side of an abandoned gravel pit on Pleasant Valley Road, approximately 8 km southeast of River Falls, SW¼SW¼NE¼ sec. 28, T. 27 N., R. 18 W., located on the River Falls East 7.5-minute quadrangle (fig. 22).

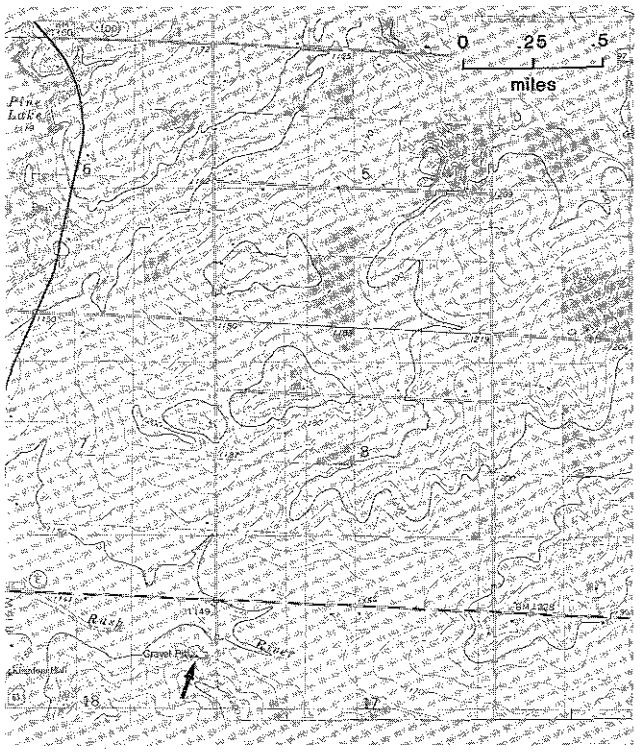

FIGURE 21.--Part of the Emerald 7.5-minute quadrangle showing the location of the type section of the River Falls Formation.

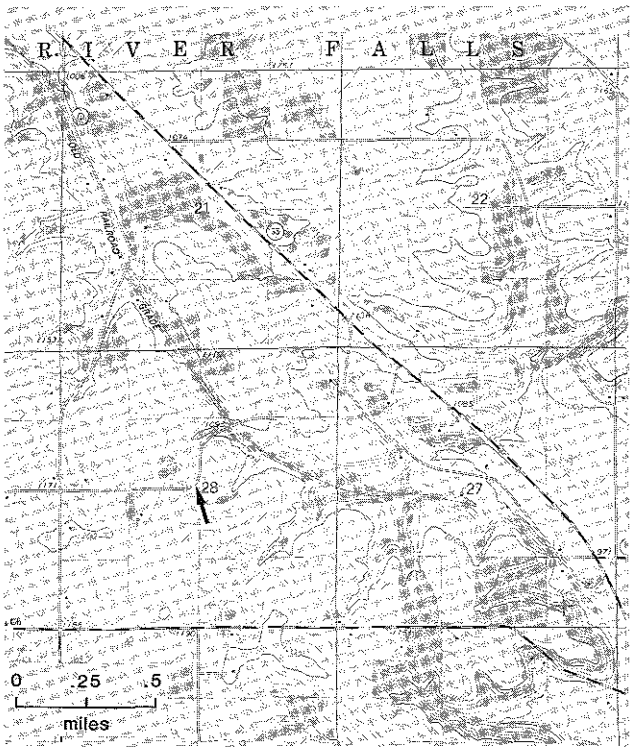

FIGURE 22.--Part of the River Falls East 7.5-minute quadrangle showing the location of the reference section of the River Falls Formation.

Description of unit.--Most of the till of the River Falls Formation is structureless basal till. However, locally in St. Croix County the upper portion of the unit is weakly stratified, containing discontinuous lenses of fine sand, and is probably of supraglacial origin. The color of the River Falls till varies vertically within the weathering profile from yellowish red (5YR 4/6) in the argillic horizon to reddish brown (5YR 4/4) in the C horizon. The River Falls Formation is deeply weathered with solum thicknesses of up to 2.8 m. The unweathered till is sandy clay loam averaging 60 percent sand, 15 percent silt, and 25 percent clay. The weathered River Falls till is also sandy clay loam; however, the particle-size varies somewhat depending on the position in the solum. Pebble lithologies average 64 percent igneous, 11

percent metamorphic, and 25 percent sedimentary rock types (samples counted at nine sites). The clay of the River Falls till averages 30 to 40 percent montmorillonite, 20 to 25 percent kaolinite, 15 to 20 percent vermiculite, 5 to 10 percent mica (illite), and as much as 5 percent quartz.

Nature of contacts.--The lower contact of the River Falls Formation, separating it from the underlying Hersey Member, is everywhere sharp and abrupt. Likewise, the upper contact between the River Falls Formation and the till and associated sand and gravel of the Late Wisconsinan age St. Croix moraine is also, where observable, sharp and distinct.

Differentiation from other units.--The till of the River Falls Formation is similar to reddish-brown till of the St. Croix moraine. However, the two can easily be distinguished by their considerably different sola thicknesses. The solum thickness on till in the St. Croix moraine rarely exceeds 0.9 m, whereas in the River Falls Formation the solum commonly exceeds 2.2 m in thickness. The River Falls can be distinguished from the underlying Hersey Member on the basis of its reddish brown color, its higher sand and lower silt content, and its higher vermiculite and lower montmorillonite content.

Regional extent and thickness.--The River Falls Formation is the surface unit in northern Pierce, eastern St. Croix, and western Dunn Counties. Its northern extent is unknown due to burial by the thick deposits of the St. Croix moraine. The thickness of the River Falls Formation ranges from less than 1 m on bedrock uplands to more than 10 m in St. Croix County. In many areas, however, its exact thickness is unknown.

Origin.--The color, texture, and clay and pebble mineralogy of the River Falls Formation are characteristic of sediment derived from the Lake Superior basin. This is supported by till fabric data, which suggest that till of the formation was deposited by a glacier that advanced from the north-northeast.

Age.--The age of the River Falls Formation is unknown. Based on its thick solum, it is likely that the River Falls is Early Wisconsinan or older.

Correlation.--The till of the River Falls Formation correlates with the "red drift" of the Hampton moraine of Minnesota, mapped by Ruhe and Gould (1954). It also appears to correlate with the Hawk Creek Till of western Minnesota (Matsch, 1972). Correlation with pre-Late Wisconsinan units to the east in Wisconsin is uncertain at this time.

Description of type section.--The type section is located about 300 m south of Highway E, in a 13-m-high exposure on the south side of an abandoned gravel pit. The soil profile description of River Falls till at the type section is given below.

Type Section of River Falls Formation

	Depth (m)	Horizon	Description
Loess	0-0.20	Ap	Dark brown (10YR 3/3) loam; weak, granular structure; very friable; clear smooth boundary.
	0.20-0.38	E	Dark yellowish brown (10YR 4/4) silty clay loam; moderate subangular blocky structure; friable, clear wavy boundary.
River Falls Formation Till	0.38-0.76	2Bt1	Dark reddish brown (5YR 3/4) sandy loam to sandy clay loam; moderate subangular blocky structure; friable, gradual wavy boundary.
	0.76-0.96	2Bt2	Reddish brown (5YR 4/4) sandy clay loam; weak subangular blocky structure; friable; gradual wavy boundary.
	0.96-1.40	2Bt3	Yellowish red (5YR 4/6) sandy clay loam with grayish brown (10YR 5/2) inclusions, weak subangular blocky structure; friable, gradual wavy boundary.
	1.40-2.16	2C	Yellowish red (5YR 4/6) sandy clay loam with dark gray (10YR 4/1) and light brownish gray (10YR 6/2) inclusions, weak subangular blocky structures; friable; abrupt, wavy boundary.
Sand and Gravel	2.16-2.81	3Btb	Dark brown (7.5YR 4/4) sandy clay loam; moderate, subangular blocky structure; friable; gradual wavy boundary.
	2.81-3.50	3C	Dark reddish brown (5YR 3/4) sandy clay loam to sandy loam; strong medium and coarse angular to subangular blocky structure; slightly compact in place. Few lenses of gray till.

Description of reference section.--The reference section is located about 50 m south of Pleasant Valley Road, in a 5-m-high exposure on the west side of an abandoned gravel pit. The soil profile description of the reference section is given below.

	Depth (m)	Horizon	Description
Wisconsinan Loess	0-0.23	Ap	Brown to dark brown (10YR 4/3) silt loam; weak granular structure; very friable; wavy boundary.
	0.23-0.35	BA	Dark yellowish brown (10YR 4/4) loam; weak subangular blocky structure; very friable; abrupt wavy boundary.
Till of the RIVER FALLS FORMATION	0.35-0.40	2Bt1	Reddish brown (7.5YR 4/4) sandy clay loam; moderate subangular blocky structure; friable; clear wavy boundary.
	0.40-0.94	2Bt2	Reddish brown (5YR 4/4) sandy clay loam; moderate subangular blocky structure; friable; common patches of sand; diffuse wavy boundary.
	0.94-1.35	2Bt3	Reddish brown (5YR 4/4) sandy clay loam; moderate subangular blocky structure; friable; clear wavy boundaries.
	1.35-2.20	2BC	Yellowish red (5YR 4/6) sandy loam; moderate subangular blocky structure; friable; clear wavy boundary.
	2.20-2.54	2C1	Reddish brown (5YR 4/4) sandy clay loam; structureless; very friable.
Sand and Gravel of the PIERCE FORMATION	2.54+	3C	Olive yellow (2.5Y 6/8) sand.

Person naming unit.--Robert W. Baker. First use of this name is in this paper. This unit was called the Baldwin till by Baker and Simpson (1981).

APPENDIX 6

ZENDA FORMATION

Source of name.--The rural locality of Zenda, south-central Walworth County, located on the Lake Geneva 7.5-minute quadrangle.

Type section.--Road cut on south side of Highway B, immediately east of intersection with Hillside Road, 1.1 miles (1.8 km) northeast of Zenda, NW¼NW¼SW¼ sec. 26, T. 1 N., R. 17 E., Walworth County, located on the Lake Geneva 7.5-minute quadrangle (fig. 23).

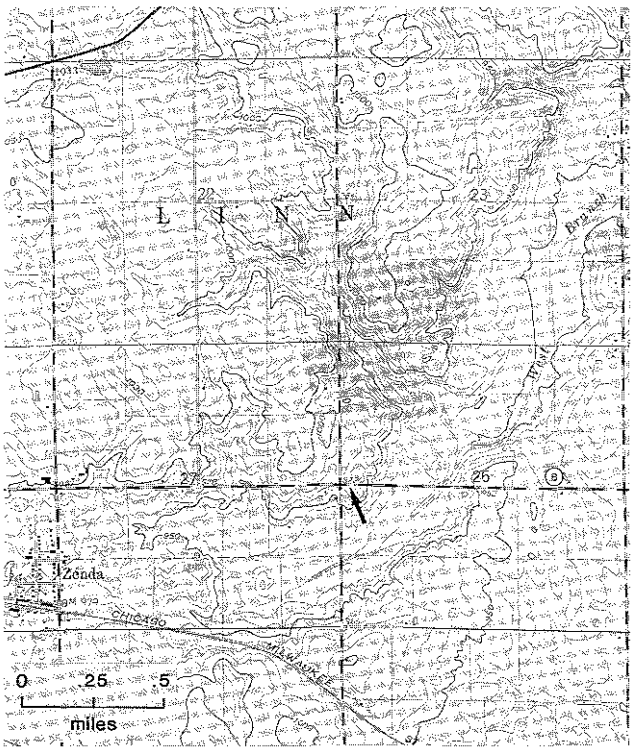

FIGURE 23.--Part of the Lake Geneva 7.5-minute quadrangle showing the location of the type section of the Zenda Formation and reference section (1) of the Tiskilwa Member.

Reference sections.--The type sections of the Capron and Tiskilwa Members of the Zenda Formation, both of which are described in the descriptions of those members (Appendixes 6a and 6b), serve as reference sections. Because both members are named from localities in Illinois, the reference sections are located in that state rather than in Wisconsin.

Description of unit.--The Zenda Formation includes two members, the Capron Member and the Tiskilwa Member. Both consist mainly of till that is pink, calcareous, and medium textured. Till of the Tiskilwa or upper member is, however, sandier and more pink, commonly having a 5YR hue, in contrast to the 7.5YR hue of Capron till (Bleuer, 1970, p. J-11 to J-13). Both members appear to have more sandy and more silty phases, and both contain some outwash sand.

Nature of contacts.--Little is known about the contact relationship of the Zenda Formation with the older Clinton Member of the Walworth Formation. The contact of the Zenda with the younger New Berlin Formation ranges from exceedingly sharp to gradational.

Differentiation from other units.--Tills of this formation are distinguished from those of the older Walworth Formation and the younger New Berlin Formation by their pinker color and lower sand content. However, in some places

where the till member of the New Berlin directly overlies the upper or Tiskilwa Member of the Zenda Formation it is difficult to distinguish between the two units; the sandy phase of the Tiskilwa is, in fact, almost indistinguishable in the field from New Berlin till that contains assimilated Tiskilwa till. This is particularly the case in much of Alden's (1918) Elkhorn moraine, where a thin discontinuous blanket of New Berlin till overlies the Tiskilwa Member. Generally, however, New Berlin till has a higher pebble and sand content than the Tiskilwa.

Regional extent and thickness.--The Zenda Formation has a very limited distribution. It occurs at the surface only in Walworth County in the southeastern part of the state (fig. 2). On the north and east it is overlapped by the New Berlin Formation; isolated exposures of Zenda till occur at a number of places east of this boundary in eastern Walworth and western Racine Counties, but its precise geographic distribution in the subsurface is not very well known.

Origin.--The Zenda Formation was deposited by glacier ice and associated meltwaters of the Lake Michigan Lobe.

Age.--Both members are considered to be Wisconsinan age. The formation may range in age from 18,000 or 20,000 years to 30,000 or 35,000 years. The lower, or Capron, Member is considered late Altonian in Illinois because it occurs between two radiocarbon-dated organic units. The older of these (the Plano Silt Member of the Winnebago Formation of Illinois) is more than 40,000 years old, and the younger (the Robein Silt of Illinois) is as old as 28,000 years (Willman and Frye, 1970). Thus the age of the lower part of the Zenda is estimated to be about 30,000 to 35,000 years old. The upper or Tiskilwa Member is considered to have been deposited in the early part of Late Wisconsinan time, or about 18,000 to 20,000 years ago.

Correlation.--Correlation of the Zenda Formation with other stratigraphic units in Wisconsin is unclear. Possibly the uppermost part of the formation correlates with the lower part of the Copper Falls Formation in the northwestern part of the state.

Description of type section.--Approximately 2.5 m of the Tiskilwa Member is well exposed at the type section of the Zenda Formation; the Capron Member is not present. Two phases of Tiskilwa till occur in the cut; one facies contains about 42 percent sand, 36 percent silt, and 22 percent clay and the other about 65 percent sand, 24 percent silt, and 11 percent clay. The former is more typical of the Tiskilwa in southern Wisconsin than the more sandy phase. No significant difference in the clay-mineral content of the two facies is apparent; analyses of three samples of the finer phase by H. D. Glass of the Illinois State Geological Survey average 24 percent expandable clay minerals, 66 percent illite, and 10 percent kaolinite plus chlorite, whereas two samples of the more sandy facies average 22 percent expandables, 65 percent illite, and 14 percent kaolinite plus chlorite. Both phases have the 5YR hue that is typical of Tiskilwa till in northern Illinois and southern Wisconsin.

Person naming formation. Allan F. Schneider. This is the first use of this unit name.

APPENDIX 6a

CAPRON MEMBER OF THE ZENDA FORMATION

Source of name.--Village of Capron, northeastern Boone County, Illinois, located on the Capron 7.5-minute quadrangle.

Type section.--Capron North Section, a roadcut 3 miles (5 km) north of Capron, Illinois, NE¼SE¼SE¼ sec. 23, T. 46 N., R. 4 E., Boone County, Illinois, located on the Capron 7.5-minute quadrangle (fig. 24).

Reference section.--Borrow pit in SE¼SW¼SE¼ sec. 5, T. 1 N., R. 15 E., Walworth County, located on the Sharon 7.5-minute quadrangle (fig. 25). According to Bleuer (1971, p. J-12, 13), Capron till overlies medium-grained outwash sand with an almost vertical contact. Apparent inclusions of a leached dark-brown loamy material similar to the B2 horizon of an older till, possibly from the Clinton Member of the Walworth Formation, were found by Bleuer in a zone along and near the contact and also in places in an adjacent roadside exposure.

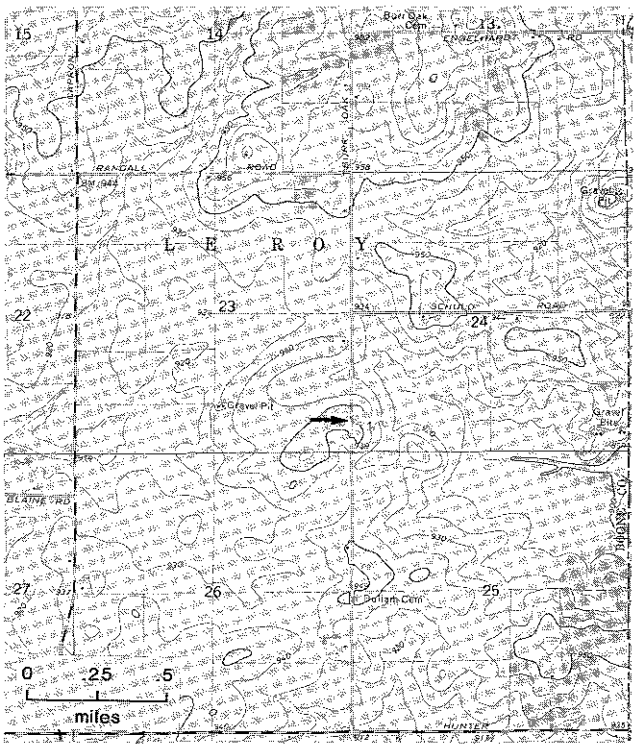

FIGURE 24.--Part of the Capron 7.5-minute quadrangle showing the location of the type section of the Capron Member of the Zenda Formation.

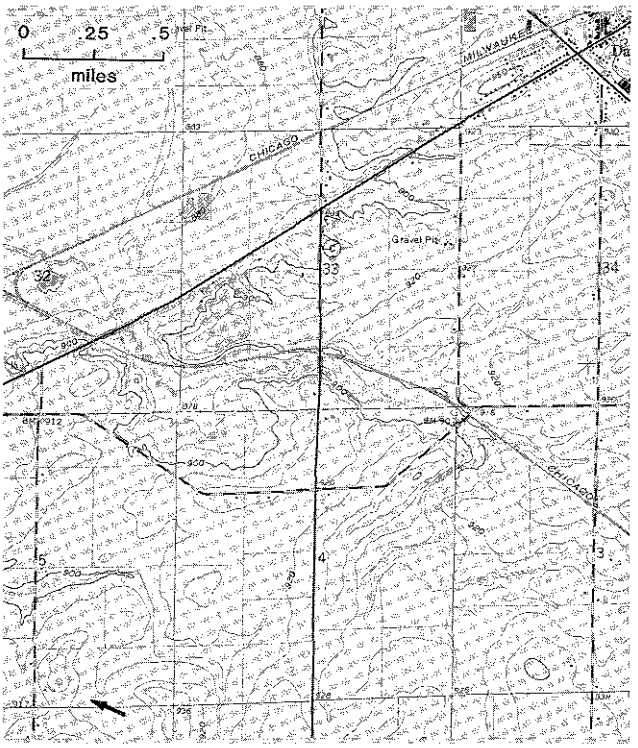

FIGURE 25.--Part of the Sharon 7.5-minute quadrangle showing the location of the reference section of the Capron Member of the Zenda Formation.

Description of unit.--In Illinois the Capron Till Member of the Winnebago Formation consists of calcareous pink till and calcareous sand (Willman and Frye, 1970, p. 64). Two compositional phases of the till are recognized, a lower silty phase and an upper sandy phase. The sandy phase contains more expandable clay minerals and less illite than the silty phase, whereas the latter contains somewhat more calcite in the clay fraction (Frye and others, 1969, p. 26). The Capron till has an intermediate cobble and pebble content; it is pinkish gray to reddish brown in color and is moderately compact and blocky (Frye and others, 1969, p. 26). According to Bleuer (1970, p. J-11), two phases of the till can also be recognized in Wisconsin. The lower phase contains 24 percent sand, 45 percent silt, and 31 percent clay in the matrix; the upper phase has 40 percent sand, 42 percent silt, and 18 percent clay (Bleuer, 1970, p. J-11). Fricke and Johnson (in press) also observed both a silty phase and a sandy phase of Capron till in Wisconsin, but they pointed out that the textural difference is not so marked as in Illinois; the lower

silty phase contains 27 percent sand, 38 percent silt, and 35 percent clay, whereas the upper sandy phase has 41 percent sand, 35 percent silt, and 24 percent clay. They give the clay-mineral composition of both phases as 28 percent montmorillonite, 61 percent illite, and 11 percent chlorite plus kaolinite. The till is moderately compact and calcareous, as in Illinois, and is light brown (7.5YR 6/4) to brown (7.5YR 4/4) in color. Nearly 80 percent of the pebble assemblage is dolomite, and about half of the stones identified by Bleuer (1970, p. J-11) were Niagaran dolomite.

Nature of contacts.--Little is known about the character of either the lower contact with the older Clinton Member of the Walworth Formation or the upper contact with the Tiskilwa Member of the Zenda Formation.

Differentiation from other units.--Till of the Capron Member is distinguished from till of both the older Clinton Member of the Walworth Formation and the younger Horicon Formation by its finer texture and slightly darker or pinker color. It is lithologically similar to till of the Tiskilwa Member of the Zenda Formation, but its color (7.5YR hue) is normally less red than the color (5YR hue) of the Tiskilwa (Bleuer, 1970, p. J-12, 13).

Regional extent and thickness.--The Capron Member is present at the surface only over a small area in southwestern Walworth County in the southeastern part of Wisconsin (fig. 2). Here it is found in the north-south-trending Capron Ridge, which enters Wisconsin at the T-juncton of Walworth County with Boone and McHenry Counties, Illinois. The ridge rises above an outwash plain on the east and is apparently overridden and truncated by the Darien moraine on the north. Along the western margin of the Capron Ridge, the Capron Member blankets the Clinton Member of the Walworth Formation, which occurs at the surface just west of that margin (Fricke and Johnson, in press). Borings on the Capron Ridge indicated that the Capron Member ranges from less than 2 to more than 10 m thick (Bleuer, 1970, p. J-12).

Origin.--Till of the Capron Member was deposited by the Lake Michigan Lobe (Frye and others, 1969, p. 6; Bleuer, 1970, p. J-12). Fricke and Johnson (in press) have suggested that the upper sandy phase may be ablation till and thus imply that the more silty phase might be its basal till equivalent.

Age.--The Capron Member is considered to be Early Wisconsinan age. The age of the Capron Member has been established by stratigraphic relations in Illinois. There the unit overlies the Plano Silt Member of the Winnebago Formation, which is greater than 40,000 radiocarbon years old, and underlies the Robein Silt, which is C-14 dated between 20,000 and 28,000 years old.

Correlation.--It is not possible to correlate the Capron Member with other Quaternary lithostratigraphic units in Wisconsin at this time.

Description of type section.--The Capron North Section in northern Illinois exposes about 0.9 m of Capron till sandwiched between 0.7 m of loess (above) and 1.1 m of calcareous sand. Both the till and the sand belong to the Capron Member. The upper third of the till is leached, the lower part is pink and calcareous (Willman and Frye, 1970, p. 64).

Persons naming member.--John C. Frye, Herbert D. Glass, John P. Kempton, and H. B. Willman (1969) and formally by H. B. Willman and J. C. Frye (1970). (This description written by Allan F. Schneider.)

APPENDIX 6b

TISKILWA MEMBER OF THE ZENDA FORMATION

Source of name.--Village of Tiskilwa, southern Bureau County, Illinois, located on the Buda 15-minute quadrangle.

Type section.--Buda East Section, a roadcut 5 miles (8 km) northwest of Tiskilwa, Illinois, SE¼SE¼SW¼ sec. 31, T. 16 N., R. 8 E., Bureau County, Illinois, located on the Buda 15-minute quadrangle.

Reference section.--(1) Road cut on south side of Highway B immediately east of intersection with Hillside Road, 1.1 miles (1.8 km) northeast of Zenda, NW¼NW¼SW¼ sec. 26, T. 1 N., R. 17 E., Walworth County, located on the Lake Geneva 7.5-minute quadrangle (fig. 23). This section also serves as the type section of the Zenda Formation and is described in Appendix 6. (2) Road cut on south side of Lovers Lane Road, immediately east of T-intersection with Bowers Road, 3.25 miles (5.2 km) northwest of Spring Prairie, northwest corner sec. 13, T. 3 N., R. 17 E., Walworth County, located on the Springfield 7.5-minute quadrangle (fig. 26). About 3 m of reddish-brown (5YR 4/4) Tiskilwa till is exposed here on the south side of the deep Sugar Creek valley. Local relations along the valley strongly suggest that this exposure is in the upper part of the Tiskilwa Member, not far below the contact with the overlying New Berlin Formation.

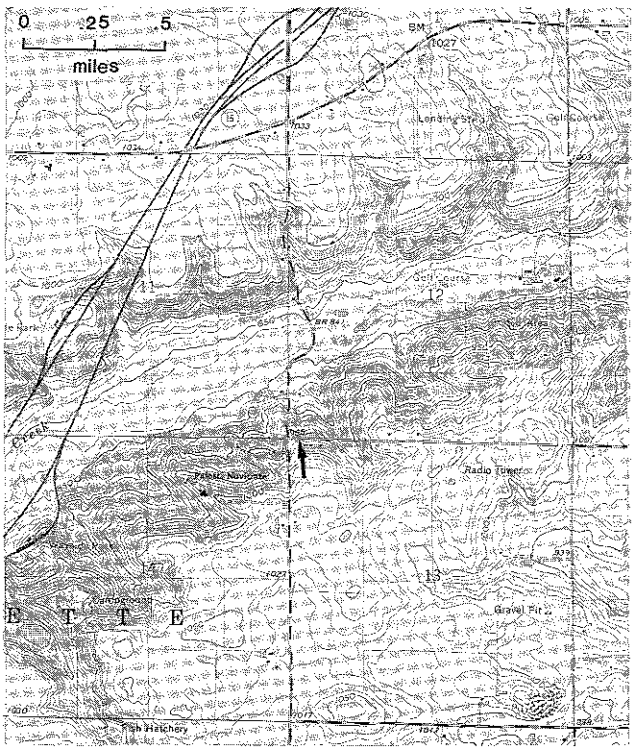

FIGURE 26.--Part of the Springfield 7.5-minute quadrangle showing the location of reference section 2 of the Tiskilwa Member of the Zenda Formation.

Description of unit.--Till of the Tiskilwa Member in Illinois, where the unit was named, is "sandy, pink-tan to reddish tan-brown, and generally is described as pink till" (Willman and Frye, 1970, p. 68). Till of the Tiskilwa Member in Wisconsin is similar. Typically it has a 5YR hue, but it ranges in color from reddish brown (5YR 4/3, 5YR 4/4, 5YR 5/4) or yellowish red (5YR 4/6) to brown (7.5YR 5/4), where oxidized. In a number of places it is about midway between 5YR 4/4 and 7.5 4/4. Where unoxidized, it is commonly dark reddish gray (5YR 4/2) or weak red (2.5YR 4/2). The till is slightly to

moderately stony. Grain-size analyses indicate that the matrix of the till is loam, having an average composition of about 42 percent sand, 35 percent silt, and 23 percent clay. At the first reference section listed above, a more sandy phase of the Tiskilwa is present, in addition to the more typical till. A single sample of the former contains 65 percent sand, 24 percent silt, and 11 percent clay; in contrast, three samples of the more typical till average 42 percent sand, 36 percent silt, and 22 percent clay. It has not yet been determined whether the sandy plase is present elsewhere in the area or not because of the similarity between Tiskilwa till and till of the New Berlin Formation that has been "contaminated" with Tiskilwa till as a result of glacial erosion and assimilation. The clay minerals average about 18 percent expandable clays, 67 percent illite, and 15 percent kaolinite plus chlorite, according to analyses made by H. D. Glass.

Nature of contacts.--Contacts of the Tiskilwa Member with the overlying New Berlin Formation are much better known than contacts with the older Capron Member. In fact, almost nothing is known about the nature of the boundary between the Tiskilwa and Capron. The contact of the Tiskilwa with the overlying New Berlin Formation is generally sharp. In most places, it involves the lower (unnamed sand and gravel) member of the New Berlin; the contact commonly coincides with or occurs just below the floors of gravel pits where the sand and gravel unit is mined. In places, this lower member of the New Berlin Formation is absent, and till of the Tiskilwa Member is directly overlain by till of the New Berlin; the contact is generally sharp. In other places, however, notably where much Tiskilwa till has been incorporated into the New Berlin, the contact is gradational and possibly unrecognizable. Where these tills are similar in texture and color, the contact can be identified only when the moisture content of both tills is moderately high.

Differentiation of other units.--Till of the Tiskilwa Member is lithologically similar, though not identical, to till of the older Capron Member of the Zenda Formation. Both are pink, medium-textured till with approximately the same grain-size distributions. Capron till is less red, however, according to Bleuer (1970, p. J-12), normally having a 7.5YR hue rather than the 5YR hue that is more typical of the Tiskilwa. Tiskilwa till is readily differentiated from both the older Clinton till and the younger New Berlin till by its pinkish color and distinctly finer texture.

Regional extent and thickness.--In northern Illinois (McHenry County), the Tiskilwa Member composes the prominent north-south-trending Marengo moraine, which is the outermost moraine of the Harvard Sublobe (Willman and Frye, 1970, p. 108). Just north of the Wisconsin state line the Marengo moraine is overlapped by the northwest-southeast-trending Darien moraine, the terminal moraine of the Delavan Sublobe (Alden, 1904, 1918; Schneider, 1982), and its proglacial outwash deposits. Thus, the Tiskilwa Member extends into Wisconsin from Illinois in south-central Walworth County. It is exposed at the surface or beneath a blanket of the New Berlin Formation in a belt roughly 7 to 11 miles (11 to 18 km) wide that extends from the state line northward to the Kettle Moraine or its associated outwash deposits. Very probably it is the principal till of Alden's (1918) Elkhorn moraine, which comprises part of this belt for a considerable distance northwest of Lake Geneva. The Tiskilwa is also known to be present at many localities farther east, where it is normally buried beneath thick drift of the New Berlin and Oak Creek Formations. Neither typical nor maximum thickness figures for the Tiskilwa Member are known at this time.

Origin.--Till of the Tiskilwa Member in Wisconsin was most likely deposited as a basal till by the Harvard Sublobe of the Lake Michigan Lobe, which in northern Illinois terminated at the Marengo moraine (Willman and Frye, 1970).

Age.--The age of the Tiskilwa Member is Late Wisconsinan. The unit was probably deposited between 18,000 and 20,000 B.P.

Correlation.--Correlation of the Tiskilwa Member with other lithostratigraphic units in Wisconsin is problematic. Possibly the unit correlates with the lower part of the Copper Falls Formation in the northwestern part of the state.

Description of type section.--The type section of the Tiskilwa Till Member of the Wedron Formation is a road cut, designated as the Buda East Section, in the Bloomington moraine of northern Illinois (Willman and Frye, 1970, p. 68-69). At the base of this cut 1.2 m of massive calcareous pinkish-tan sandy till containing cobbles and small boulders is exposed. This till is overlain by 1.2 m of sand and gravel recognized in Illinois as part of the Henry Formation, which is overlain in turn by 2.4 m of Richland Loess (Frye and Willman, 1965, p. 95; Willman and Frye, 1970, p. 68).

Persons naming member.--H. B. Willman and John C. Frye (1970). (This description written by Allan F. Schneider.)

APPENDIX 7

NEW BERLIN FORMATION

Source of name.--City of New Berlin, southeastern Waukesha County, Wisconsin, located on the Waukesha, Wauwatosa, Muskego, and Hales Corners 7.5-minute quadrangles.

Type section.--Gravel pit complex operated by Kohler Pit, Inc., and New Berlin Redi-Mix, Inc. on north side of Highway I (Lawnsdale Road) 0.5 to 1.0 mile (0.8 to 1.6 km) west of Highway Y (Racine Avenue), SE¼ sec. 19 and SW¼ sec. 20, T. 6 N., R. 20 E., Waukesha County, located on the Muskego 7.5-minute quadrangle (fig. 27).

Reference sections.--(1) Gravel pit operated by Robert Stewart in the village of Fontana, SE¼NW¼NE¼ sec. 15, T. 1 N., R. 16 E., Walworth County, located on the Walworth 7.5-minute quadrangle (fig. 28). (2) Gravel pit operated by R.

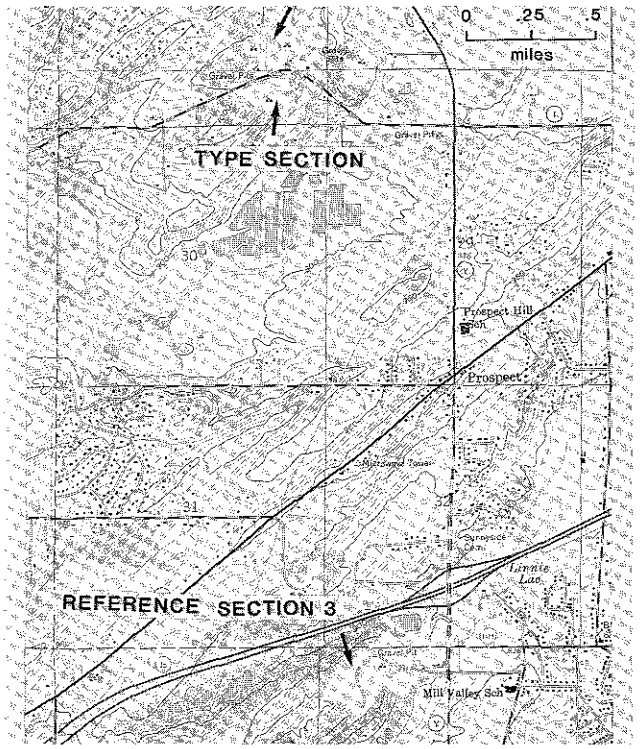

FIGURE 27.--Part of the Muskego 7.5-minute quadrangle showing the locations of the type section and reference section 3 of the New Berlin Formation.

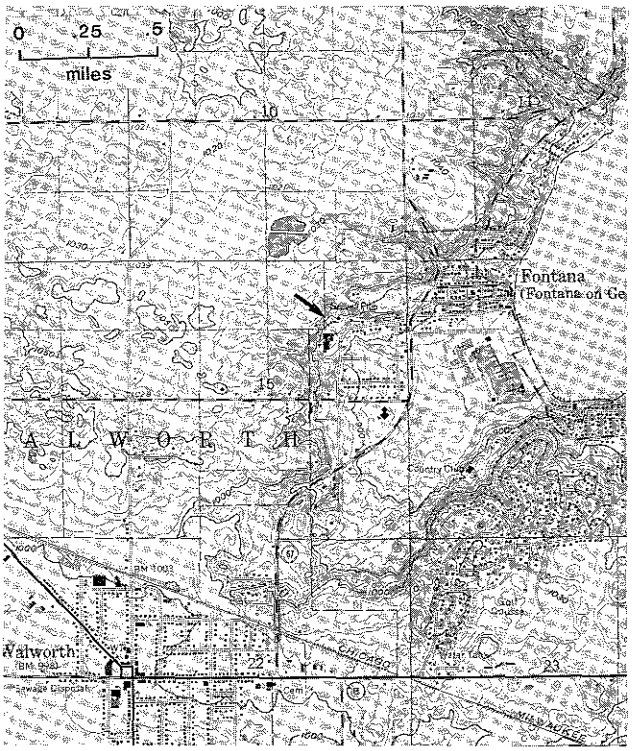

FIGURE 28.--Part of the Walworth 7.5-minute quadrangle showing the location of reference section 1 of the New Berlin Formation.

W. Miller & Sons, Inc., 1 mile (1.6 km) northeast of the city of Lake Geneva on the northwest side of Highway 36, W½ SW¼ sec. 19, T. 2 N., R. 18 E., Walworth County, located on the Lake Geneva 7.5-minute quadrangle (fig. 29). (3) Gravel pit operated by Valley Sand and Gravel Company south of Highway 15 on the west side of Highway Y (Racine Avenue), NW¼ sec. 5, T. 5 N., R. 20 E., Waukesha County, located on the Muskego 7.5-minute quadrangle (fig. 27). At all three of these reference sections both the lower (sand and gravel) member and the upper (till) member of the New Berlin Formation are well exposed. The lower member is the thicker of the two units, generally reaching a thickness

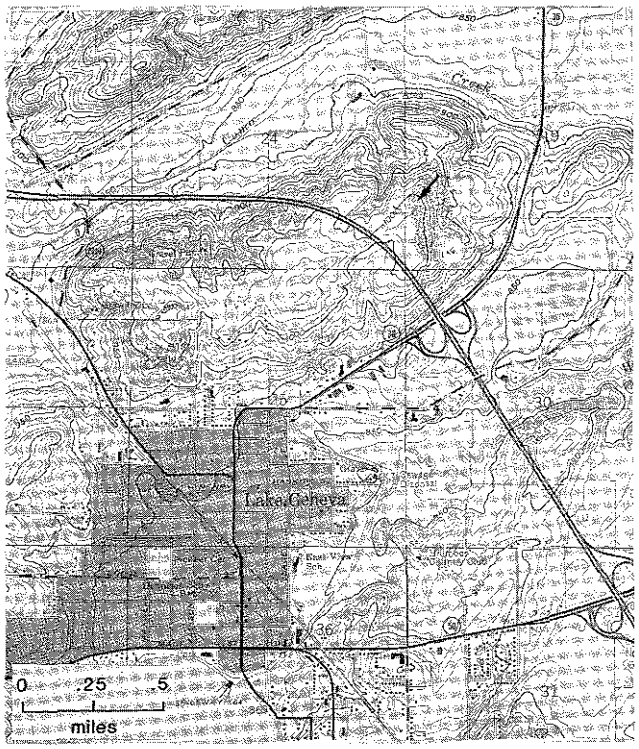

FIGURE 29.--Part of the Lake Geneva 7.5-minute quadrangle showing the location of reference section 2 of the New Berlin Formation.

of 12 or 15 m. The upper member commonly ranges from 2 to 8 m thick at these sections. The contact between the two units is sharp at all three localities. The contact between the lower member and the underlying Tiskilwa Member of the Zenda Formation is well displayed at reference section 2. Both "pure" New Berlin till and "contaminated" New Berlin till can also be observed at the Miller pit. Other significant aspects of the formation visible at these reference sections are described below.

Description of unit.--The New Berlin Formation consists of two principal members, a lower sand and gravel unit and an upper till unit. Both members can be recognized throughout most of the area where the formation is at or near the surface. Neither unit is formally defined at this time, however. The upper member typically is gravelly sandy loam till, averaging about 58 percent sand, 29 percent silt, and 13 percent clay in the matrix (less-than-2-mm fraction). In some places it is considerably more sandy than this, containing as much as 70 or 72 percent sand. In other places, however, it is somewhat less sandy and would fall into the gravelly loam category. Oxidized till is yellowish brown (10YR 5/4 to 7.5YR 5/4 or 7.5YR 4/4) or, less commonly, brown (10YR 5/3); unoxidized till is grayish brown (10YR 5/2 or 2.5Y 5/2). The till everywhere is strongly calcareous and has a pH value of about 8. These characteristics are due to the presence of very large amounts of crushed carbonate (dolomite) rock in all size fractions. Dolomite pebbles and cobbles also dominate the stone assemblage, which includes a wide variety of igneous and metamorphic rock types. Illite is the principal clay mineral, making up about 66 percent of the clay-mineral complex; expandable clay and kaolinite plus chlorite are nearly equal, each accounting for 17 percent of the total, as shown by analyses made by H. D. Glass of the Illinois State Geological Survey. In parts of Walworth County, particularly in the area mapped by Alden (1918) as the Elkhorn moraine, New Berlin till has a distinct pinkish cast, which is attributed to the incorporation and assimilation of pink till from the underlying Tiskilwa Member of the Zenda Formation that is now known to be the surface drift in much of Alden's Elkhorn moraine. At several sites, as at the Stewart pit (the first designated reference section), the till splits into

two units, separated from each other by deposits of outwash sand and gravel similar to those found in the lower member of the formation. Two discrete till units, designated informally as 1A and 1B, have been recognized at several places along the Lake Michigan shoreline (Mickelson and others, 1977). At other localities, as at the Valley Sand and Gravel Company pit (the third reference section), some of the till is conformable with the underlying sand and gravel member and some cross-cuts the structure of the gravel (Whittecar and Mickelson, 1979).

Nature of contacts.--Both the upper and lower boundaries of the New Berlin Formation are generally sharp. The lower contact, with the underlying Tiskilwa Member of the Zenda Formation, is commonly the sharper; it has been observed in several gravel pits in southeastern Wisconsin, where the top of the Tiskilwa generally marks the floors of the pits. The upper contact, with the overlying Oak Creek Formation, is disturbed or irregular in some places.

Differentiation from other units.--Till of the New Berlin Formation is readily identified by its abundant pebbles, sandy texture, brown to yellowish-brown color, and high carbonate content. It is far more stony, much sandier, and much more loosely packed than till of the Oak Creek Formation. It is generally more stony, less silty, and lighter in color than the older Tiskilwa Member of the Zenda Formation. However, in places where New Berlin till has incorporated much Tiskilwa till, its color becomes somewhat pink and the till is difficult to distinguish from the Tiskilwa. This is particularly true in a belt that extends from Lake Geneva to the area north and west of Elkhorn. Both till units are definitely present here, and in some places they are distinct, especially where they have been found in contact, but in other places they are difficult to distinguish. Till of the New Berlin Formation is also similar to till of the Clinton Member of the Walworth Formation. The Clinton Member is older, however, and thus occupies a lower stratigraphic position than the New Berlin; also, its area of surficial distribution is west of the Darien moraine, rather than east (fig. 2). According to Alden (1918), till of the New Berlin Formation can be distinguished from till of the Horicon Formation (deposited by the Green Bay Lobe) by its higher content of Niagaran dolomite pebbles.

Regional extent and thickness.--The New Berlin Formation is widely distributed in southeastern Wisconsin (fig. 2). It is the surface unit throughout much of Waukesha and Walworth Counties, and it is also present in parts of Kenosha, Racine, Milwaukee, Washington, and Ozaukee Counties. Geomorphologically, it covers the area behind (northeast of) the Darien moraine and between the Kettle Moraine on the west and the Valparaiso moraine or its equivalent on the east. It extends eastward in the subsurface to Lake Michigan, at least in places, because it is probably exposed near the base of the shore bluff as far south as Sheridan Park in southern Milwaukee County. Whether it is present beneath thick deposits of the Oak Creek Formation in eastern Racine and eastern Kenosha Counties is not known, however.

The New Berlin Formation is at least 22 m thick. The lower unit is generally the thicker of the two units and ranges in thickness from 0 to about 12 m. Several gravel pits in Walworth and Waukesha Counties expose the full thickness of the unit, with both the lower and upper contacts being visible. The upper unit of the formation is generally thinner, ranging up to about 10 m in thickness.

Origin.--The lower sand and gravel unit of the New Berlin Formation is interpreted as a proglacial outwash unit deposited as an outwash plain in front of and around the margins of the advancing Delavan Sublobe of the Lake Michigan Lobe (Alden, 1904, 1918; Schneider, 1982). The upper unit of the formation is interpreted as basal till deposited by the Delavan Sublobe, which terminated

at the Darien moraine on the southwest and along the Kettle Moraine on the west and northwest. Whittecar and Mickelson (1979) have postulated that both an "advance" till and a "retreat" till are present in the Waukesha drumlin field, based upon a study of internal structures in the drumlins. The formation also includes thick, coarse ice-contact deposits, which reach their greatest extent adjacent to the Fox River in western Kenosha, western Racine, and eastern Walworth Counties.

Age.--The New Berlin Formation was deposited in Late Wisconsinan time, probably between 14,000 and 16,000 B.P. No radiocarbon dates are available for confirmation of its precise age, however.

Correlation.--The New Berlin Formation is correlated with the Horicon Formation of the Green Bay Lobe. It is equivalent to at least part of the Haeger Till Member of the Wedron Formation of northeastern Illinois (Willman and Frye, 1970); the lower part of the formation possibly correlates with the older Malden and Yorkville Till Members of the Wedron Formation.

Description of type section.--The type section of the New Berlin Formation is in the heart of the Waukesha drumlin field. The locality is a compound gravel pit, which formerly consisted of several separate pits but which now are more or less merged into one large operation. Except for some variation in the thicknesses of the two members of the formation, a similar section is present throughout most of the site. The lower member consists of well sorted and stratified deposits of sand and gravel; between 10 and 13 m of this unit is well exposed in the pit walls. The upper member, although somewhat finer grained than average, is typical of this part of the formation; it is a highly calcareous pebbly loam containing 43 percent sand, 37 percent silt, and 20 percent clay. The upper two-thirds of the till is oxidized to a brown or yellowish-brown color; the lower part of the unit is unoxidized and gray and rests sharply on the sand and gravel member. Total thickness of the till ranges from 2 to 10 m. About 7 to 9 m is exposed in the upper part of most of the pit walls. X-ray analysis of the less-than-0.002-mm clay fraction from the till shows 13 percent expandable clay minerals, 70 percent illite, and 17 percent kaolinite plus chlorite (H. D. Glass, written communication, 1982).

Person naming formation.--Allan F. Schneider. This is the first use of this unit name.

APPENDIX 8

OAK CREEK FORMATION

Source of name.--City of Oak Creek, southeastern Milwaukee County, Wisconsin, located on the Greendale, South Milwaukee, Franksville, and Racine North 7.5-minute quadrangles.

Type section.--Oakwood Road South Section, a Lake Michigan bluff exposure between Oakwood Road and Elm Road, just north of the Oak Creek Power Plant, NE¼NE¼NE¼ sec. 36, T. 5 N., R. 22 E., and NW¼ sec. 31, T. 5 N., R. 23 E., Milwaukee County, located on the Racine North 7.5-minute quadrangle (fig. 30).

Reference section.--Sheridan Park Section, a Lake Michigan bluff exposure at the north end of Sheridan Park, just south of the St. Francis Power Plant, SW¼NW¼ and NW¼SW¼ sec. 24, T. 6 N., R. 22 E., Milwaukee County, located on the South Milwaukee 7.5-minute quadrangle (fig. 31). This is the best exposure of

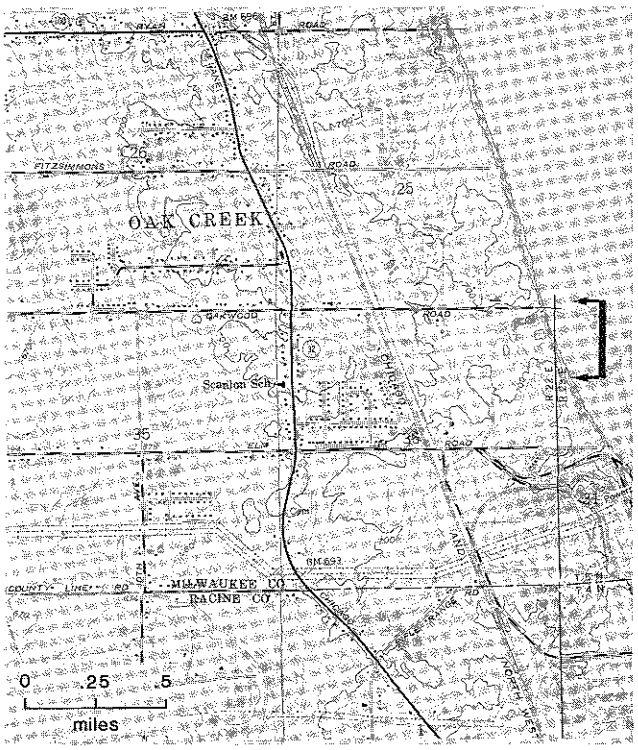

FIGURE 30.--Part of the Racine North 7.5-minute quadrangle showing the location of the type section of the Oak Creek Formation.

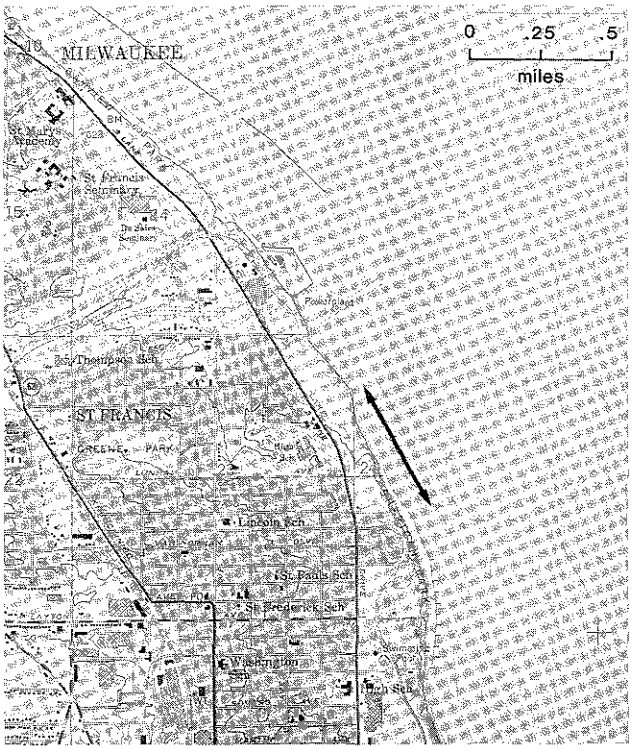

FIGURE 31.--Part of the South Milwaukee 7.5-minute quadrangle showing the location of the reference section of the Oak Creek Formation.

multiple tills along the Lake Michigan shoreline in south-eastern Wisconsin. Several till units are present, including two that belong to the Oak Creek Formation (tills 2B and 2C of Mickelson and others, 1977), a thicker 6-m unit (2B) in the lower half of the exposure and a thinner 2-m unit (2C) at or near the top of the bluff. Both units contain interbeds of silt and clay. They are separated by a thick sand and gravel unit, which apparently grades upward into lacustrine silts and silty clays, all of which are included in the Oak Creek Formation. Two older till units (1A and 1B of Mickelson and others, 1977), ranging from 0 to 4 m thick, are present at the base of the bluff, where they underlie a boulder lag that separates these units from the Oak

Creek Formation. These older units are distinctly sandier and more stony than Oak Creek till and are tentatively placed in the New Berlin Formation.

Description of unit.--The Oak Creek Formation includes fine-textured glacial till, lacustrine clay, silt, and sand, and some glaciofluvial sand and gravel. Three till units were identified by Mickelson and others (1977), but these are not formally named in this paper. The lacustrine and glaciofluvial sediments seem to be much more characteristic of the formation in the eastern part of its areal extent (near Lake Michigan) than farther west, where the unit consists predominantly of till. This till is everywhere strongly calcareous and fine grained, commonly containing between 80 and 90 percent silt and clay in the matrix (less-than-2-mm fraction). Because the relative amounts of silt and clay vary from place to place, the texture of the till ranges from silty clay through clay loam and silty clay loam to silt loam. Commonly, however, the deposit is silty clay or silty clay loam till. The average composition is about 12 percent sand, 43 percent silt, and 45 percent clay. Stones are generally small and not terribly abundant. Oak Creek till normally has a 10YR hue; the color of the oxidized till nearly everywhere is brown (10YR 4/3 to 5/3), yellowish brown (10YR 5/4 to 5/6), or dark yellowish brown (10YR 4/4). In a few places it has a 7.5YR hue (7.5YR 4/4, brown). Where the till is unoxidized, it is gray (10YR 5/1). Illite is the dominant clay mineral in the less-than-0.002-mm fraction, averaging 72 percent of the clays; expandable clay minerals and kaolinite plus chlorite are about equal, 15 percent and 13 percent, respectively (H. D. Glass, written communication, 1982). Dolomite dominates the pebble assemblage, but the drift contains a considerable variety of igneous and metamorphic rock types from the Canadian Shield; basalt is particularly common. Perhaps the most diagnostic item, however, is the presence of dark gray shale fragments, which are presumably derived from the Lake Michigan basin.

Nature of contacts. Till of the Oak Creek Formation overlies the upper, or till, unit of the New Berlin Formation. Although the contact is sharp in most places where it has been observed, in some places it is marked by interbedding, probably produced by the incorporation of thrust slices of the older till. In eastern Kenosha and southeastern Racine Counties, Oak Creek till is sharply overlain by lacustrine deposits, including both sandy shallow-water sediments and massive to laminated and varved deposits laid down in quieter waters of glacial Lake Chicago. From Milwaukee northward, the Oak Creek Formation is overlain by till and associated deposits of the Kewaunee Formation. In many places, according to soil scientists who have mapped in the area, till of the Oak Creek Formation carries a thin loess cap. Nowhere is the loess sufficiently thick to extend through the solum, and thus the loess is not considered significant enough to be recognized here as a lithostratigraphic unit.

Differentiation from other units.--Till of the Oak Creek Formation is readily distinguished from all other tills in the state by its color (both oxidized and unoxidized), by its high silt-clay content, by its abundant dolomite clasts, and by the presence of dark gray to black shale chips. The underlying New Berlin till is much coarser grained and somewhat lighter in color than till of the Oak Creek Formation. The younger Kewaunee Formation tills are distinctly more red and generally lack the shale fragments found in the Oak Creek.

Regional extent and thickness.--The Oak Creek Formation is found in southeastern Wisconsin, where it occurs as the surface drift in a north-south belt that extends from the Illinois state line northward through Kenosha, Racine, Milwaukee, and eastern Waukesha Counties at least as far as Ozaukee and Washington Counties (fig. 2). Its western limit for much of this distance is the Valparaiso moraine, whose distal (western) margin is followed, in general, by

the Fox River. The eastern boundary of the formation from the state line northward to Racine is the plain of glacial Lake Chicago. Between Racine and Milwaukee the formation extends to Lake Michigan, and from Milwaukee northward the formation is overlapped by the Ozaukee Member of the Kewaunee Formation, which borders the lake in this area. In addition to being the surface drift in the Valparaiso moraine, Oak Creek till is the dominant constituent of the Tinley moraine and the several Lake Border moraines, as well as in areas between these ridges. East of the front of the Tinley moraine (Alden's outermost Lake Border moraine), the till is much thicker than farther west. Although its maximum thickness is unknown, bluff exposures along the Lake Michigan shoreline in southern Milwaukee County show that the Oak Creek Formation reaches a thickness of at least 35 m in some places.

Origin.--Till of the Oak Creek Formation was deposited by ice of the Lake Michigan Lobe as it moved west-southwestward out of the Lake Michigan basin and crossed a large area of southeastern Wisconsin. Lacustrine sediment in the formation was laid down mainly in proglacial environments during brief intervals of ice-front recession.

Age.--The Oak Creek Formation was deposited during Late Wisconsinan time, between about 14,000 and 13,000 and 12,500 B.P.

Correlation.--The till of the Oak Creek Formation correlates with the Wadsworth Till Member of the Wedron Formation in Illinois (Willman and Frye, 1970), with which it is contiguous for many miles along the Wisconsin-Illinois state line. Very probably it is equivalent in age to the upper part of the Horicon Formation of the Green Bay Lobe.

Description of type section.--The type section is a bluff exposure along the Lake Michigan shoreline between the end of Oakwood Road and the end of Elm Road, immediately north of the Oak Creek Power Plant. Numerous mudflows and slump blocks commonly conceal parts of the exposure, but because the beach is narrower in the northern part of this shore segment, the Oak Creek Formation is generally much better exposed from the ravine at Oakwood Road southward for about 600 m than farther to the south. Two to three till units are present in the upper half of the exposure. These range in thickness from 1.2 to 5.2 m and are separated by layers of sand and gravel or lacustrine sand and silt. All units in the section belong to the Oak Creek Formation. A sample from one of these till units contains 7 percent sand, 48 percent silt, and 45 percent clay; its clay-mineral composition is 13 percent expandables, 69 percent illite, and 18 percent kaolinite plus chlorite (H. D. Glass, written communication, 1982). The lower half of the exposure consists mostly of lacustrine deposits--silt and fine sand, but with till interbeds. Silty clay loam or silty clay till, ranging from less than 1.5 m at the north end of the exposure to 4.6 m thick near the south end, appears to cap the bluff nearly everywhere. Bluff height is about 30 m.

Person naming formation.--Allan F. Schneider. This is the first use of this unit name.

APPENDIX 9

HORICON FORMATION

Source of name.--City of Horicon, Dodge County, Wisconsin.

Type section.--Same as the Mapleview Member, Appendix 9a.

Reference sections.--The type section for the Liberty Grove Member and Mapleview Member serve as reference sections for this unit.

Description of unit.--The Horicon Formation includes till, associated sand and gravel, and other stratified deposits. The till is generally brown (7.5YR hue) or, less commonly, reddish brown (5YR hue) and sandy. Sand content varies considerably but is generally between 60 percent and 80 percent. Clast composition also varies considerably depending on location and the till facies (supraglacial or subglacial) present. Details of pebble lithology and clay mineralogy are given in member descriptions. Most of the area of the Horicon Formation has not been studied in detail, and mean values of clay percentage or other lithologic parameters would be meaningless at this time.

Nature of contacts.--This formation is the surficial unit in much of south-central Wisconsin (fig. 2). In most of that area the formation lies directly on bedrock or sand and gravel with a sharp contact. In areas close to Green Bay it is overlain by reddish, finer-grained till of the Kewaunee Formation. This contact is usually clear and abrupt.

Differentiation from other units.--Till of this formation can be distinguished from the overlying Kewaunee Formation fairly readily in the field. The Kewaunee Formation is redder (2.5 or 5YR hues) and finer grained. According to Alden (1918), the till of the Horicon Formation can be distinguished from the otherwise similar New Berlin Formation (deposited by the Lake Michigan Lobe) by its lower percentage of Niagaran dolomite pebbles.

Regional extent and thickness.--With the exception of the Copper Falls Formation, the Horicon Formation covers a larger area of the state than any other (fig. 2). It is at the surface in much of eastern Wisconsin and is present in numerous sections below deposits of the Kewaunee Formation. No detailed studies of thickness have been done but in buried valleys, it is evidently in excess of 100 m thick. In places near its southwestern edge and along the Niagaran escarpment it is less than 1 m thick.

Origin.--The till of the Horicon Formation was deposited by ice of the Green Bay Lobe. In at least some locations subglacial and supraglacial facies can be identified. Large amounts of sand and gravel are associated with the till in counties along its western extent, but these have not been mapped in enough detail to formalize as lithostratigraphic units.

Age and correlation.--The Horicon Formation was deposited during Late Wisconsinan time, evidently between 13,000 and 18,000 B.P. No radiocarbon dates are available to date the deposition of the formation. The formation correlates time-stratigraphically with the New Berlin Formation of the Lake Michigan Lobe and the two units are in contact along the Kettle Moraine in eastern Wisconsin.

Description of type section.--The type section is the same as the type section of the Mapleview Member, described in Appendix 9a.

Person naming unit.--David M. Mickelson. This is the first use of this unit name.

APPENDIX 9a

MAPLEVIEW MEMBER OF THE HORICON FORMATION

Source of name.--Mapleview Road, a town road running east from Highways 45, 47, and 52 just south of Antigo in Langlade County. Located in the northwest corner of the Mattoon 7.5-minute quadrangle (fig. 32).

Type section.--Road cut on the south side of Mapleview Road, SE¼SW¼SW¼ sec. 34, T. 31 N., R. 10 E., Langlade County located on the Mattoon 7.5-minute quadrangle. Road cut is just west of intersection of Mapleview Road and Maple Road (fig. 32).

Reference section.--Lower till in Ski Hill Section, road cut at entrance to County Ski Area off Highway 52, NW¼NW¼NW¼ sec. 8, T. 32 N., R. 13 E., Langlade County, located on the Pickerel 7.5-minute quadrangle (figs. 33, 34).

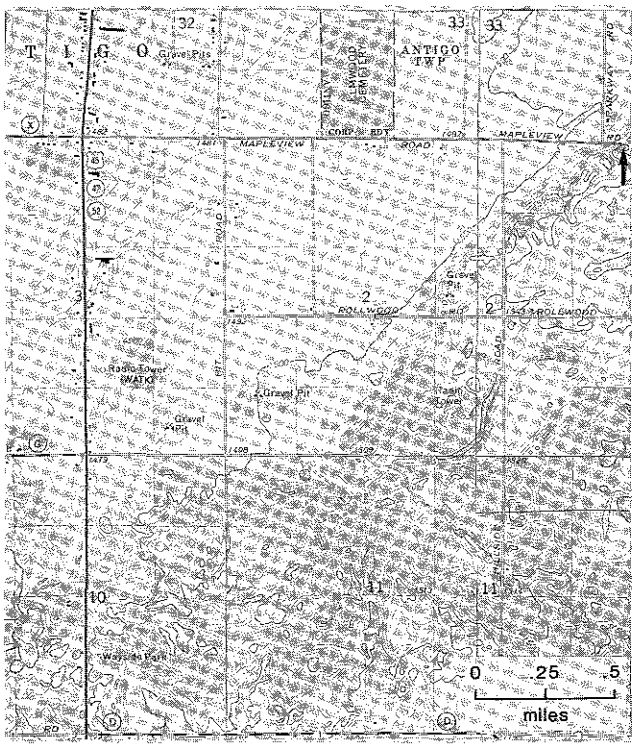

FIGURE 32.--Parts of the Aniwa and Mattoon 7.5-minute quadrangles showing the location of the type section of the Mapleview Member.

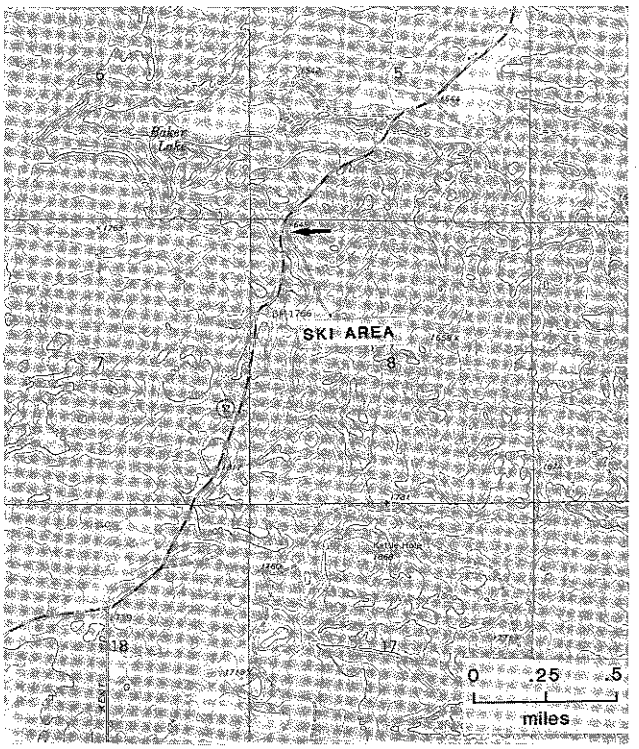

FIGURE 33.--Part of the Pickerel 7.5-minute quadrangle showing the location of the Ski Area reference section of the Mapleview Member.

Description of unit.--The bulk of the Mapleview Member consists of cobbly, pebbly, silty sand till with scattered boulders in Langlade County; the fraction smaller than 2 mm averages 83 percent sand, 13 percent silt, and 4 percent clay in Langlade County. What is presumably the same unit to the east in Oconto County averages 77 percent sand, 19 percent silt, and 4 percent clay and to the south in Shawano County averages 83 percent sand, 14 percent silt, and 6 percent clay, but measurements in these two counties are from a small number of samples. Field colors are generally dull reddish brown (5YR 4/4) or reddish brown (5YR 4/6) but more commonly brown (7.5YR 4/4, 7.5YR 4/6). Pebble lithology averages 33 percent igneous, 40 percent metamorphic, and 26 percent sedimentary rock types (18 samples counted). Clay minerals average 69

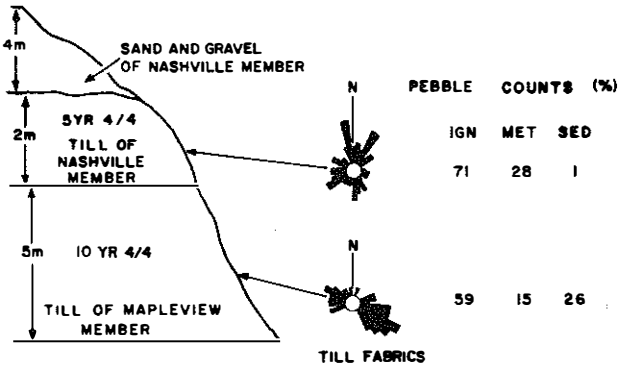

FIGURE 34.--Sketch of exposure at Ski Area reference section.

percent illite, 13 percent kaolinite plus chlorite 5 percent vermiculite, and 14 percent smectite (Stewart, 1973).

Nature of contacts.--The Mapleview Member is generally thick, and because of poor exposure the lower contact has not been observed. In the end moraine the till interfingers with washed sediment. Some well logs and reports by Thwaites (1934) indicate that the till generally overlies sand or sand and gravel. In most places the Mapleview Member is the surface material. Subglacial till is overlain by scattered supraglacial debris or fluvial sediment. At the ski-area reference section (figs. 33, 34), where the Mapleview Member is overlain by the Nashville Member of the Copper Falls Formation, the contact is relatively sharp.

Differentiation from other units.--The Mapleview Member is similar to the Nashville Member of the Langlade Lobe, but the Mapleview Member contains about 25 percent dolomite pebbles, which are nearly lacking in the Nashville Member. The Mapleview Member is distinguished from older units to the west by the greater abundance of carbonates, illite, and chlorite (Stewart and Mickelson, 1976). It is distinguished from the younger Kewaunee Formation to the east by its brown, less red, color.

Regional extent and thickness.--The Mapleview Member is the surface unit from the west edge of the Outer moraine in Langlade County eastward at least to the Mountain moraine or to the community of Mountain, where a younger unit overlies it. To the north, in Langlade County north of Bryant, the Mapleview Member is covered by the Nashville Member (Nelson and Mickelson, 1974, Mickelson, Stewart and Nelson, 1974). The southern extent of this unit is unknown. The unit is typically 10 m or more thick in end moraine areas, but its thickness is generally unknown elsewhere.

Origin.--The Mapleview Member is till deposited by glacier ice of the Green Bay Lobe. In areas of exposure, the till, which is probably largely subglacial till, is overlain in places by a thin discontinuous layer of more sandy material interpreted to be washed supraglacial debris and by a thin layer of loess or slopewash sediment.

Age.--The Mapleview Member was probably deposited in Late Wisconsinan time, around 15,000 or 14,000 B.P.

Correlation.--The Mapleview Member is partly contemporaneous with the Nashville Member of the Langlade Lobe, and it interfingers with that unit along the boundary between the Langlade Lobe and Green Bay Lobe (Mickelson, Nelson, and Stewart, 1974).

Description of type section.--The type section is located about 100 m west of the intersection of Mapleview Road and Maple Road, about 3 km east of Highways 45, 47 and 52. The roadcut is on the south side of Mapleview Road, is 8 m

high, and consists entirely of Mapleview subglacial till, with the exception of possible supraglacial debris at the top of the section. A sample taken 4.5 m below the surface contained 8 percent igneous, 39 percent metamorphic, and 53 percent sedimentary clasts in the pebble fraction. This proportion of sedimentary rock is large compared to most of the other samples in Langlade County. A sample collected 2.5 m below the surface contained 80 percent sand, 16 percent silt, and 5 percent clay in the less-than-2-mm fraction (less-than-2-micrometre clay). When the exposure was described vegetation covered much of the cut and any stratification or variability that might be present was not observed.

Person naming member. David Mickelson. Name was first used informally by McCartney and Mickelson (1982).

APPENDIX 9b

LIBERTY GROVE MEMBER OF THE HORICON FORMATION

Source of name.--Liberty Grove Township, northern Door County, Wisconsin, located on the Sister Bay, Ellison Bay, and Washington Island 15-minute quadrangles.

Type section.--Road cut on north side of Waters End Road, just west of the intersection with Highway ZZ, 3 miles (4.8 km) northeast of Sister Bay, SE¼SE¼NW¼ sec. 35, T. 32 N., R. 28 E., Door County, located on the Sister Bay 15-minute quadrangle (fig. 35).

Reference sections.--(1) Road cut on north side of Hill Road, just west of T-intersection with Highway ZZ; SE¼SE¼SW¼ sec. 35, T. 32 N., R. 28 E., Door County, located on the Sister Bay 15-minute quadrangle (fig. 35). This cut is similar to the type section, exposing 3-4 m of calcareous brown (7.5YR 5/4 to 10YR 5/3) coarse-grained till in a drumlin of the Liberty Grove drumlin field, well known to local residents as the Hill Road drumlin. (2) Road cut on north side of Highway H, about 0.5 mile (0.8 km) east of intersection of Highways H and XC, SE¼SE¼SW¼ sec. 2, T. 26 N., R. 24 E., Door County, located on the Brussels 7.5-minute quadrangle (fig. 36). From 3 to 4 m of light yellowish-brown (10YR 6/4) sandy till is exposed for a distance of more than 200 m in this relatively fresh cut.

Description of unit.--The Liberty Grove Member contains coarse-grained till, best described texturally as pebbly sandy loam. Because of its abundant stones, road cuts and other exposures generally give the impression that the material is gravel, rather than till. In many places, particularly where the till is thin and rests directly on bedrock, it is a very rubbly deposit containing many subangular pebbles, cobbles, and boulders. Most of the clasts are dolomite derived from the underlying Silurian units. A count of 117 boulders more than 6 inches in diameter reported by Thwaites and Bertrand (1957, p. 843) from till in southern Kewaunee County showed 73 percent Niagaran dolomite, 8 percent light-colored igneous rocks, 16 percent dark-colored igneous rocks, and 3 percent miscellaneous rock types. Based on a limited number of analyses, the matrix of the till (less than 2-mm fraction) contains between 50 and 60 percent sand, but in many places the sand content may be higher. About 30 to 40 percent of the matrix is silt, and the clay content ranges from 5 to 15 percent. X-ray analyses by H. D. Glass of the Illinois State Geological Survey indicate that the till averages 16 percent expandable clay minerals, 65 percent illite, and 19 percent kaolinite plus chlorite. The color of the till ranges from light brown (7.5YR 6/4) or brown (7.5YR 4/4 to 5/4 or 10YR 5/3) to light yellowish brown (10YR 6/4) or yellowish brown (10YR 5/4). Commonly it is almost exactly midway between 7.5YR 5/4 and 10YR 5/3 on

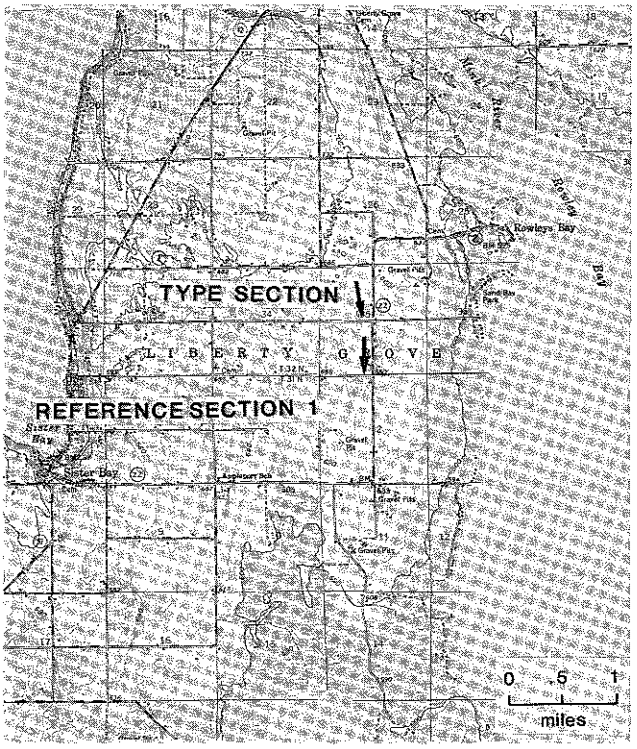

FIGURE 35.--Part of the Sister Bay 15-minute quadrangle showing the locations of the type section and reference section 1 of the Liberty Grove Member of the Horicon Formtion.

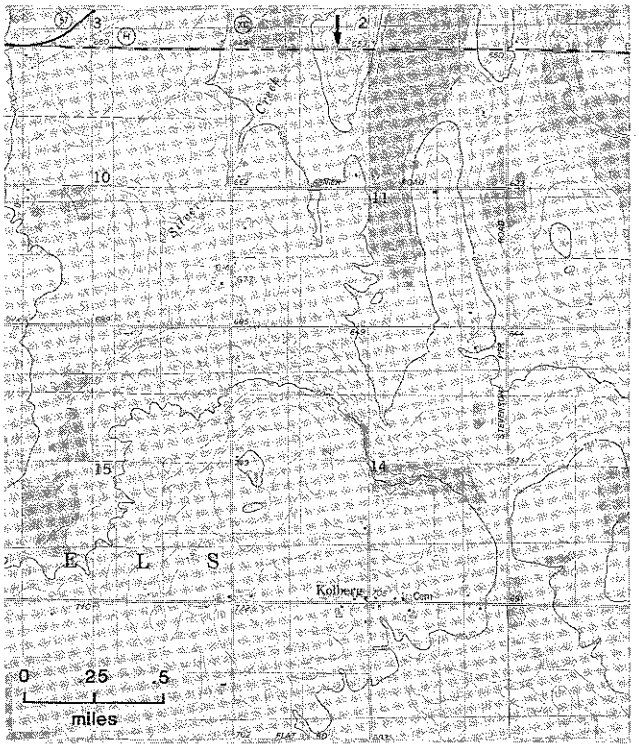

FIGURE 36.--Part of the Brussels 7.5-minute quadrangle showing the location of reference section 2 of the Liberty Grove Member of the Horicon Formation.

the Munsell charts. In many places it has a pale pinkish or salmon cast, which is attributed to the incorporation of ground-up Niagaran dolomite.

Nature of contacts.--The Liberty Grove Member rests on bedrock at all localities where the base of the unit has been seen. In most of these places it overlies Silurian dolomite of the Alexandrian or Niagaran Series, but it has also been found in contact with the Maquoketa Formation of Late Ordovician age. Where it is not the surface deposit, the Liberty Grove generally underlies calcareous red clayey till of the Kewaunee Formation, especially the Glenmore Member of that formation. In some places it probably underlies the Two Rivers Member. At a few sites in Door County it underlies an unnamed pink sandy till of unknown origin and distribution. The contact with the Glenmore Member is generally sharp; the contact with the pink till is sharp to diffuse.

Differentiation from other units.--The Liberty Grove Member is fairly similar to the Mapleview Member of the Horicon Formation. Till of the Liberty Grove, however, is finer grained and distinctly lighter in color, ranging from brown (7.5YR hue) to yellowish brown (10YR hue), whereas Mapleview till ranges from brown (7.5YR hue) to reddish brown (5YR hue). Liberty Grove till differs greatly from the fine grained reddish-brown till of the Glenmore Member and other members of the Kewaunee Formation; the Liberty Grove is much coarser grained and much lighter (more yellowish) in color than the Kewaunee units.

Regional extent and thickness.--The Liberty Grove Member is best known from northern Door County (fig. 2), where it is the surficial deposit throughout much of the area north of Sturgeon Bay (Schneider, 1981). It extends southward, mainly as a subsurface unit beneath the Glenmore Member of the Kewaunee

Formation, through southern Door County and at least as far south as central and southern Kewaunee County. The Liberty Grove is a thin unit and is generally less than 3 m thick in much of Door County. Although its maximum thickness is unknown, in some places, as in the Liberty Grove drumlin field, it probably ranges up to 10 m thick.

Origin.--The Liberty Grove Member of the Horicon Formation is glacial till deposited by ice of the Green Bay Lobe, which crossed northern Door County flowing in a direction of S. 5° to 20° E. (Schneider, 1981).

Age.--The Liberty Grove Member is Late Wisconsinan age. Although unconfirmed by radiocarbon dates, the Liberty Grove Member was likely deposited about 14,000 to 15,000 years B.P.

Correlation.--The Liberty Grove Member is correlated with the Mapleview Member of the Horicon Formation, which has been mapped on the west side of the Green Bay lowland. Very likely, it is equivalent to the informally named Wayside till recognized by McCartney and Mickelson (1982) in southern Brown County. The Liberty Grove is part of the widespread till of the Door Peninsula that was placed in the Cary Substage by Thwaites and Bertrand (1957).

Description of type section.--The type section of the Liberty Grove Member is a road cut through a 20-foot high drumlin in the Liberty Grove drumlin field (Kowalke, 1952; Thwaites and Bertrand, 1957, p. 847; Schneider, 1981). About 3 m of till is well exposed. Although the cut on the north side of Waters End Road serves as the type section, the unit is also well exposed on the south side of the road. Both cuts have remained free of vegetation for many years, and the exposed drift is very typical of the Liberty Grove Member as it is described above. The clay-mineral composition of the till here is 16 percent expandable clays, 67 percent illite, and 17 percent kaolinite and chlorite (H. D. Glass, written communication, 1982).

Person naming member.--Allan F. Schneider. This is the first formal use of this unit name. The name was used by Schneider (1981).

APPENDIX 10

KEWAUNEE FORMATION

Source of name.--Kewaunee County, Wisconsin.

Type section.--The Kewaunee site located in the lake bluff at the south edge of the city of Kewaunee, NE¼SE¼SE¼ sec. 19, T. 23 N., R. 25 E., Kewaunee County, located on the Kewaunee 7.5-minute quadrangle (fig. 37).

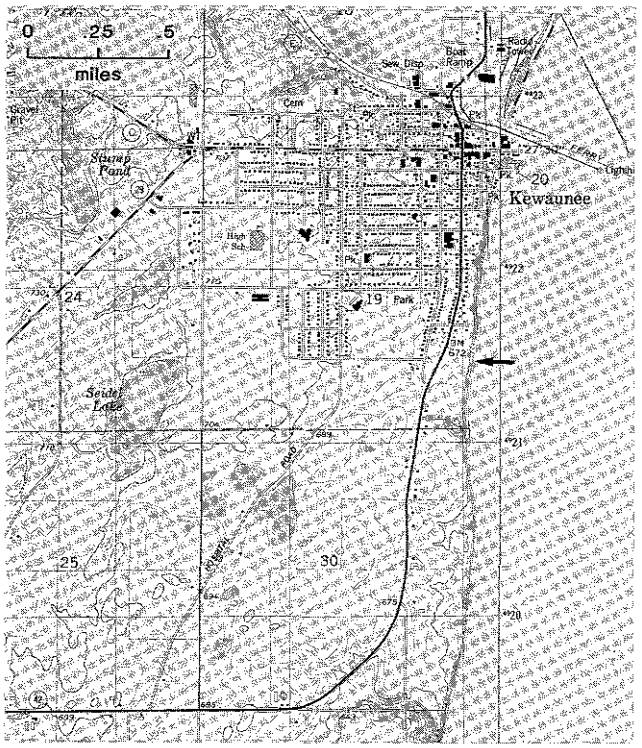

FIGURE 37.--Part of the Kewaunee 7.5-minute quadrangle showing the location of the type section of the Kewaunee Formation.

Reference section.--All type sections of included members described in Appendixes 10 a, b, c, d, e, f, g, h, and i.

Description of unit.--The formation consists of the Two Rivers, Valders, Haven, Ozaukee, Glenmore, Chilton, Branch River, Middle Inlet, Kirby Lake, Silver Cliff Members, and several unnamed members. All till in the formation is characterized by brown (7.5YR 5/4) or reddish brown (5YR 4/4) color. All of the till and associated deposits are calcareous but have varying amounts of sand, silt, and clay (see member descriptions).

Nature of contacts.--The Kewaunee Formation is at the surface over much of northeast Wisconsin. In places it is overlain by younger organic and alluvial deposits of an unnamed formation. The basal contact of the formation is generally distinct.

Differentiation from other units.--Although the Kewaunee Formation is variable in color, it is nearly everywhere more red than the underlying Horicon, New Berlin, or Oak Creek Formations. It has significantly less sand than deposits of the Horicon or Waukesha Formation and about the same or slightly more sand than the Oak Creek Formation. Properties of individual members are given in Appendices 10 a, b, c, d, e, f, g, h, and i.

Regional extent and thickness.--The Kewaunee Formation varies in thickness from less than 1 m to at least 18 m thick. Its extent is shown in figure 2.

Origin.--The Kewaunee Formation contains till deposited by ice of the Lake Michigan and Green Bay Lobes. In many places subglacial till is present but supraglacial till is present locally. The formation also contains sand and gravel that is fluvially deposited and sand, silt, and clay that was deposited in a lacustrine environment.

Age and correlation.--The formation is the time equivalent to parts of the Wedron and Lake Michigan Formations of Illinois and the younger parts of the Copper Falls Formation in northern Wisconsin. It includes the Two Creeks Bed which is dated at about 11,800 B.P., and so is both older and younger than this. The maximum age of the unit is not fixed with precision but is probably 13,000 to 12,500 years. Its minimum age is probably about 11,000 to 11,400 years. This formation is equivalent to what was called the "Valders till" by many writers after Thwaites (1943).

Description of type section.--The type section is a lake bluff exposure at the south edge of the city of Kewaunee and can be reached by walking from Highway 42 toward the lake bluff along a line of Lombardy poplar trees, then walking south along the bluff top about 100 m. At the top of the section is 2 to 2.5 m of till of the Two Rivers Member. This overlies a small exposure of organic material about 0.2 m thick. In places this overlies about 1 m of oxidized gravel. Below this is 3.5 m of unoxidized (gray) till of the Haven Member. This overlies 1.5 m of gravel and then 3 m of what is presumed to be unoxidized till of the Ozaukee Member. This till overlies 5 m of poorly laminated silt and clay with some fine sand beds. This laminated sediment and an underlying till are not clearly associated with the Kewaunee Formation and the base of the formation is now assumed to be at the top of the laminated sediment.

Person naming unit.--David Mickelson. This is the first use of this unit name.

APPENDIX 10a

OZAUKEE MEMBER OF THE KEWAUNEE FORMATION

Source of name.--Ozaukee County, Wisconsin, on the shoreline of Lake Michigan.

Type section.--Lake Park Section, immediately north of the Port Washington, Wisconsin Harbor, NW¼SE¼NE¼ sec. 28, T. 11 N., R. 22 E., Ozaukee County, located on the Port Washington East 7.5-minute quadrangle (fig. 38).

Reference section.--Virmond Park Section, NE¼NE¼SW¼ sec. 28, T. 9 N., R. 22 E., Ozaukee County, located on the Thiensville 7.5-minute quadrangle (fig. 39). About 23 m of Ozaukee till overlie lake sediment and older till at the top of the bluff.

Description of unit.--The Ozaukee Member contains pebbly, clayey, and silty till and associated lake sediment. The color of its clay fraction ranges from light reddish brown (5YR 6/3) or pinkish gray (5YR 6/2) to light gray (10YR 6/1). The till ranges from hard and blocky to crumbly when dry and is very plastic when wet. Most exposures occur on the faces of slump scarps.

The till of the Ozaukee Member contains numerous dolomite pebbles and cobbles and a lesser quantity of igneous rock types. The unit contains an average of 13 percent sand, 47 percent silt, and 40 percent clay. X-ray analysis of the relative quantities of selected clay minerals, reveals 20 to 30 percent expandables, 50 to 63 percent illite, and about 20 percent kaolinite and chlorite (Acomb, Mickelson, and Evenson, 1982).

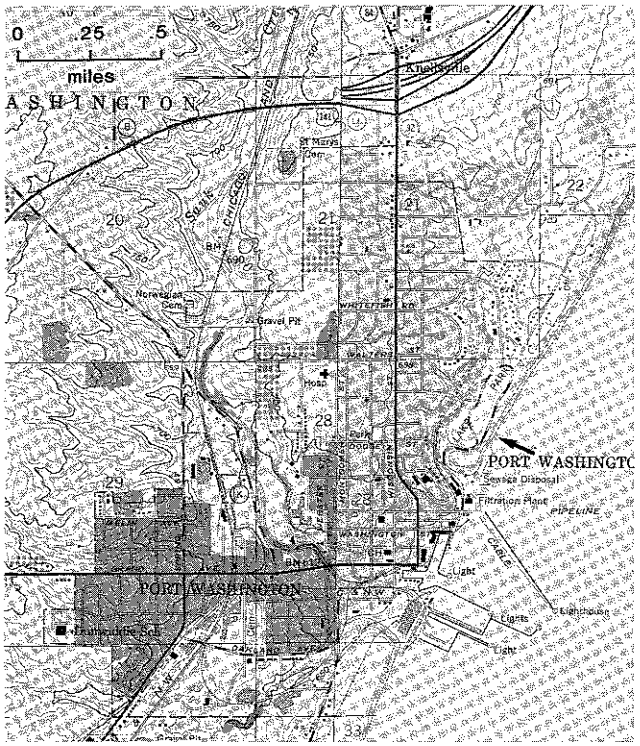

FIGURE 38.--Parts of the Port Washington East and West 7.5-minute quadrangles showing the location of the type section of the Ozaukee Member.

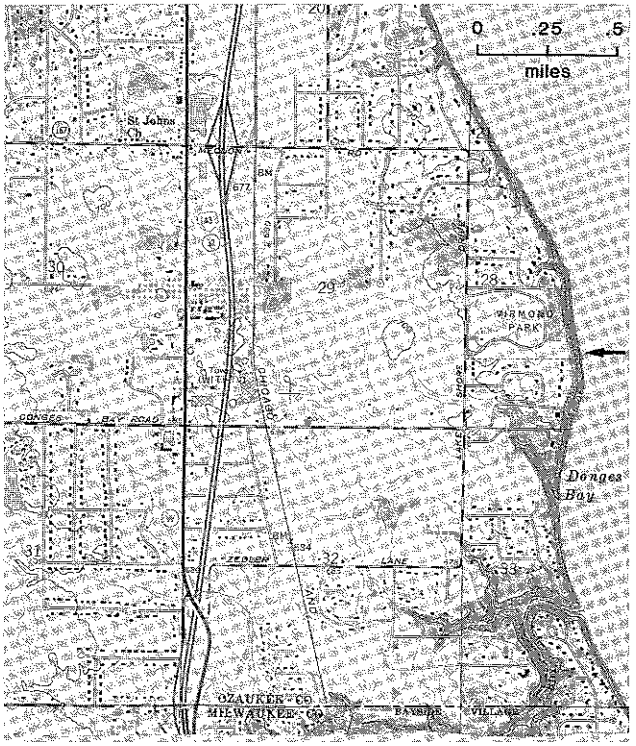

FIGURE 39.--Part of the Theinsville 7.5-minute quadrangle showing the location of the Virmond Park reference section of the Ozaukee Member.

Nature of contacts.--The lower contact of the Ozaukee Member is somewhat gradational where the underlying material is of similar grain size (clay and silt) and sharp when the underlying material is coarser grained sediment (sand or gravel).

In Milwaukee and Ozaukee Counties the Ozaukee Member is the surface unit. The sediment exposed south of Kewaunee that is correlated with the Ozaukee Member has distinct upper and lower contacts but north of Kewaunee the contacts are less distinct.

Differentiation from other units.--The Ozaukee Member is most easily differentiated from the gray older units of the area by its red color. It can be distinguished from the younger (also red) till units by its fine grain size and high illite percentage (Acomb, Mickelson, and Evenson, 1982).

Regional extent and thickness.--The Ozaukee Member is present at the top of the Lake Michigan coastal bluff from Milwaukee northward to about the Ozaukee-Sheboygan county line. In this area the member extends inland to Alden's (1918) red till boundary which roughly parallels the ice marginal Milwaukee River. This boundary defines a wedge of red till increasing in width from about 1.6 km in the Milwaukee area to almost 14.5 km north of Port Washington (fig. 2). North of the Ozaukee-Sheboygan county line the unit is correlated with similar material which crops out in the Kewaunee County lake bluff and possibly with material reported in boreholes at Haven, Wisconsin.

The member varies in thickness from about 19.5 m (at Shorewood and Virmond Park) to only 2.4 m in other locations. In shoreline exposures the member has an average thickness of about 9 m.

Origin.--The Ozaukee Member contains basal till deposited by ice flowing southward in the Lake Michigan basin and associated fluvial and lacustrine deposits.

Age.--Radiocarbon dates from the Ozaukee Member do not exist. However, if the unit correlates with the material overlying the Cheboygan Bryophyte Bed of Michigan (Farrand, Zahner, and Benninghoff, 1969), an age of about 12,900 years is suggested.

Correlation.--The Ozaukee Member may be correlative with the Shorewood or Member named by Lineback and others (1974) in the Lake Michigan basin and with units of similar texture and mineralogy in Michigan (Taylor, 1978). The unit is the time equivalent of the Branch River Member of Green Bay Lobe (Appendix 10e).

Description of type section.--At the type section at Lake Park the Ozaukee Member is exposed in the upper portion of the bluff bordering Lake Michigan. Total bluff height above Lake Michigan is approximately 37 m. The upper half of the bluff exposes the Ozaukee Member, the lower half is slumped material.

Person naming unit.--Larry Acomb and David M. Mickelson. This unit name was first used informally by Acomb (1978), and subsequently by Acomb, Mickelson and Evenson (1982).

APPENDIX 10b

HAVEN MEMBER OF THE KEWAUNEE FORMATION

Source of name.--The rural locality of Haven, Sheboygan County, located on the Sheboygan North 15-minute quadrangle.

Type section.--Nuclear Power Plant site in the lake bluff, NW¼NW¼NE¼ sec. 22, T. 16 N., R. 23 E., located on the Sheboygan North 7.5-minute quadrangle (fig. 40).

Reference section.--(1) In the lake bluff, secs. 7 and 8, T. 18 N., R. 23 E., located on the Manitowoc 7.5-minute quadrangle (fig. 41). Here about 5 m of lake sediment and discontinuous Valders till overlie about 15 m of Haven till. The Haven till extends to beach level in the southern one-half of the section. (2) In the lake bluff NE¼ sec. 31, T. 23 N., R. 25 E., located on the Kewaunee 7.5-minute quadrangle (fig. 42). Here about 2 m of Two Rivers till are at the top of the bluff, underlain by about 2 m of lake sediment. Haven till about 2 m thick underlies this and is in turn underlain by lake sediment and Ozaukee till (Acomb, Mickelson, and Evenson, 1982).

Description of unit.--The Haven Member is primarily pebbly, sandy and clayey silt till. Its clay fraction varies in color from light pinkish gray (5YR 7/2) to pale red and light reddish brown (2.5YR 6/3; 5YR 6/3). When dry the unit varies from hard and blocky to crumbly and when wet the unit is quite plastic.

Numerous dolomite pebbles and cobbles and some igneous rock types are found throughout the member. The Haven till is composed of approximately 15 percent sand, 56 percent silt, and 28 percent clay. Semiquantitative analysis of selected clay minerals shows an average illite content of 56 percent and more expandables (25 percent) than kaolinite and chlorite (19 percent) (Acomb, Mickelson and Evenson, 1982). Lacustrine sediment in the unit is present, but has not been described.

Nature of contacts.--The upper and lower contacts of Haven Member range from sharp to diffuse depending on the grain size distribution of the neighboring material.

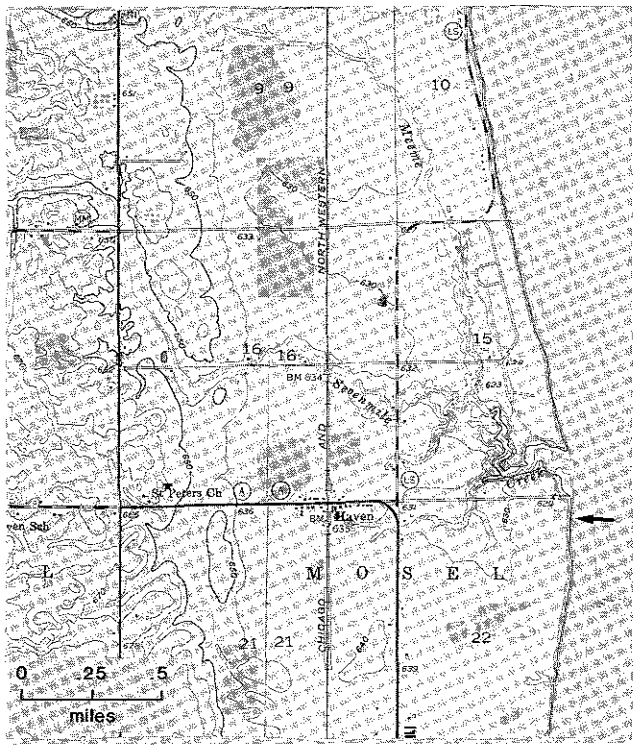

FIGURE 40.--Parts of the Howards Grove and Sheboygan North 7.5-minute quadrangles showing the location of the type section of the Haven Member.

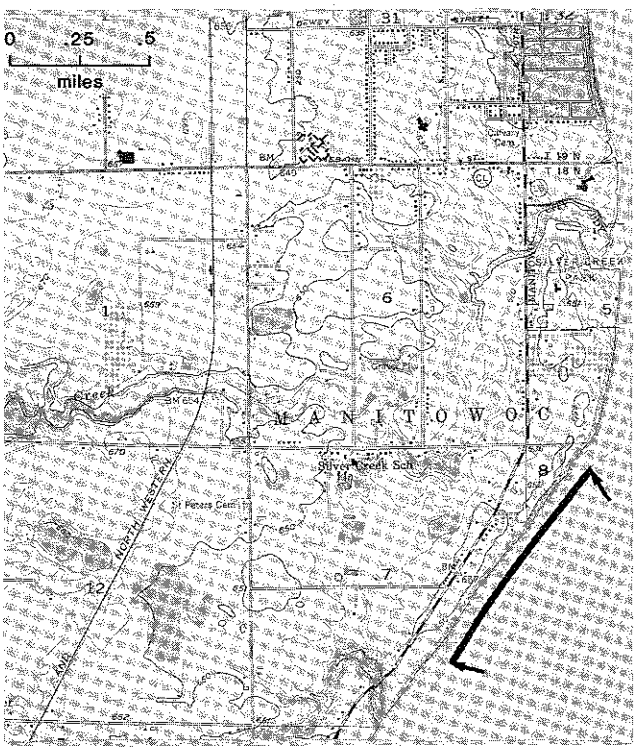

FIGURE 41.—Part of the Manitowoc 7.5-minute quadrangle showing the location of reference section 1 of the Haven Member.

Differentiation from other units.--The Haven Mamber is most easily distinguished from the very similar Ozaukee, Valders, and Two Rivers Members by its grain size and clay mineralogy. It has less clay than the Ozaukee Member and less sand than either the Valders or the Two Rivers Member. Its clay mineralogy makes it almost indistinguishable from the Ozaukee Member; however, it has distinctly less expandable clay than either the Valders or Two Rivers Member.

Regional extent and thickness.--The Haven Member is almost continuously exposed in the eroding shoreline buffs of Lake Michigan, from south of Sheboygan, Wisconsin, to north of Algoma, Wisconsin. It is the till exposed below the Two Creeks Forest Bed at Two Creeks, Wisconsin (Goldthwait, 1907; Thwaites and Bertrand, 1957; Black, 1970; Evenson, 1973). Inland the unit extends to the Kettle Moraine as mapped by Thwaites and Bertrand (1957) and Alden (1918) (fig. 2). Inland exposures of the Haven Member are limited due to a surface cover consisting of the Valders Formation. The thickness of the unit varies from a maximum of almost 15 m to a minimum of about 2.4 m.

Origin.--The till of the Haven Member was deposited by ice advancing in the Michigan basin. It also includes associated fluvial and lacustrine deposits.

Age.--It is difficult to precisely pin down the age of the Haven Member. However, because it underlies the Two Creeks Forest Bed and overlies the Ozaukee Member, a reasonable age is about 12,600 years.

Correlation.--The till of the Haven Member is probably equivalent to the Manitowoc Till Member of Illinois (Lineback and others, 1974) in the Lake Michigan basin. On the Michigan shoreline, however, these units have not been

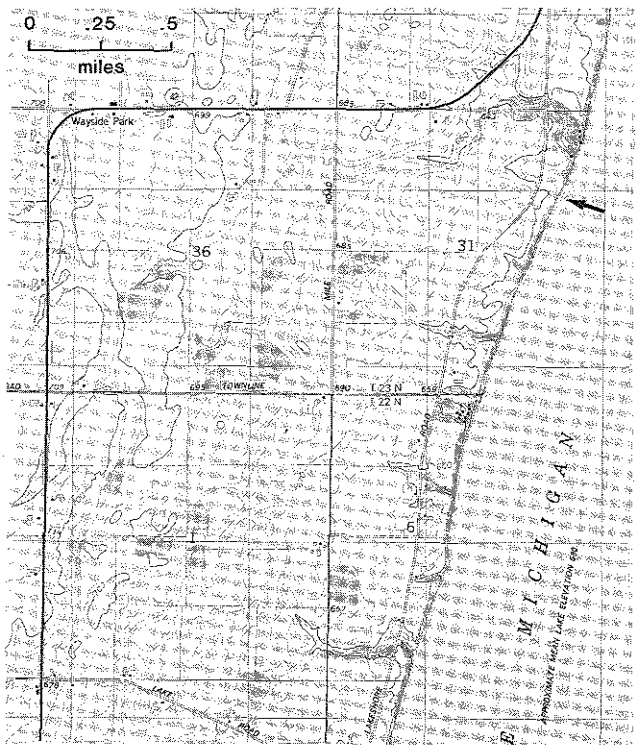

FIGURE 42.--Part of the Kewaunee 7.5-minute quadrangle showing the location of reference section 2 of the Haven Member.

fully differentiated or mapped. Its time equivalent in the Green Bay Lobe is the Chilton Member (Appendix 10b).

Description of type section.--The type section lies in a lake bluff about 1.6 km east of the village of Haven. Total bluff height is about 15 m. At the time of description the lower 10 to 12 m of the bluff exposed the Haven Member. The Haven Member at this site is overlain by 3 to 4 m of till of the Valders Member.

Person naming unit.--Larry Acomb and David Mickelson. This unit name was first used informally by Acomb (1978) and subsequently by Acomb, Mickelson, and Evenson (1982).

APPENDIX 10c

VALDERS MEMBER OF THE KEWAUNEE FORMATION

Source of name.--Village of Valders, Manitowoc County, located on the Reedsville 15-minute quadrangle.

Type of section.--Valders Lime Quarry, SW¼NE¼ sec. 32, T. 19 N., R. 22 E., located on the Valders 7.5-minute quadrangle (fig. 43).

Reference section.--(1) Stoney Point Section, in the lake bluff, sec. 34, T. 16 N., R. 23 E., located on the Sheboygan North 7.5-minute quadrangle (fig. 44). Here somewhat less than 2 m of Valders till overlies sandy, stoney till. (2) Pods Section, in the lake bluff, sec. 22, T. 16 N., R. 23 E., located on the Sheboygan North 7.5-minute quadrangle (fig. 45). Here discontinuous lenses and pods of Valders till are present in lake sediment in the upper part of the bluff.

Description of unit.--The Valders Member contains a pebbly and cobbly, sandy, silty till. In most exposures it is somewhat crumbly when dry, and plastic when wet. Its color ranges from pink (5YR 7/3) and reddish yellow (5YR 6/6, 7/6) to reddish brown (2.5YR 5/4).

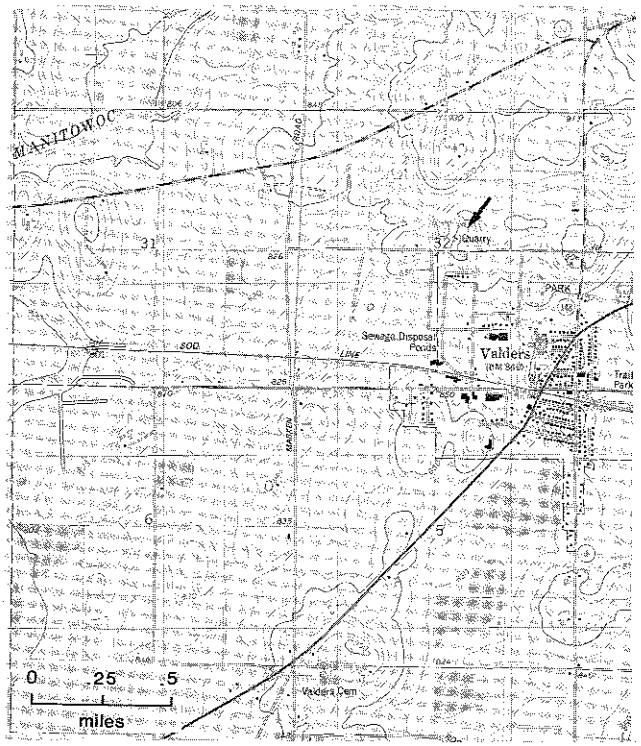

FIGURE 43.--Part of the Valders 7.5-minute quadrangle showing the location of the type section of the Valders Member.

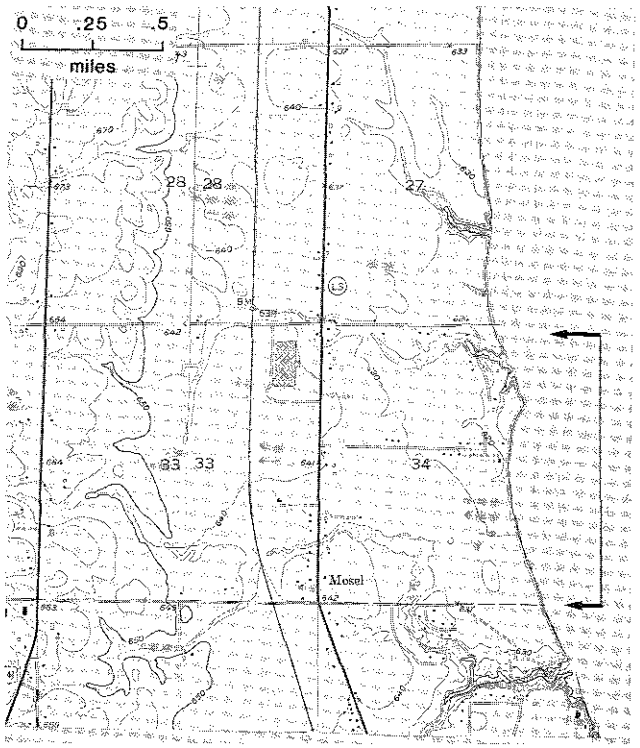

FIGURE 44.--Parts of the Howards Grove and Sheboygan North 7.5-minute quadrangles showing the location of reference section 1 of the Valders Member.

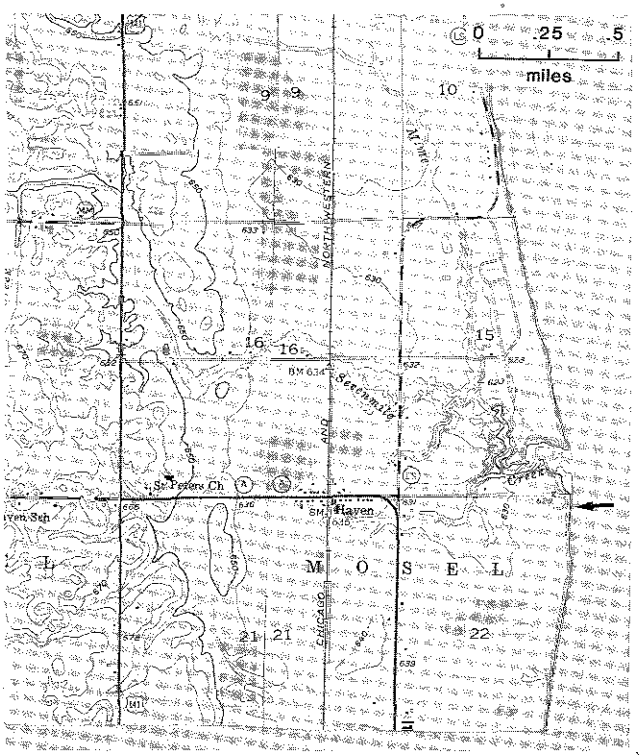

FIGURE 45.--Parts of the Howards Grove and Sheboygan North 7.5-minute quadrangles showing the location of reference section 2 of the Valders Member.

Till of the Valders Member is quite pebbly, containing numerous cobbles and sand lenses. Its average sand, silt, and clay content is 30 percent, 52 percent, and 17 percent respectively. Clay mineral analysis shows 46 percent expandables, 42 percent illite and 12 percent kaolinite and chlorite. The unit is distinctly over-consolidated.

Nature of contacts.--The lower contact of the Valders Member in exposures inland of the lake bluff is usually sharp; however, along the shoreline the lower contact can be gradational, or interbedded with sand of a lower member.

The Valders Member is the surface unit over much of its known extent (fig. 2). In these areas there is a well developed soil developed on the Valders Member, and it is leached to greater than 75 cm (Mickelson and Evenson, 1975). North and east of the East Twin River the Valders Member is presumably covered by the Two Rivers Member but the contact has not been seen.

Differentiation from other units.--The Valders Member is most easily distinguished from other till in the region by its clay mineralogy. It has the most expandable clay (46 percent) and least illite (mean about 40 percent) of any unit in the area. Additionally, the Valders Member can be differentiated from the older members by its coarser grained texture (more sand, pebbles, and cobbles).

Regional extent and thickness.--The Valders Member is presumed to extend along the Lake Michigan shoreline from south of Sheboygan to north of Algoma. However, the unit is not exposed in the lake bluff north of Two Rivers. Inland the unit reaches the Kettle Moraine in Sheboygan County and drapes over the Kettle Moraine in the Valders area. It is present at the surface immediately west of the East Twin River, but not to the east. The Valders Member averages about 2.4 m thickness and ranges only between 1.8 and 3 m.

Origin.--The Valders Member contains basal glacial till deposited by ice of the Lake Michigan Lobe and associated fluvial and lacustrine deposits.

Age.--The Valders Member is thought to be stratigraphically below the Two Creeks Bed, suggesting an age of more than 12,000 years. Radiocarbon dates on material from Kellners Lake (Goodwin, 1976) indicate earlier deposition; however, the dated sediment was probably contaminated with dead carbon.

Correlation.--A lateral equivalent in Lake Michigan or on the Michigan shoreline has not been recognized to date; however, it is presumed that the unit is at least locally represented both on the lake bottom and in the Michigan bluffs. More work may establish its existence in these areas. The Chilton Member of the Green Bay Lobe is a time equivalent of the Valders Member.

Description of type section.--At the type section about 2 m of till of the Valders Member overlies a striated dolomite surface in the northeast corner of the quarry. Along the northern part of the quarry exposure brown, sandy till of the Horicon Formation about 2 m thick lies between the Valders till and the underlying dolomite surface.

Person naming member.--First use of the unit name was by F. T. Thwaites (1943). Redescribed by Larry Acomb (1978). Subsequently used by Acomb, Mickelson, and Evenson (1982) and others. This description written by Larry Acomb and David M. Mickelson.

APPENDIX 10d

TWO RIVERS MEMBER OF THE KEWAUNEE FORMATION

Source of name.--The city of Two Rivers, Manitowoc County, located on the Manitowoc 15-minute quadrangle.

Type section.--Car Dealer Section, NW¼SW¼NW¼ sec. 31, T. 20 N., R. 25 E, located on the Two Rivers 7.5-minute quadrangle (fig. 46). Section is behind Chevrolet dealership on east side of Highway 42 on the north side of Two Rivers.

Reference Section.--(1) Two Creeks Section, NE¼NE¼ sec. 2, T. 21, N., R. 24 E., located on the Two Creeks 7.5-minute quadrangle (fig. 47). About 2 m of Two Rivers till overlies sand and silt containing the Two Creeks Bed. Beneath the lake sediments is Haven till at beach level. (2) In the lake bluff, NE¼ sec. 31, T. 23 N., R. 25 E., located on the Kewaunee 7.5-minute quadrangle (fig. 48). Two Rivers till about 3 m thick is present at the top of the bluff. This unit may include subglacial and supraglacial facies. This is underlain by lake sediment, Haven till, more lake sediment and probably Ozaukee till (Acomb, Mickelson, and Evenson, 1982).

Description of unit.--The till of the Two Rivers Member is pebbly and cobbly, sandy silt. Its color is either light reddish brown to pink (5YR 6/4, 7.5YR 7/4) or reddish yellow (5YR 6/6, 7/6), and the unit is rather crumbly when dry. When wet the Two Rivers till is plastic.

The pebbles and cobbles are predominantly locally derived dolomite; however, igneous rock types are not infrequent. The till of the Two Rivers Member consists of 31 percent sand, 50 percent silt, and 19 percent clay in the less-than-2-mm fraction. Its clay mineral assemblage includes an average of about 35 percent expandable clay, 52 percent illite, and 13 percent kaolinite plus chlorite.

Nature of contacts.--The lower contact of the Two Rivers Member with the lacustrine sediment is often diffuse and veined. At the Two Rivers moraine there is a zone of alternating till and lacustrine sediment that is interpreted to be subaqueous flow till. In other shoreline exposures the lower contact is highly distorted by load-cast involutions (Mickelson and Evenson, 1974).

In the Point Beach area of Wisconsin the Two Rivers Member is overlain by sandy near-shore deposits. This contact is sharp. Inland, the Two Rivers Member is present at the surface and has a well developed soil developed on it, but is leached only to depths of less than 60 cm (Mickelson and Evenson, 1975).

Differentiation from other units.--The Two Rivers Member is distinguished from the very similar Valders, Haven, and Ozaukee Members by its clay mineralogy, color, and grain-size distribution. It is more orange, coarser grained, and has more expandable clay and less kaolinite and chlorite than the Haven and Ozaukee Members, whereas it has less expandable clay and more illite than the Valders Member. (The grain-size distribution and color of the Valders and Two Rivers Members are very similar).

Regional extent and thickness.--The Two Rivers Member extends from Two Rivers northward to at least Algoma along the Lake Michigan bluff top (fig. 2). Inland the margin of unit roughly parallels the East Twin River to north of the Kewaunee River where it probably merges with the Glenmore Member of the Green Bay Lobe. The width of the onshore portion of the member is approximately 6 miles (10 km). It is the till overlying the Two Creeks Bed. The relatively thin Two Rivers Member averages about 2.4 m in thickness.

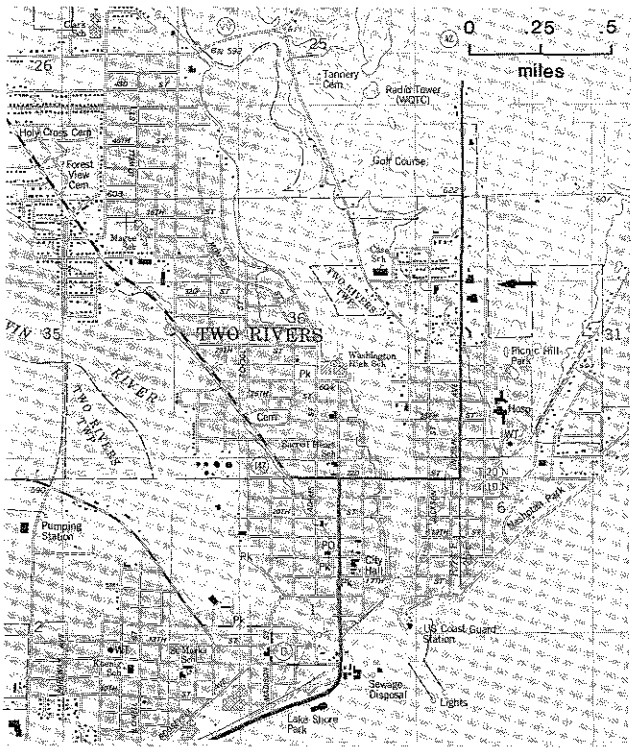

FIGURE 46.--Part of the Two Rivers 7.5-minute quadrangle showing the location of the type section of the Two Rivers Member.

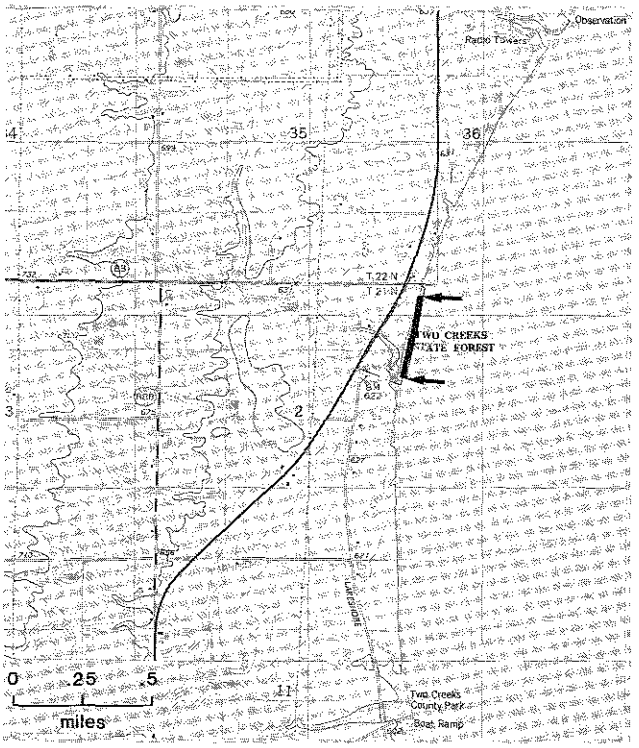

FIGURE 47.--Part of the Two Creeks 7.5-minute quadrangle showing the location of section for 1 of the Two Rivers Member.

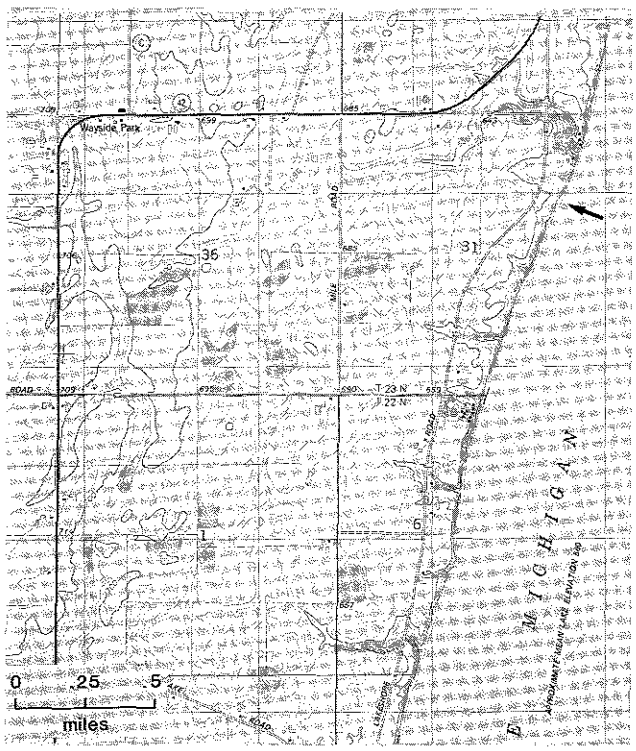

FIGURE 48.--Part of the Kewaunee 7.5-minute quadrangle showing the location of reference section 2 of the Two Rivers Member.

Origin.--The Two Rivers Member contains basal till, deposited by glaciers flowing southward in the Lake Michigan basin, and associated fluvial lacustrine deposits.

Age.--The Two Rivers Member directly overlies the very well dated Two Creeks Bed, meaning that it was deposited shortly after 11,500 B.P.

Correlation.--The Two Rivers Member is correlated laterally with the Two Rivers Till Member mapped in Lake Michigan (Lineback and others, 1974) and with materials in Michigan reported by Taylor (1978). The unit is the time equivalent of the Glenmore Member of the Green Bay Lobe (Appendix 10g).

Description of type section.--At the type section, located behind the Chevrolet dealership, in a west facing pit, approximately 3 m of red clay till overlies sandy sediment presumed to be of lacustrine origin. A drill hole indicates the lacustrine deposits to be about 15 m thick. The till section is complex and probably includes thrusted masses of Valders till and soil material.

Person naming member.--Edward B. Evenson (1973). Described by Larry Acomb and David Mickelson.

APPENDIX 10e

BRANCH RIVER MEMBER OF THE KEWAUNEE FORMATION

Source of name.--The Branch River in Morrison Township, located on the Denmark 15-minute quadrangle.

Type section.--Greenleaf Quarry, SE¼SW¼ sec. 4, T. 21 N., R. 20 E., Brown County. Quarry is on the north side of Highway 96, 0.4 miles (0.7 km) east of Greenleaf and is located on the Greenleaf 7.5-minute quadrangle (fig. 49).

Reference sections.--(1) Road cut on east side of Campbell Road, 0.25 miles (0.4 km) south of Collins Road, NW¼NW¼ sec. 24, T. 21, N., R. 20 E., located on the Greenleaf 7.5-minute quadrangle (fig. 50). Till of the Branch River Member is about 2 m thick over dolomite. (2) Small borrow pit on the southwest corner of the intersection of Highways Z and PP, NE corner, sec. 28, T. 21 N., R. 20 E., located on the Greenleaf 7.5-minute quadrangle (fig. 51). Till of the Branch River Member is about 1 m thick and overlies gravel of unknown thickness. The till is overlain locally by about 1 m of Chilton till.

Description of unit.--The till of the Branch River Member is brown (7.5YR 5/4) and averages 34 percent sand, 48 percent silt, and 23 percent clay. The 0.0625-to-0.037-mm fraction contains less than 1 percent calcite and about 27 percent dolomite. The mean magmetic susceptibility value is 6.8 (McCartney and Mickelson, 1982).

Nature of contacts.--Where the Branch River Member is the surface unit, in a small part of Brown County, it is overlain locally by organic deposits and alluvium. Where overlain by the Chilton Member the contact is distinct. Where the Branch River Member overlies dolomite or till and gravel of the Horicon Formation the contact is also distinct. Its contact with the correlative Silver Cliff Member is an arbitrary vertical contact at the Fox River.

Differentiation from other units.--Till of the Branch River Member is distinguished from that of the underlying Horicon Formation by its somewhat more reddish color and less abundant sand. It is distinguished from the overlying Chilton and Glenmore Members by its more abundant sand (34 percent in Branch River, 17 percent in Chilton, 15 percent in Glenmore.)

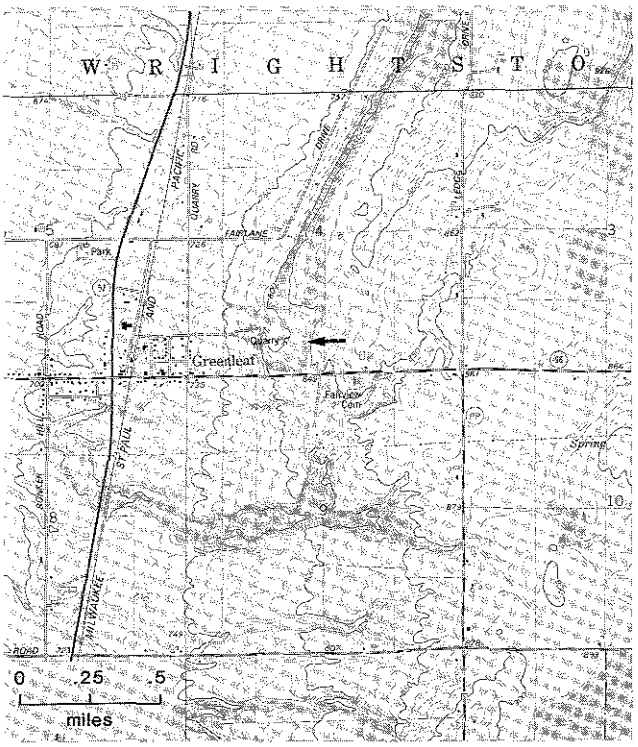

FIGURE 49.--Part of the Greenleaf 7.5-minute quadrangle showing the location of the type section of the Branch River Member and reference section 1 of the Chilton Member.

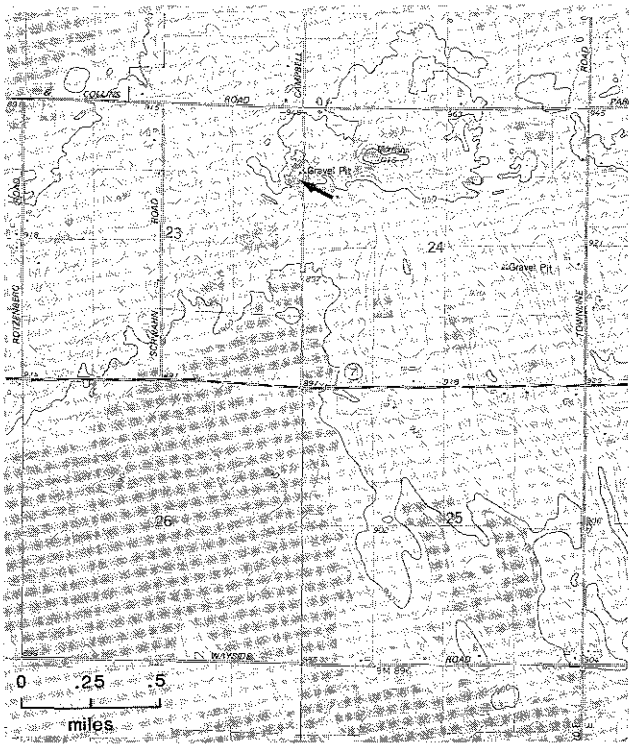

FIGURE 50.--Part of the Greenleaf 7.5-minute quadrangle showing the location of reference section 1 of the Branch River Member.

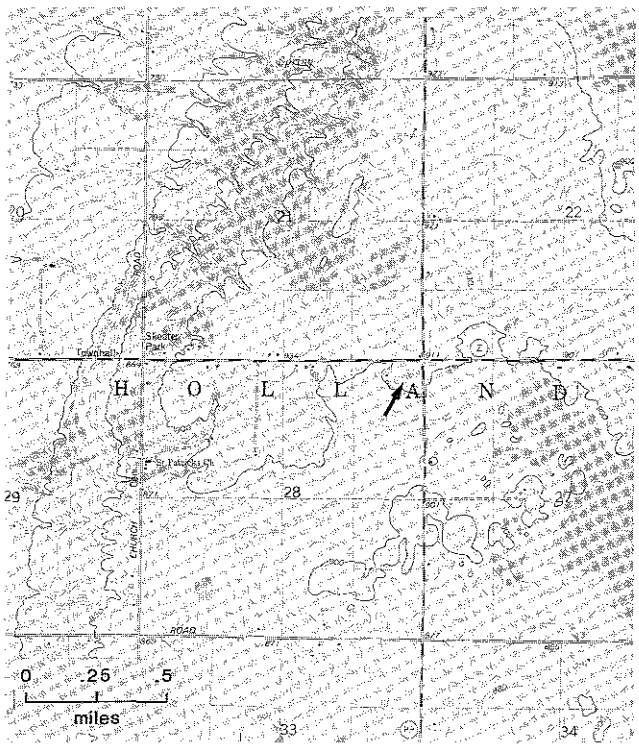

FIGURE 51.--Part of the Greenleaf 7.5-minute quadrangle showing the location of reference section 2 of the Branch River Member.

Regional extent and thickness.--The extent of the Branch River Member is not well known in the subsurface. Its surface exposure is shown in figure 2. Average thickness is probably about 2 m although very few sections have been described.

Origin.--Till of this member was deposited by ice of the Green Bay Lobe.

Age and correlation.--The Branch River Member is correlative with the Silver Cliff Member west of the Fox River (Appendix 10h). It is probably correlative with the Ozaukee Member in the area covered by the Lake Michigan Lobe and may also be correlative with the Haven Member. At no location are materials of this member in contact with materials of either the Haven or Ozaukee Member and there are no radiocarbon dates to allow firm correlation. Because the Branch River Member is below the Chilton Member, it was deposited before the Two Creeks Bed.

Description of type section.--In 1979 the best exposure was along the east face of material stripped for the quarry operation. Under spoil material is 0.5 to 1.5 m of Chilton till, leached to its base. Much of this is in the B horizon of the soil. Beneath the Chilton till is 0.1 to 0.5 m of sand of unknown association. Lying below the sand and above dolomite is about 1 m of Branch River till that is unleached. No Glenmore till has been seen in the quarry face.

Person naming unit.--David M. Mickelson. This unit name was used informally by McCartney and Mickelson (1982).

APPENDIX 10f

CHILTON MEMBER OF THE KEWAUNEE FORMATION

Source of name.--City of Chilton, Calumet County, located on the Chilton 15-minute quadrangle.

Type section.--The DePere Site, a gravel pit just north of Brown County Highway X near the top of the Silurian escarpment. Located in the southeast corner of sec. 38, T. 23 N., R. 20 E., on the Depere 7.5-minute quadrangle (fig. 52).

Reference sections.--(1) Greenleaf Quarry, SE¼SW¼ sec. 4, T. 21 N., R. 20 E., Brown County (see Appendix 10e and fig. 49 for description). (2) Brillion Quarry, SW¼SW¼SW¼ sec. 24, T. 20 N., R. 20 E., Calumet County, located on the Brillion 7.5-minute quadrangle (fig. 53). On the north face of the quarry 2 to 3 m of Chilton till overlies till of the Horicon Formation. A sand lens separates two slightly differing units of Chilton till.

Description of unit.--The till of the Chilton Member is reddish-brown (5YR 4/4) and averages 17 percent sand, 49 percent silt, and 33 percent clay in the less-than-2-mm fraction. The 0.0625-to-0.037 mm fraction contains less than 1 percent calcite and about 32 percent dolomite. The mean value of magnetic susceptibility is 6.4 (McCartney and Mickelson, 1982). In many places the till appears to have two phases but these have not been defined, nor have consistent differences been found at many locations.

Nature of contacts.--The Chilton Member is the surface unit in eastern Calumet County (fig. 2). Here it is overlain in places by organic and alluvial deposits of an unnamed unit of Holocene age. The lower contact with underlying Horicon Formation or Branch River Member is generally distinct. Its contact with the correlative Kirby Lake Member is an arbitrary vertical contact at the Fox River.

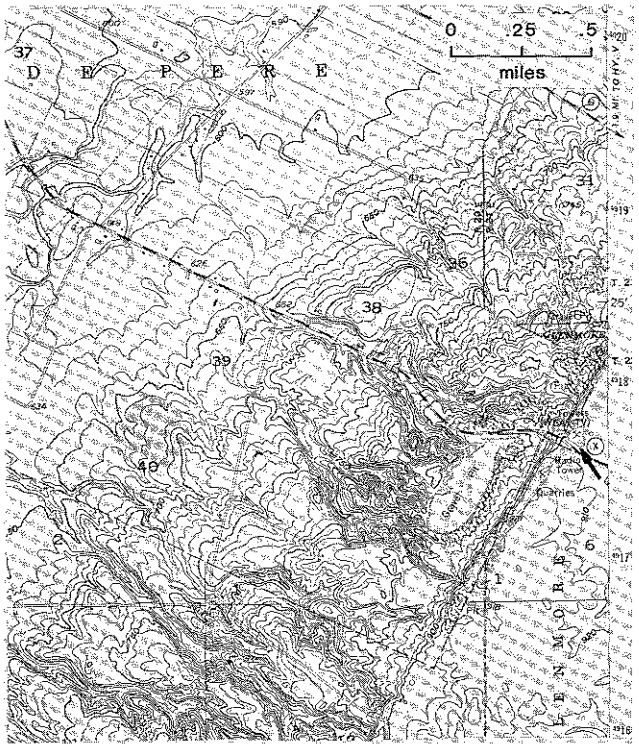

FIGURE 52.--Part of the DePere 15-minute quadrangle showing the location of the type sections of the Chilton and Glenmore Members.

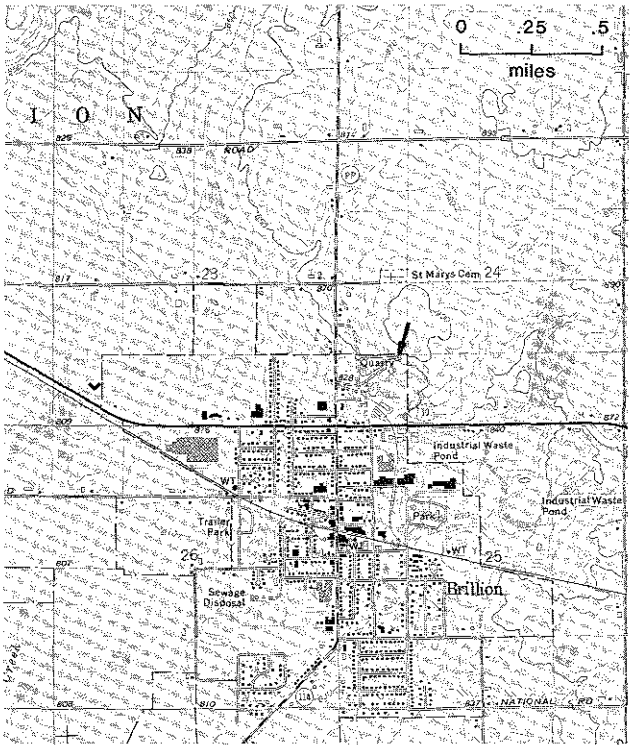

FIGURE 53.--Portion of the Brillion 7.5-minute quadrangle showing the location of reference section 2 of the Chilton Member.

Differentiation from other units.--Till of the Chilton Member contains less sand than the underlying Branch River Member (17 percent in Chilton, 34 percent in Branch River). It is distinguished from till of the Valders Member to the east by its lower percentage of sand (17 percent in Chilton, 30 percent in Valders). It is distinguished from the overlying till of the Glenmore Member by its higher magnetic susceptibility (6.4 in Chilton, 3.9 in Glenmore). It is distinguished from the Kirby Lake Member by its geographic position east of the Fox River (McCartney and Mickelson, 1982).

Regional extent and thickness.--Till of the Chilton Member is generally 1 to 3 m thick. Associated deposits of sand and gravel may be considerably thicker. The extent of the unit is shown in figure 2.

Origin.--Till of this member was deposited by glacial ice of the Green Bay Lobe. Phases of this till (McCartney and Mickelson, 1982) may represent subglacial origins of two separate ice advances or they may be subglacial and supraglacial facies of a single advance.

Age and correlation.--The Chilton Member is correlative with the Valders Member of the Lake Michigan Lobe (Black, 1980; Acomb, Mickelson and Evenson, 1982; McCartney and Mickelson , 1982), and the Kirby Lake Member (Appendix 10i) to the west. At its type section it underlies organic material dated at 11,980 $\pm$ 100 B.P. (ISGS-480) and the member was deposited before the Two Creeks Bed.

Description of type section.--The type section is on the north-facing exposure of a gravel pit about 100 m northwest of a large radio tower. This is also the type section of the Glenmore Member. The uppermost unit is Glenmore till,

approxmately 6 m thick. It has low magnetic susceptibility (average of two samples, 3.3). This directly overlies organic material (wood fragments, spruce needles) and what is interpreted to be a soil developed in sand about 2 m thick. This sand of the Chilton Member overlies 2.5 m of till of the Chilton Member with high magnetic susceptibility (average of two samples, 6.4). Beneath this till is gravel at least 8 m thick but its lithostratigraphic association is not known.

Person naming unit.--David Mickelson. This unit name was first used by McCartney and Mickelson (1982).

APPENDIX 10g

GLENMORE MEMBER OF THE KEWAUNEE FORMATION

Source of name.--Township of Glenmore, Brown County, located on the DePere 15- and 7.5-minute quadrangles.

Type section.--The DePere Site, a gravel pit just north of Highway X near the top of the Silurian escarpment. Located in the southeast corner of sec. 38, T. 23 N., R. 20 E., on the Depere 7.5-minute quadrangle (fig. 52).

Reference sections.--(1) The Highway W Site located on the south side of an unnamed creek, 60 m east of Highway W, NW¼NE¼ sec. 3, T. 20 N., R. 20 E., in Calument County, located on the Brillion 7.5-minute quadrangle (fig. 54). Exposed in this section is about 12 m of Glenmore till containing many wood fragments. Two drill holes about 5 m south of the top of the exposure penetrated sand at about stream level and what is assumed to be dolomite bedrock 1 m below this. (2) A low roadcut (2.5 m) on south side of School Road at NW¼NW¼NE¼ sec. 32, T. 22 N., R. 21 E., Brown County, located on the Morrison 7.5-minute quadrangle (fig. 55). All till exposed is Glenmore till.

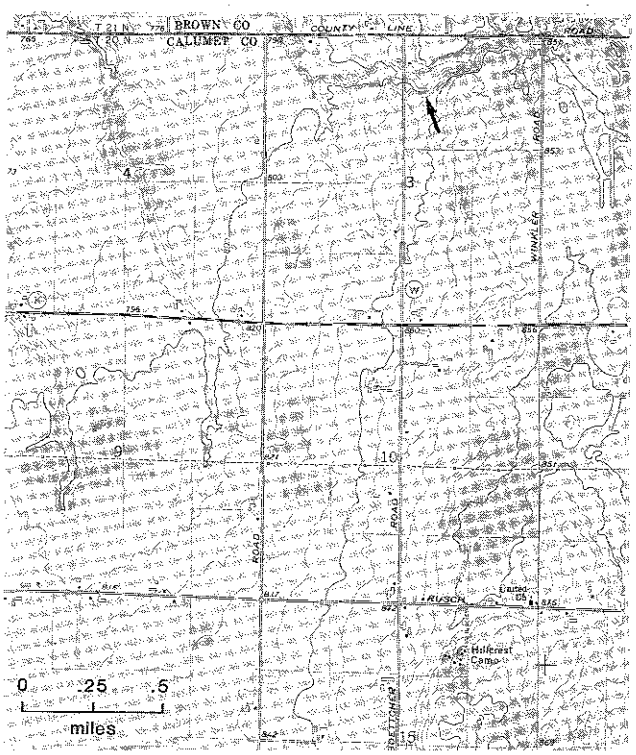

FIGURE 54.--Part of the Brillion 7.5-minute quadrangle showing the location of reference section 1 of the Glenmore Member.

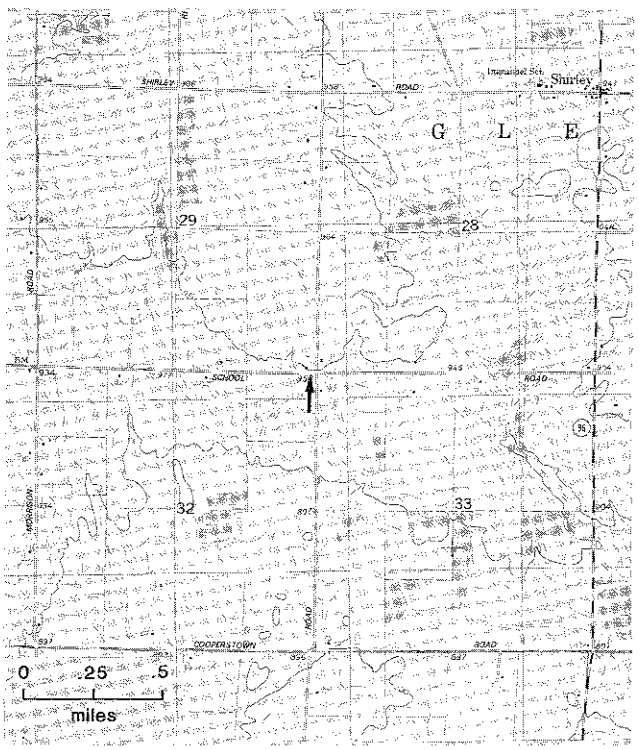

FIGURE 55.--Part of the Morrison 7.5-minute quadrangle showing the location of reference section 2 of the Glenmore Member.

Description of unit.--The till of the Glenmore Member is dull reddish-brown (5YR 4/4) and averages 15 percent sand, 48 percent silt and 37 percent clay in the less than 2-mm fraction. The 0.0625-to-0.037 mm fraction contains less than calcite and 32 percent dolomite. The mean value of magnetic susceptibility is 3.9 (McCartney and Mickelson, 1982).

Nature of contacts.--The Glenmore Member is the surface unit in many places where it is present (fig. 2). In places it is overlain by organic sediment or lacustrine silt and clay of younger, unnamed units. The lower contact is usually abrupt although when it overlies till of the Chilton Member magnetic susceptibility often must be measured to identify the contact.

The contact between the Glenmore Member and the Middle Inlet Member is an arbitrary vertical contact at the Fox River.

Differentiation from other units.--Till of the Glenmore Member is distinguishable from till of the underlying Chilton Member by its lower magnetic susceptibility (mean 3.9 in Glenmore and 6.4 in Chilton). It is distinguished from the older Branch River Member by the greater amount of silt and clay (85 percent in Glenmore, 66 percent in Branch River). Till of the Glenmore Member is distinguished from the correlative till of the Two Rivers Member by having less sand (15 percent in Glenmore, 31 percent in Two Rivers). Till of the Glenmore Member can also be distinguished from older units by greater depth of leaching (Mickelson and Evenson, 1975).

Regional extent and thickness.--Till of the Glenmore Member is as much as 8 m thick. It appears that the thickest sections are in the Denmark moraine, within 2 km of the outer extent of the unit. Gravel of the member may be thicker than 8 m in places. The extent of the Glenmore Member is shown in figure 2.

Origin.--Till of this member was deposited by glacial ice of the Green Bay Lobe. Sand and gravel associated with the till was fluvially deposited.

Age and correlation.--The Glenmore Member is correlative with the Two Rivers Member deposits by the Lake Michigan Lobe and the Middle Inlet Member (Appendix 10j) deposited by the western portion of the Green Bay Lobe. At its type section it overlies organic material dated at 11,980 $\pm$ 100 B.P. (ISGS-480) and the member was therefore deposited before the Two Creeks Bed (McCartney and Mickelson, 1982).

Description of type section.--The type section is on the north-facing exposure of a gravel pit about 100 m northwest of a large radio tower. This is also the type section of the Chilton Member. The uppermost unit is Glenmore till, approximately 6 m thick. It has low magnetic susceptibility (average of two samples, 3.3). This directly overlies organic material (wood fragments, spruce needles) and what is interpreted to be a soil developed in sand about 2 m thick. This sand of the Chilton Member overlies 2.5 m of till of the Chilton Member with high magnetic susceptibility (average of two samples, 6.4). Beneath this till is gravel at least 8 m thick but its lithostratigraphic association is not known.

Person naming unit.--David M. Mickelson. This unit name was first used by McCartney and Mickelson (1982).

APPENDIX 10h

SILVER CLIFF MEMBER OF THE KEWAUNEE FORMATION

Source of name.--Township of Silver Cliff in western Marinette County.

Type section.--Road cut at the crest of the Inner Mountain moraine on the north side of Eagle River Road in SW¼SW¼SW¼ sec. 9, T. 34 N., R. 18 E., Marinette County located on the Roaring Rapids 7.5-minute quadrangle (fig. 56).

Reference sections.--(1) Road cut on the north side of Eagle River Road about 0.9 miles (1.5 km) east of the type section in SW¼SW¼SW¼ sec. 10, T. 34 N., R. 18 E., Marinette County, located on the Leahman Lake 7.5-minute quadrangle (fig. 57). The Silver Cliff till is overlain by silty sand and yellowish medium sand in this cut. (2) The type section of the Kirby Lake Member described in Appendix 10i.

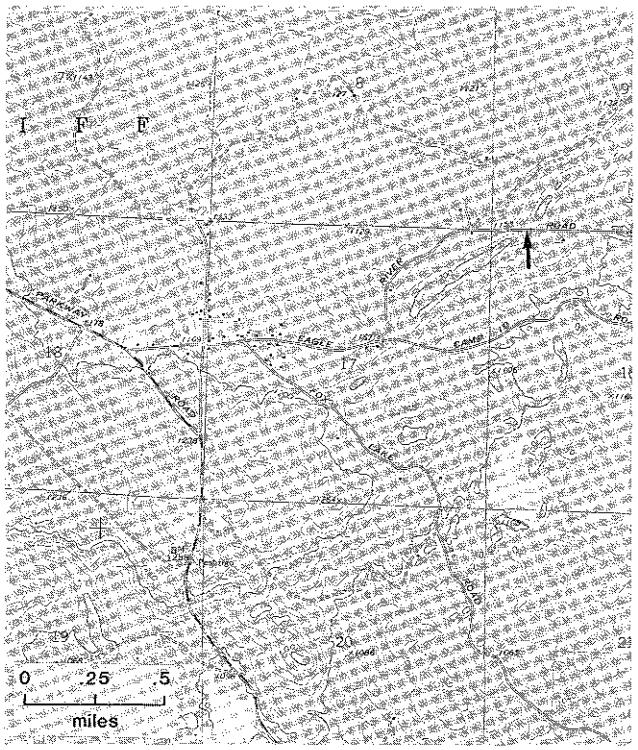

FIGURE 56.--Part of the Roaring Rapids 7.5-minute quadrangle showing the type section of the Silver Cliff Member.

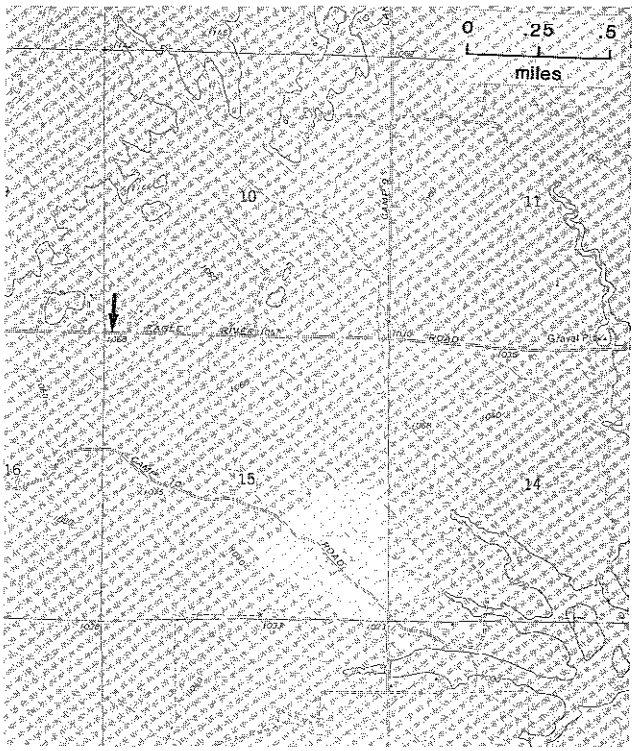

FIGURE 57.--Part of the Leahman Lake 7.5-minute quadrangle showing the location of reference section 1 of the Silver Cliff Member.

Description of unit.--The sand:silt:clay ratio in the till averages 61:32:7 in Marinette and Oconto Counties. The till is generally reddish brown (5YR 4 to 5/4). Carbonates average 27 percent (standard deviation 7 percent) in the less-than-0.063-mm fraction, 9 percent (standard deviation 4 percent) in the 0.13-to-0.25-mm fraction, and 39 percent (standard deviation 13 percent) in the 1-to-2-mm fraction, based on eleven analyses. Carbonates are typically leached to a depth of 1 to 2 m.

Nature of contacts.--The Silver Cliff Member is generally poorly exposed. It commonly unconformably overlies sorted sand and silt, but in some places it lies on older till or pre-Pleistocene rock. It is the surface unit in some areas, but is unconformably overlain by silty sand, sand, or gravelly sand in many areas, and to the east it is overlain by younger till units. Its contact with the correlative Branch River Member is an arbitrary vertical contact at the Fox River.

Differentiation from other units.--The till of this unit is distinguished from the till of the older Horicon Formation by its redder color and slightly finer grain size. The Silver Cliff till is considerably coarser than the younger Kirby Lake till. Where the Kirby Lake till is absent, the Silver Cliff till may be difficult to distinguish from the younger Middle Inlet till, but in similar settings the Silver Cliff is leached of carbonates to a greater depth than the Middle Inlet.

Regional extent and thickness.--The Silver Cliff Member is thin and discontinuous. Its western boundary is the eastern moraine of the Mountain system (Thwaites, 1943) in Marinette and Oconto Counties. Its southern and northern limits are unknown.

Origin.--Most of the material in the Silver Cliff Member is till deposited by ice of the west half of the Green Bay Lobe, but some lenses of fluvial sand and gravel occur in the till.

Age.--The Silver Cliff till was deposited in Late Wisconsinan time, presumably before 12,000 B.P.

Correlation.--The Silver Cliff Member is probably the time equivalent of the Branch River Member on the east side of the Green Bay Lobe.

Description of type section.--The roadcut is about 2 m high and apparently consists entirely of the Silver Cliff till, a sample of which contained 62 percent sand, 31 percent silt, and 7 percent clay. Mapleview till may be present at road level and extend to an unknown depth.

Person naming unit.--M. C. McCartney, modified by Lee Clayton. This unit name originally used informally by McCartney (1979) and subsequently by McCartney and Mickelson (1982).

APPENDIX 10i

KIRBY LAKE MEMBER OF THE KEWAUNEE FORMATION

Source of name.--Kirby Lake, a lake 15 km west of Crivitz, Marinette County, in the northeast corner of the Crivitz 7.5-minute quadrangle.

Type section.--Road cut on south side of Highway W, 0.1 miles (0.16 km) west of Kirby Lake Road, NE¼NW¼SE¼ sec. 27, T. 32 N., R. 19 E., Marinette County, located on the Crivitz 7.5-minute quadrangle (fig. 58).

Reference section.--Till at the base of the gravel pit in the township of Amberg at the SW¼SW¼NW¼ sec. 27, T. 35 N., R. 21 E., Marinette County located on the Wausaukee 15-minute quadrangle (fig. 59).

Description of unit.--The Kirby Lake till averages 36 percent sand, 47 percent silt, and 17 percent clay (in the less-than-2-mm fraction) in Marinette and Oconto Counties. The till is quite variable in grain size (standard deviations of 14, 10, and 10 percent in the sand, silt, and clay). At the type section the unit is more clayey. The till is commonly reddish brown (2.5YR 4/4 and 5YR 5/3 to 4) but infrequently is yellowish red (5YR 3/6) or light brown 7.5YR 6/4). Carbonate content averages 31 percent (8 percent standard deviation) in the less-than-0.63-mm fraction, 14 percent (5 percent standard deviation) in the 0.13-to-0.25-mm fraction, and 44 percent (14 percent standard divation) in the 1-to-2-mm fraction in 21 samples (McCartney, 1979).

Nature of contacts.--The Kirby Lake Member is generally poorly exposed. It overlies sandy till, bedded sand, bedded silt and clay, or pre-Pleistocene rock. It is overlain by bedded sand, silty sand, or till. The contact

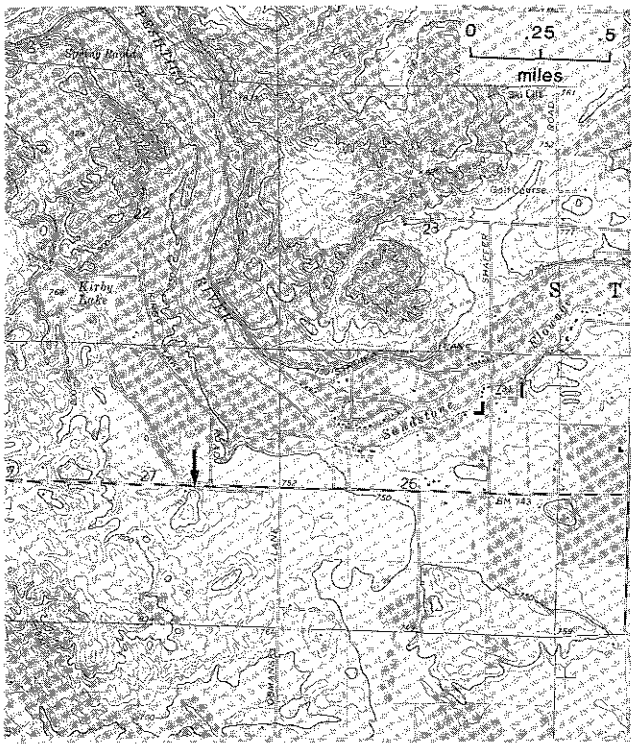

FIGURE 58.--Part of the Crivitz 7.5-minute quadrangle showing the location of the type section of the Kirby Lake Member. This section also is reference section 2 of the Silver Cliff Member and reference section 2 of the Middle Inlet Member. A sketch of the section is given in figure 60.

FIGURE 59.--Part of the Wausaukee 15-minute quadrangle showing the location of the reference section of the Kirby Lake Member.

between the Kirby Lake Member and the correlative Chilton Member is an arbitrary vertical contact at the Fox River.

Differentiation from other units.--The Kirby Lake till is distinguished from both underlying and overlying till by its finer grain size.

Regional extent and thickness.--The Kirby Lake till is patchy at the surface in the southern half of Marinette County and is absent at the surface in the northern half of the county. The western limit of the till is the eastern edge of glacial Lake Oconto and the eastern moraine of the Athelstane moraine system south of Athelstane (Thwaites, 1943). North of Athelstane the Kirby Lake till is covered by the Middle Inlet till. The Middle Inlet till also covers the Kirby Lake till to the west of an irregular ice margin that is partly contiguous with the western moraine of the Athlestane moraine system of Thwaites (1943). The Kirby Lake till is typically very thin at the surface (less than 1 m thick) but has been found to be as much as 10 m thick in the subsurface.

Origin.--Much of the Kirby Lake Member is subglacial till deposited by ice of the Green Bay Lobe.

Age.--The Kirby Lake till was deposited during Late Wisconsinan time, before deposition of the Two Creeks Bed.

Correlation.--The Kirby Lake is probably the age equivalent of the Chilton Member, deposited by ice of the east half of the Green Bay Lobe.

Description of type section.--A sketch of the type section is shown in figure 60. Till of the Middle Inlet Member is approximately 2 m thick at the top of the section. A sample from this unit contains 67 percent sand, 24 percent silt, and 9 percent clay. Clay minerals from this unit are 49 percent illite, 19 percent chlorite and kaolinite, and 33 percent expandables (Herbert Glass, personal communication). Below this is approximately 1 m of Kirby Lake till that contains 38 percent sand, 41 percent silt, and 21 percent clay. Clay minerals from this unit are 46 percent illite, 17 percent kaolinite and chlorite, and 38 percent expandables (Herbert Glass, personal communication).

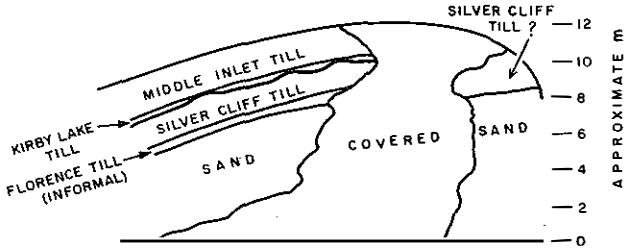

FIGURE 60.--Diagrammatic sketch of Crivitz Section, the type section of Kirby Lake Member, showing relationship of units.

The Kirby Lake till overlies about 4 m of Silver Cliff till containing 50 percent sand, 37 percent silt, and 13 percent clay. Clay minerals of this unit are 46 percent illite, 16 percent kaolinite and chlorite, and 39 percent expandables (Herbert Glass, personal communications). Beneath the Silver Cliff till is about 1 m of till that contains 48 percent sand, 35 percent silt and 17 percent clay and is tentatively correlated with the informally named Florence till of Florence County. Clay minerals are 37 percent illite, 20 percent kaolinite and chlorite, and 43 percent expandables (Herbert Glass, personal communications). Below the Florence till sand of unknown association extends to the base of the section.

Person naming unit.--M. C. McCartney, modified by Lee Clayton. This unit name originally used informally by McCartney (1979) and subsequently by McCartney and Mickelson (1982).

APPENDIX 10j

MIDDLE INLET MEMBER OF THE KEWAUNEE FORMATION

Source of name.--Township of Middle Inlet in central Marinette County.

Type section.--Road cut in NE¼NW¼SE¼ sec. 8, T. 33 N., R. 23 E., Marinette County, located on the Stephenson 15-minute quadrangle (fig. 61). This cut is on Caylor Road, about 0.9 miles (1.5 km) north of Highway JJ, on the north side of the road.

Reference sections.--(1) Road cut at NE¼NE¼SW¼ sec. 8, T. 33 N., R. 23 E., on the west side of Caylor Road, about 0.4 miles (0.7 km) north of Highway JJ, located on the Stephenson 15-minute quadrangle (fig. 61). The whole exposure is Middle Inlet till. (2) The Crivitz section, described as the type section of the Kirby Lake Member (Appendix 10i) and shown on figures 58 and 60.

Description of unit.--The Middle Inlet till averages 64 percent sand, 28 percent silt, and 8 percent clay (in the less-than-2-mm fraction) in Marinette and Oconto Counties. Most colors are brown (7.5YR 5/3 to 4) or, more commonly reddish brown (5YR 5/3 to 4). Carbonate content averages 32 percent (7 percent standard deviation) in the smaller-than-0.063-mm fraction, 13 percent (5 percent standard deviation) in the 0.13-to-0.25-mm fraction, and 32 percent (12 percent standard divation) in the 1-to-2-mm fraction in 28 samples (McCartney, 1979).

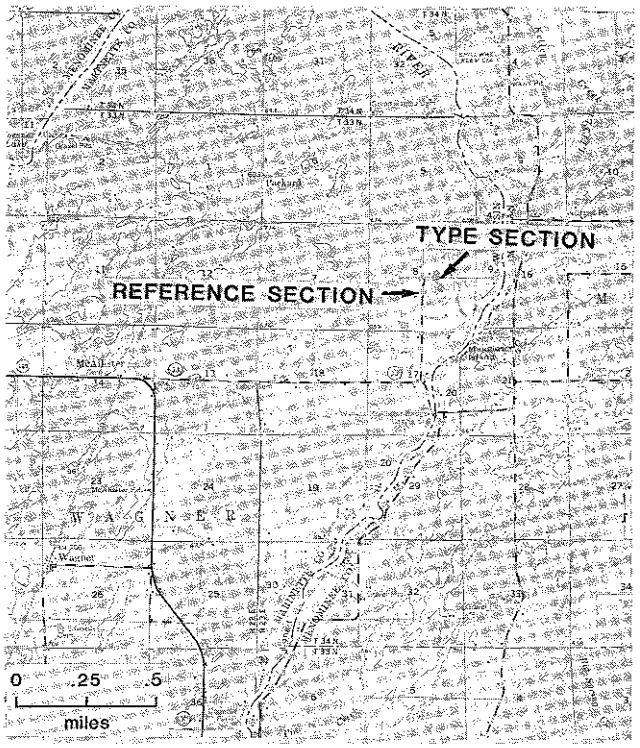

FIGURE 61.--Part of the Stephenson 15-minute quadrangle showing the location of the type section and reference section 1 of the Middle Inlet Member.

Nature of contacts.--The Middle Inlet till commonly overlies bedded sand or silty sand. In some areas it directly overlies the Kirby Lake till, and the contact is sharp. The contact between the Middle Inlet Member and the correlative Glenmore Member is an arbitrary vertical contact at the Fox River.

Differentiation from other units.--The Middle Inlet till is coarser and slightly lighter colored than the Kirby Lake till. Where the Kirby Lake is missing and the Middle Inlet rests directly on the Silver Cliff, they may be hard to distinguish. In similar landscape settings, the Middle Inlet can be distinguished from the Silver Cliff by depth of leaching; the Middle Inlet is typically leached about 0.1 m, whereas the Silver Cliff is leached about 1 m.

Regional extent and thickness.--The Middle Inlet till is the surface till in much of Marinette County. Its western border is, at least in part, the eastern moraine of the Athelstane moraine system (Thwaites, 1943). The till has not been traced out of Marinette and Oconto Counties, so its extent to the north, south, and east is unknown. The Middle Inlet Member is probably thin in most areas, but its base has been seen in too few places to determine the average thickness.

Origin.--The Middle Inlet Member is composed largely of subglacial till deposited by ice of the Green Bay Lobe.

Age.--The Middle Inlet Member was deposited in Late Wisconsinan time, probably after the Two Creeks Bed.

Correlation.--The Middle Inlet Member probably correlates with the Glenmore Member, deposited on the east side of the Green Bay Lobe.

Description of type section.--The type section is about 4.5 m high and is composed entirely of Middle Inlet till.

Person naming unit.--M. C. McCartney, modified by Lee Clayton. This unit name was first used informally by McCartney (1979) and subsequently by McCartney and Mickelson (1982).

APPENDIX 11

COPPER FALLS FORMATION

Source of name.--Copper Falls in Copper Falls State Park, Ashland County, Wisconsin, shown on the Mellen 7.5-minute quadrangle.

Type section.--Cutbank on west side of Bad River, about 0.5 miles (0.8 km) northwest of Copper Falls, in Copper Falls State Park, SW¼SE¼NW¼ sec. 17, T. 45 N., R. 2 W., Ashland County, located on the Mellen 15-minute quadrangle (fig. 62). A sketch of units present is shown in figure 63.

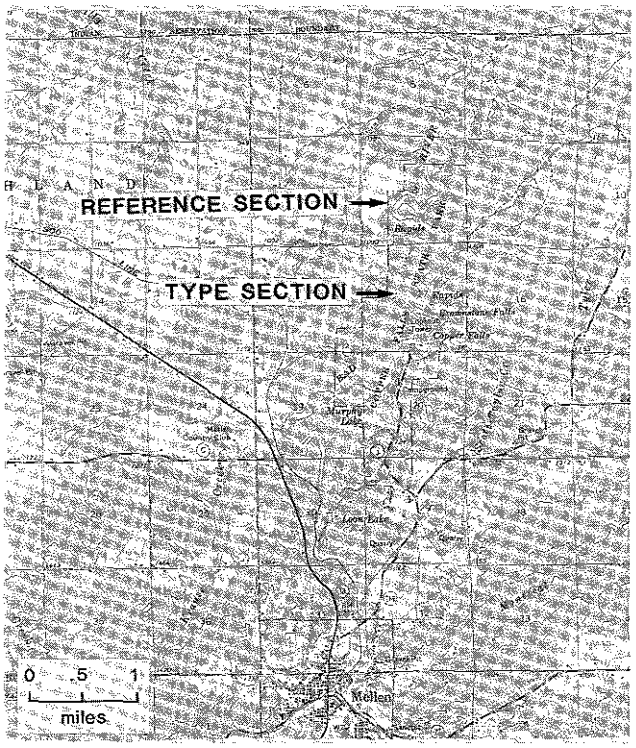

FIGURE 62.--Part of the Mellen 7.5-minute quadrangle, showing the location of the type section of the Copper Falls Formation.

Reference section.--Cutbank on west side of Bad River, about 0.8 miles (1.3 km) north of the type section, in Copper Falls State Park, SW¼NE¼SW¼ sec. 8, T. 45 N., R. 2 W., Ashland County, (fig. 62). A sketch of the units present is shown in figure 64. Till units may have been removed by shore erosion above Unit I. Correlation with the type section is unclear, but the greenish till near the bottom of Unit D of the reference section may correlate with the greenish till near the top of unit G of the type section; if so, it seems likely that units C and D of the type section occur below unit B of the reference section.

Description of unit.--The Copper Falls Formation consists largely of fluvial sand and gravel and till. The till typically consists of 35 to 80 percent sand, 15 to 50 percent silt, 2 to 15 percent clay, and a few percent pebbles, cobbles, and boulders. The till deposited by the main Superior Lobe in Douglas County averages about 70 percent sand, 25 percent silt, and 5 percent clay, whereas the till deposited by the Chippewa Sublobe in Bayfield, Ashland, and Iron Counties averages about 60 percent sand, 35 percent silt, and 5 percent clay. In all four counties the proportion of sand increases southward; it averages 45 percent in the type area. Copper Falls till is commonly reddish brown, ranging from 2.5YR to 7.5YR 3 to 4/4 to 6; it is generally redder to the north and browner to the south in Douglas, Bayfield, Ashland, and Iron Counties. It is only slightly calcareous in most areas; in northern

Douglas County the coarse-silt fraction is between 0.5 and 1.5 percent carbonate, predominantly calcite.

Nature of contacts.--The base of the formation is ill defined. It rests on pre-Pleistocene rock in the few places its base has been seen in Douglas, Bayfield, Ashland, and Iron Counties (Clayton, in press), but presumably older Pleistocene units occur below the Copper Falls. The Copper Falls Formation is overlain by the Miller Creek Formation (Appendix 12).

Differentiation from other units.--The till of the Copper Falls Formation is sandier and browner than the till of the Miller Creek Formation. The till of the Miller Creek Formation contains as much as 35 percent sand only in few places where it overlies sand and gravel.

Regional extent and thickness.--The Copper Falls Formation is at the surface as far north as the Miller Creek Formation (fig. 2). It occurs as far east as the dolomitic till of the Green Bay Lobe and as far west as the Minnesota border. Its southern limit is unclear, but has been shown at the St. Croix and Chippewa moraines on figure 2. Because of the lack of detailed studies, the unit must be rather diffusely defined at this time, and it may have to be more clearly defined later when more of its members have been defined and traced.

The Copper Falls Formation is several tens of metres thick in many parts of Douglas, Bayfield, Ashland, and Iron Counties.

Origin.--Roughly half, or perhaps more, of the Copper Falls Formation consists of fluvial sediment, deposited by melt-water streams in front of the glacier, on stagnant ice, or beneath the glacier in the form of eskers. Most of the rest of the formation is till deposited by the main Superior Lobe, the Chippewa Sublobe, the Wisconsin Valley Lobe, or the Langlade Lobe.

Age and Correlation.--The bulk of the Copper Falls Formation was probably deposited in Late Wisconsinan time, although the chronology of older parts has not been worked out, and it is possible that it includes some Early Wisconsinan material.

It is probably equivalent, at least in part, to the Cromwell Formation of Minnesota (Wright, Mattson, and Thomas, 1970). The Jardine Creek till of Need (1980), Johnson (1980), and Need, Johnson, and Mickelson (1981) is either equivalent to or a subdivision of the Copper Falls Formation.

Description of type section.--Everything in the type section belongs to the Copper Falls Formation. The till members have not been formally defined because they have not yet been successfully correlated beyond the type section. There is considerable lateral variability in the type section, and the column in figure 63 was measured in the middle part of the cutbank, north of its highest point, where it is about 45 m high. The lower 6 m, up from river level, is covered by slumped material. The next 4.5 m consists of clay, silt, sand, and gravel, probably of lacustrine or fluvial origin, or both. Above that is 2.5 m of reddish brown till, with closely-spaced columnar joints, averaging 52 percent sand, 39 percent silt, and 9 percent clay (three samples). Above a sharp contact is 9.5 m of reddish brown (but darker and redder than underlying unit) till, averaging 51 percent sand, 39 percent silt, and 10 percent clay (six samples). Above that is a 2 m covered interval with seeps and then 5.5 m of fine sand with silt beds, probably of offshore origin. Above that is 5 m of reddish brown till (similar in color to next lower till), averaging 35 percent sand, 53 percent silt, and 12 percent clay (five samples); small inclusions of greenish calcareous till and a thin bed of sand occur near the top of the unit. (The greenish gray till also occurs as a layer about 2 cm thick, about 17 m above river level, in the reference section

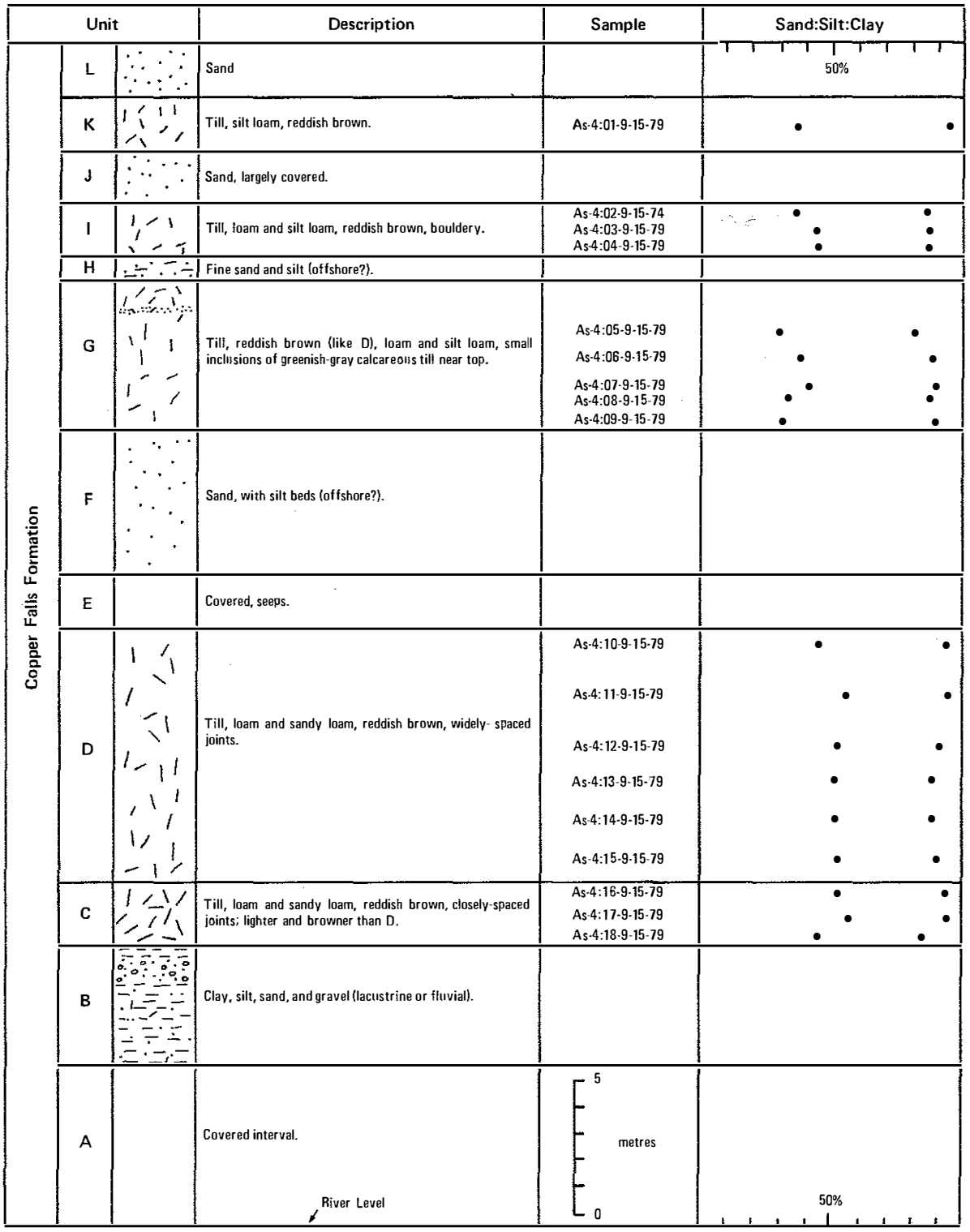

FIGURE 63.--Type section of Copper Falls Formation. Bottom of section (river level) is near an elevation of 290 m (950 feet). Location shown in figure 62.

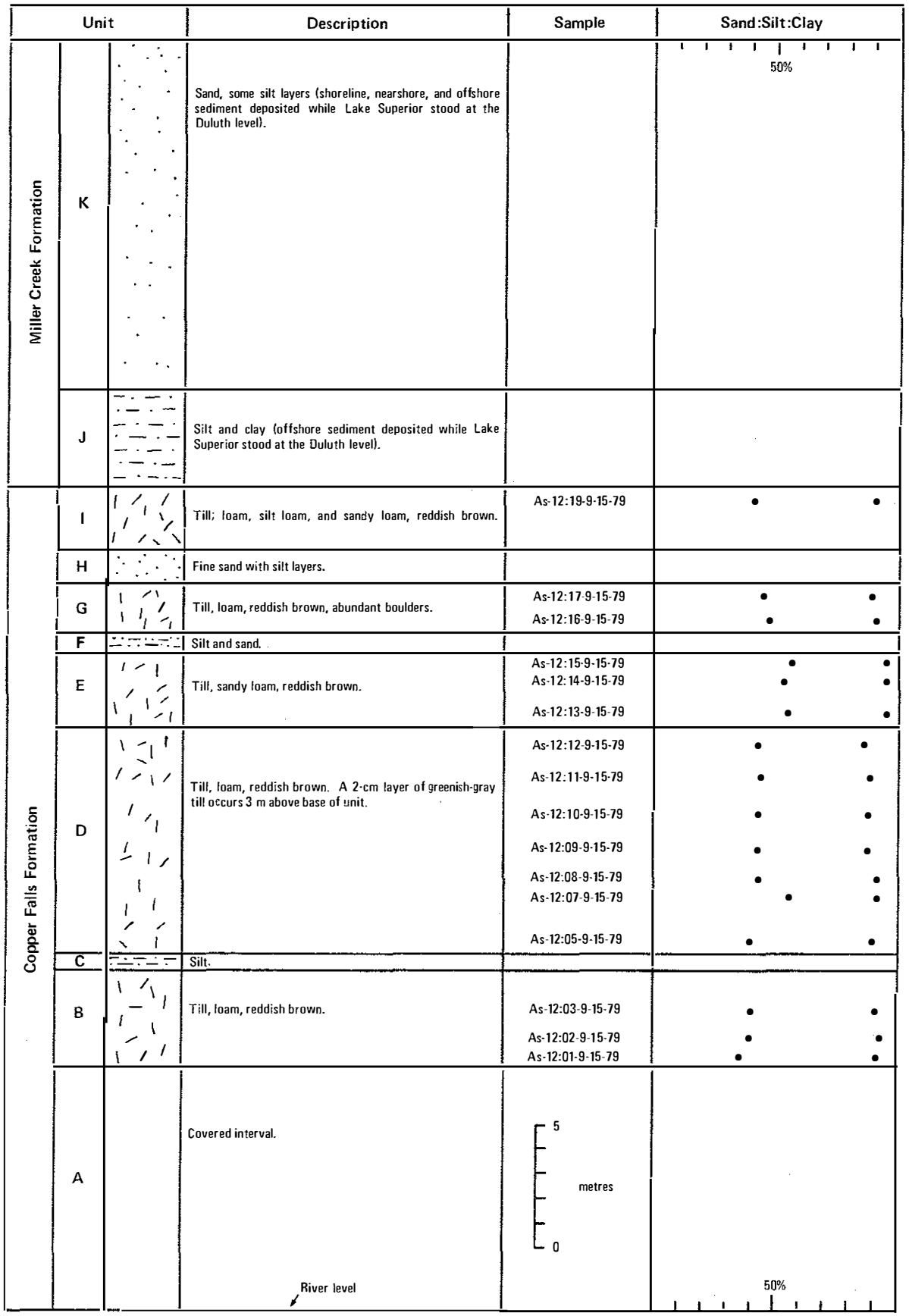

FIGURE 64.--Reference section of Copper Falls Formation. Bottom of section (river level) is near an elevation of 273 m (895 feet). Location shown on figure 62.

on the west side of the river 1.3 km to the north.) Above that is 1 m of silt and fine sand, probably of offshore origin. Above that is 2 m of reddish brown till (more bouldery than the next lower till) averaging 43 percent sand, 45 percent silt, and 12 percent clay (three samples). Above that is 2 m of sand, and then 2 m of reddish brown till with 38 percent sand, 55 percent silt, and 7 percent clay (one sample). At the top of the cutbank is 2 m of sand. It is likely that the upper three till layers consist of flow till, representing several supraglacial debris flows. They are part of a collapse hummock and probably represent a single glacial advance. The lower two till units may have been deposited during the same or during a separate advance or advances.

Person naming unit.--Lee Clayton. This unit name is being used for the first time in this paper.

APPENDIX 11a

NASHVILLE MEMBER OF THE COPPER FALLS FORMATION

Source of name.--Township of Nashville, Forest County, Wisconsin, located on the Nashville 7.5-minute quadrangle.

Type section.--Gravel pit in a drumlin, SE¼SW¼SE¼ sec. 7, T. 35 N., R. 12 E., southwest part of Forest County, located on the Nashville 7.5-minute quadrangle (fig. 65, 66).

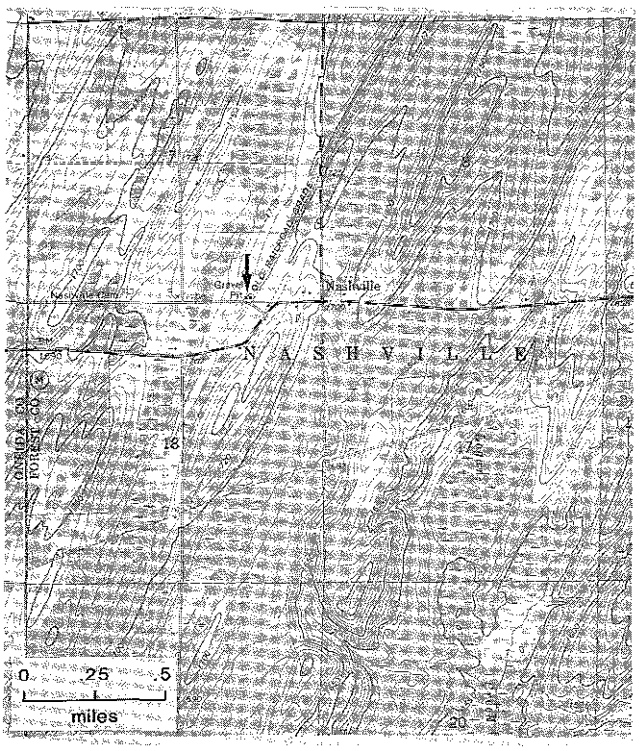

FIGURE 65.--Portion of Nashville 7.5-minute quadrangle showing the location of the type section of the Nashville Member.

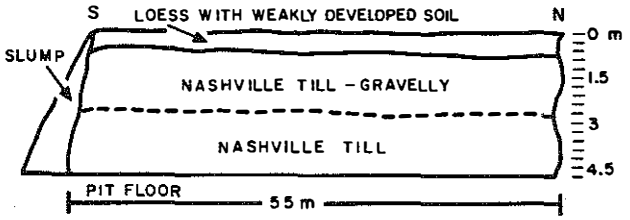

FIGURE 66.--Sketch of the west face of the gravel pit that is the type section of Nashville Member.

Reference sections.--(1) Upper till unit (and probably sand beneath) in Pine Lake gravel pit, SE¼NW¼NW¼ sec. 26, T. 37 N., R. 12 E., Forest County, located on the Argonne 7.5-minute quadrangle (fig. 67). (2) Gravel pit in drumlin on west side of Highway 55, NW¼NE¼SW¼ sec. 31, T. 36 N., R. 12 E., on the Crandon 7.5-minute quadrangle (fig. 68). About 2 m of Nashville till overlies over 25 m of sand and gravel of the Mapleview Member.

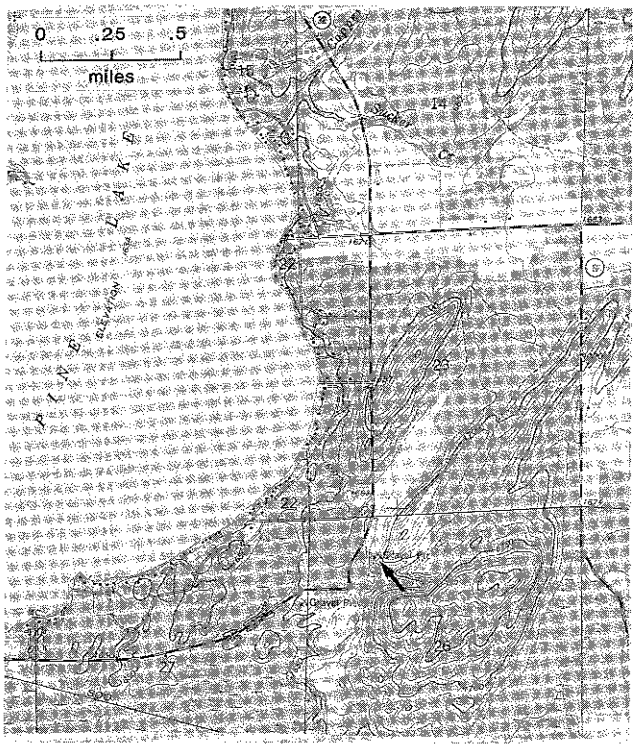

FIGURE 67.--Portion of the Argonne 7.5-minute quadrangle showing the location of reference section 1 of the Nashville Member.

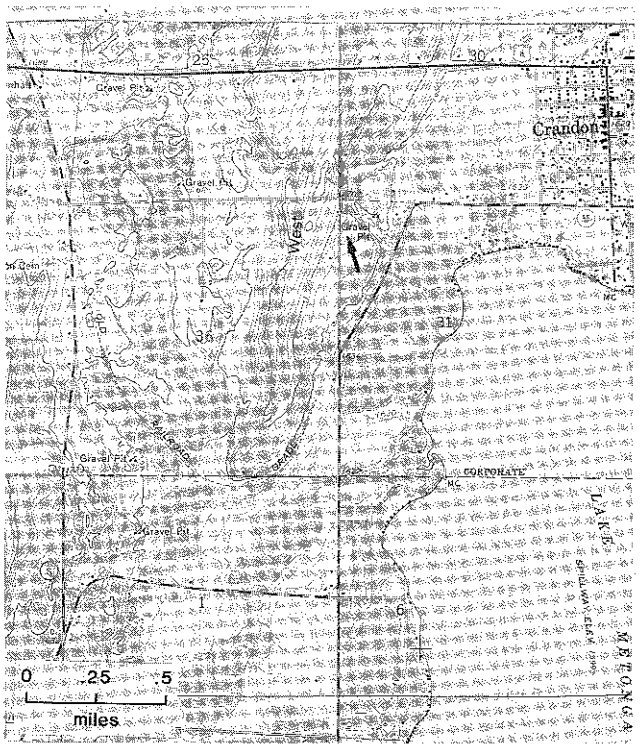

FIGURE 68.--Portion of the Crandon 7.5-minute quadrangle showing the location of reference section 2 of the Nashville Member.

Description of unit.--The till of the Nashville Member is a pebbly, cobbly sandy loam, averaging 77 percent sand, 16 percent silt, and 7 percent clay in the less-than-2-mm fraction, and containing numerous sand lenses within it. The percentage of sand increases slightly in the northern part of Forest County. Moist field colors of the till range from a reddish-brown (5YR 4/4) to yellowish red (5YR 4/6) to dark brown (7.5YR 4/4 to 7.5YR 4/6), with more reddish hues apparent in areas near the Michigan border. Clay mineral percentage using a semiquantitative analysis (Stewart, 1973) show the till to have approximately 80 percent illite, 12 percent chlorite and kaolinite, 5 percent vermiculite, and 3 percent smectite (Simpkins, 1979). The pebble lithologies in the unit average 95 percent igneous and metamorphic and 5 percent sedimentary. The percentage of sedimentary clasts presumably increases towards the east.

Nature of contacts.--Unless it is at the surface the Nashville Member is generally bounded by sand and gravel or till derived from the Green Bay Lobe (Horicon Formation) below and by sand and gravel from the Langlade Lobe (Copper Falls Formation) above. The contacts are usually sharp, although some clasts of till can be found in stratified drift overlying the till.

Differentiation from other units.--Where the Nashville Member directly overlies till of the Mapleview Member, differentiation of the units can be made on

the basis of the percentage of dolomite or sedimentary pebbles, the latter unit having the most.

Regional extent and thickness.--The Nashville Member is the surficial unit in southern Forest and northern Langlade Counties. The till is also present in eastern Vilas and Oneida Counties. The average thickness of the Nashville Member is 6.1 m and ranges from 2 m to 17 m.

Origin.--The Nashville Member contains subglacial till deposited by glacial ice of the Langlade Lobe. In areas of exposure, subglacial till is sometimes overlain by thin, discontinuous supraglacial till. Associated deposits of sand and gravel are also included.

Age and Correlation.--The Nashville Member is Late Wisconsinan age. It is the stratigraphic equivalent of the informally named Kempster and Moccasin Lake tills described by Nelson (1973) in the area of the Parrish and Summit Lake moraines of the Langlade Lobe, respectively. It is the stratigraphic equivalent of the Mapleview Member of the Green Bay Lobe, although till of the Nashville Member is known to overlie the Mapleview Member in eastern Langlade County (Mickelson and others, 1974). Complex intertonguing of these units also occurs in an interlobate area in eastern Langlade County and northward to northern Florence County. The Nashville till is also the approximate stratigraphic equivalent of the Bass Lake till of the Wisconsin Valley Lobe, although the latter is shown to cross-cut the informally named Kempster till in the Parrish moraine (Nelson, 1973).

Description of type section.--A sketch of the west face of the gravel pit is shown on figure 66. All of the material exposed in the upper part of the pit is Nashville till, supraglacial (gravelly) and subglacial facies are probably present. Gravel, presumably of the Nashville Member is present at the base of the pit.

Person naming unit.--William Simpkins, modified by David Mickelson. This unit name was first used informally by Simpkins (1979).

APPENDIX 12

MILLER CREEK FORMATION

Source of name.--A tributary of Amnicon River, Douglas County, Wisconsin, shown on the Poplar NE 7.5-minute quadrangle.

Type section.--Same as for Hanson Creek and Douglas Members; a bluff section located on Poplar NE 7.5-minute quadrangle (fig. 69).

Reference sections.--(1) Same as for Hanson Creek and Douglas Members. (2) The shore bluff of Oronto Bay of Lake Superior, about 1.7 miles (2.8 km) northwest of Saxon Harbor, NE¼NW¼NE¼ sec. 10, T. 47 N., R. 1 W., Iron County, Wisconsin (fig. 70). The section, containing a representative exposure of the Miller Creek Formation east of the Bayfield Peninsula, is shown in figure 71. The uppermost till unit (F) is the surface unit over most of the region. The lower till units (B, C, D) plunge below beach level a short distance southeast of the section.

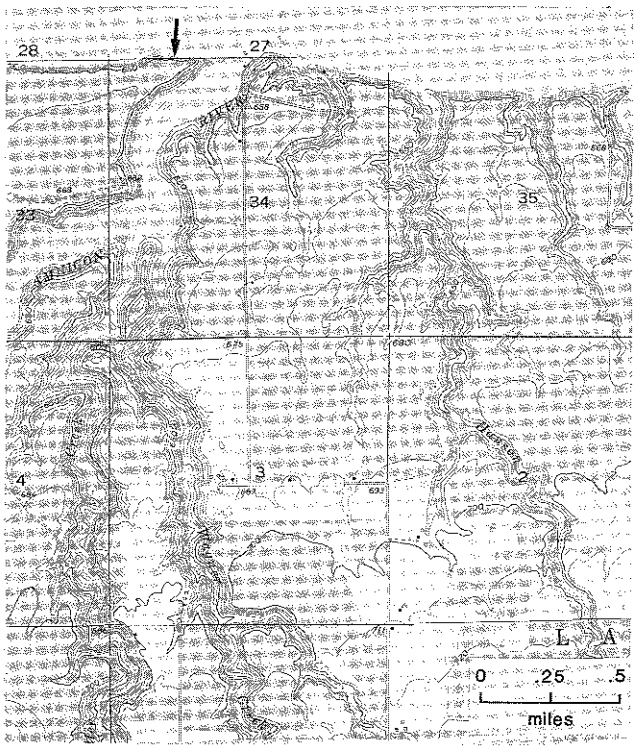

FIGURE 69.--Part of the Poplar NE 7.5-minute quadrangle showing the type sections of the Miller Creek Formation and the Hanson Creek and Douglas Members.

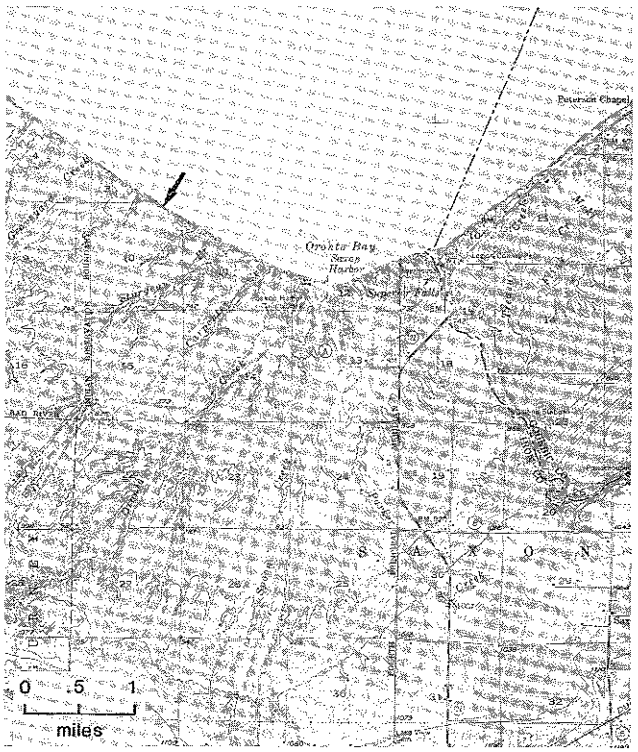

FIGURE 70.--Part of the Little Girls Point 15-minute quadrangle showing the location of reference section 2 of the Miller Creek Formation.

Description of unit.--The Miller Creek Formation contains reddish clay sediment of the Superior lowland. In the past it has been called Red Clay. It includes the Hanson Creek and Douglas Members west of the Bayfield Peninsula. East of the Bayfield Peninsula it includes units that may correlate with the Hanson Creek and Douglas Members; they tend to be more silty and less clayey than the units west of the Bayfield Peninsula. In addition to these units, which are largely till, the formation also contains offshore sediment, which

is generally reddish bedded silt and clay, overlying, between, or underlying the till units. A small amount of interbedded sand and gravel is also included in the formation.

Nature of contacts.--Except for modern fluvial, lacustrine, and organic deposits, the Miller Creek Formation is the surface unit in the Superior lowland. Where observed, the contact with the underlying Copper Falls Formation or pre-Pleistocene units is sharp.

Differentiation from other units.--The Miller Creek Formation is somewhat redder and is more clayey and silty than the underlying Copper Falls Formation. The till of the Miller Creek Formation typically contains less than 20 percent sand, although it may have as much as 60 percent sand where it overlies fluvial sand. In contrast, the till of the Copper Falls Formation generally contains more than 35 percent sand.

Regional extent and thickness.--The Miller Creek Formation occurs in most places below the 330-m contour in northwestern Wisconsin, that is, almost everywhere below the Duluth level of Lake Superior (fig. 2). East of Gurney, however, it occurs above the Duluth beach, to an elevation of 370 m, where it makes up the end moraines near Saxton. The formation is typically about 10 to 20 m thick, but it is more than 90 m thick near the cities of Superior and Ashland.

Origin.--Probably at least three-fourths of the Miller Creek Formation is till deposited by ice of the main Superior Lobe or of the Chippewa Sublobe, and most of the rest is offshore sediment.

Age and correlation.--The Miller Creek Formation was deposited in latest Wisconsinan and earliest Holocene time; greater detail is given in the discussion of the Hanson Creek and Douglas Members. The Wrenshall Formation in Minnesota (Wright, Mattson, and Thomas, 1970) consists of offshore sediment deposits in the southwestern end of the Superior basin. The Wrenshall can be traced to the Wisconsin border, but its relationship to the members of the Miller Creek Formation is unclear; it may overlie the Hanson Creek Member and underlie or be laterally equivalent to the Douglas Member.

Description of type section.--See description of Hanson Creek type section.

Person naming unit.--Lee Clayton. This unit name is being used for the first time in this report.

APPENDIX 12a

HANSON CREEK MEMBER OF THE MILLER CREEK FORMATION

Source of name.--Hanson Creek, draining into Lake Superior 1 km east of the mouth of the Amnicon River, Douglas County, Wisconsin.

Type section.--Bluff about 0.9 miles (1.5 km) west of the mouth of Hanson Creek, SE¼SW¼SW¼ sec. 27, T. 49 N., R. 12 W., Douglas County, located on the Poplar NE 7.5-minute quadrangle (fig. 69).

Reference section.--Bluff 0.2 miles (0.3 km) southwest of the mouth of Pearson Creek, SE¼SE¼NW¼ sec. 22, T. 49 N., R. 11 W., Douglas County, located on the Cloverland 7.5-minute quadrangle (fig. 72).

Description of unit.--The Hanson Creek till averages 10 percent sand, 32 percent silt, and 58 percent clay in the less-than-2-mm fraction west of the Bayfield Peninsula in Bayfield and Douglas Counties. The till is typically dark reddish brown (5YR 3/4) and commonly contains dark gray (5YR 4/1) and

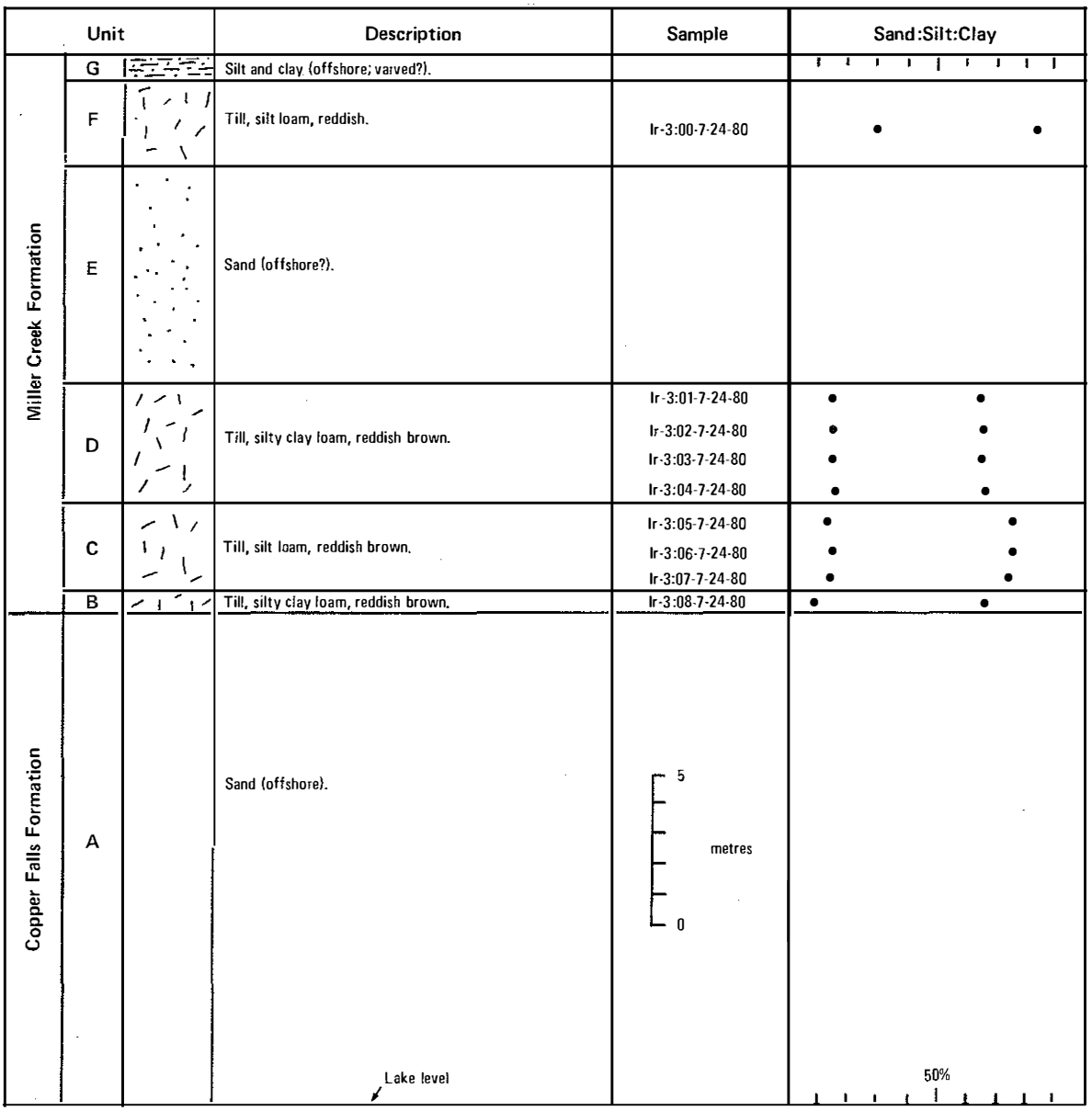

FIGURE 71.--Sketch of reference section 2 of the Miller Creek Formation. Location shown in figure 70.

reddish-brown (2.5YR 4/4) stringers. It contains 54 percent illite, 34 percent smectite, 6 percent vermiculite, and 6 percent kaolinite plus chlorite in the less-than-0.002-mm fraction. Carbonate content averages 11 percent in the less-than-0.063-mm fraction and 3 percent in the 0.063-to-0.037-mm fraction.

Nature of contacts.--The Hanson Creek Member overlies Copper Falls sandy till, silty offshore deposits, or pre-Pleistocene rock. It is overlain in most places by Douglas till but in some places by sand.

Differentiation from other units.--Hanson Creek till is siltier and browner than Douglas till and finer grained than the Copper Falls till. Lake sediment associated with the Hanson Creek and Douglas Members has not been differentiated.

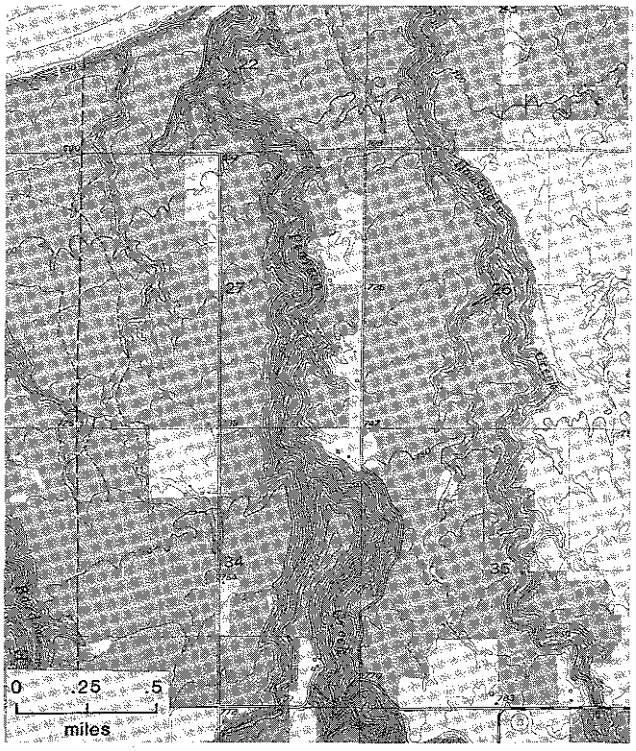

FIGURE 72.--Part of the Cloverland 7.5-minute quadrangle showing the location of the reference section of the Hanson Creek Member.

Regional extent and thickness.--The Hanson Creek Member occurs along the Superior shoreline throughout Douglas County. Its eastern limit in Bayfield County is the mouth of the Iron River. Water-well logs indicate that the unit may pinch out under the Douglas Member about 8 to 13 km south of the shoreline in northeastern Douglas County, or it may extend as far south as the Duluth beach of Lake Superior (at an elevation of about 330 m). In the Superior bluffs it ranges from 0.5 to 11 m in thickness, averaging 7.5 m.

Origin.--The Hanson Creek Member consists largely of till deposited by the Superior Lobe.

Age.--The Hanson Creek Member has never been dated, but it was probably deposited in latest Wisconsinan time, perhaps around 11,000 B.P.

Correlation.--The Hanson Creek Member has not been correlated westward beyond Douglas County nor eastward around the Bayfield Peninsula. However, at least two till members of the Miller Creek Formation exist in the Superior lowlands east of the Bayfield Peninsula, and presumably the Hanson Creek correlates with the lowest one.

Description of type section.--The type section is a lake bluff, which can be reached from a campground just to the south. The bluff is 16 m high. The upper 8.5 m consists of Douglas till, and the lower 7.5 m consists of Hanson Creek till. Seven samples of Hanson Creek till 0.2 km west of the type section average 5 percent sand, 34 percent silt, and 61 percent clay.

Person naming unit.--E. A. Need (1980), modified by Lee Clayton. This unit name was first used informally by Need (1980) and Johnson (1980).

APPENDIX 12b

DOUGLAS MEMBER OF THE MILLER CREEK FORMATION

Source of name.--Douglas County, Wisconsin.

Type section.--Same as Hanson Creek Formation.

Reference sections.--(1) Bluff exposure 0.7 miles (1.2 km) west of the mouth of the Iron River, SW¼NE¼NW¼ sec. 4, T. 49 N., R. 9 W., Bayfield County (typical clay facies); located on the Brule and Port Wing 15-minute quadrangles (fig. 73). (2) Bluff on the northwestern side of Bark Point, SW¼NE¼NE¼ sec. 26, T. 51 N., R. 7 W., Bayfield County (the more sandy facies); located on the Cornucopia 15-minute quadrangle (fig. 74).

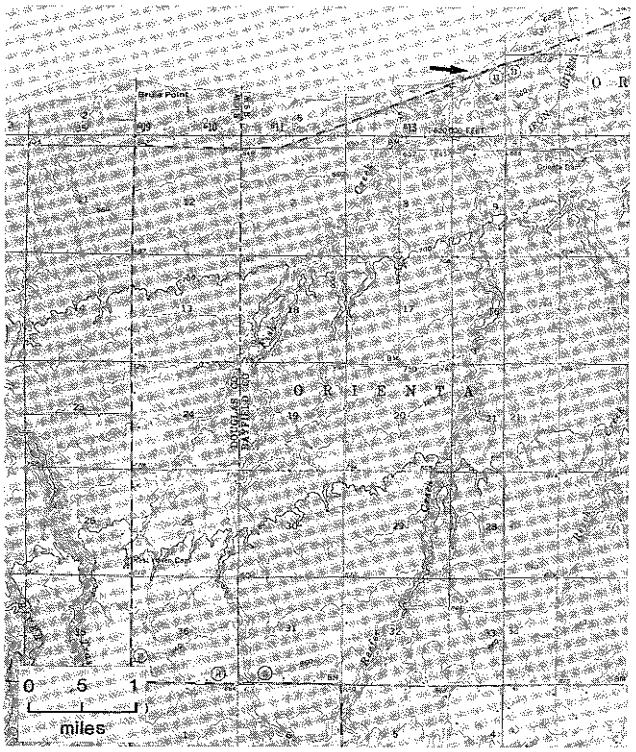

FIGURE 73.--Parts of the Brule, Port Wing, and Iron Lake 15-minute quadrangles showing the location of reference section 1 of the Douglas Member.

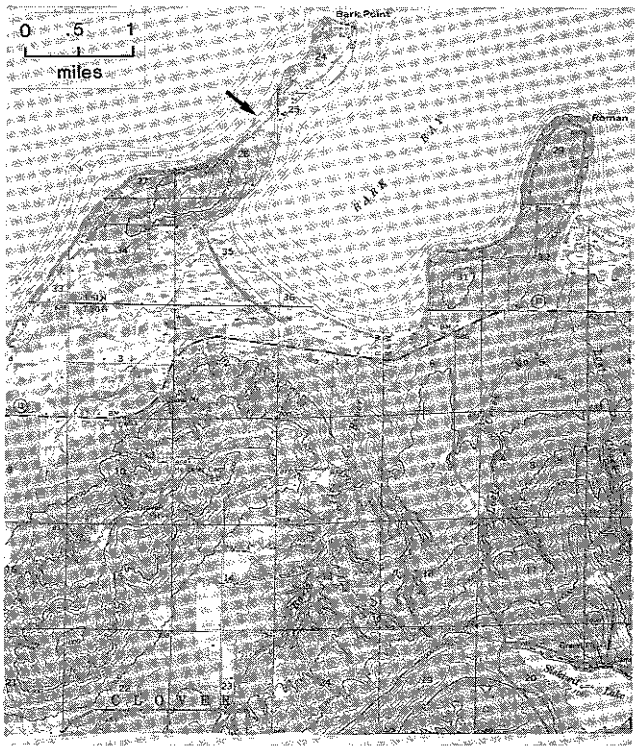

FIGURE 74.—Part of the Corpucopia 15-minute quadrangle showing the location of reference section 2 of the Douglas Member.

Description of unit.--In most places the Douglas Creek Member consists of till averaging 10 percent sand, 26 percent silt, and 64 percent clay in the less-than-2-mm fraction. It is typically reddish brown (2.5YR 4/4). It averages 54 percent illite, 32 percent smectite, 9 percent vermiculite, and 5 percent kaolinite and chloride in the less-than-0.002-mm fraction. Carbonates average 13 percent in the less-than-0.063-mm fraction and 4 percent in the 0.063-to-0.037-mm fraction.

Where the Douglas till overlies sand, it averages 40 percent sand, 27 percent silt, and 33 percent clay in the less-than-2-mm fraction. Carbonates average 9 percent in the less-than-0.063-mm fraction and 3 percent in the 0.063-to-0.037-mm fraction.

Nature of contacts.--The Douglas Member overlies till of the Hanson Creek Member, till of the Copper Falls Formation, sand and gravel of either the Miller Creek or Copper Falls Formation, laminated clay and silt of the Miller Creek Formation, and pre-Pleistocene rock. It is generally the surface unit but in a few places it is overlain by fluvial or lacustrine sand and gravel deposits or offshore silt and clay deposits of the Miller Creek Formation or younger fluvial, lacustrine, and organic deposits.

Differentiation from other units.--Typical Douglas till is redder and more clayey than Hanson Creek till. The sandy facies is much more sandy than the Hanson Creek till but not as sandy as most Copper Falls till.

Regional extent and thickness.--The Douglas Member occurs in Superior bluffs from Wisconsin Point eastward to the mouth of Bark River (fig. 2); the more clayey facies occurs west of Port Wing and the more sandy facies occurs east of Port Wing. The Douglas till is probably the surficial unit throughout most of Superior bluffs, the more clayey facies ranges from 1 to 15 m thick, averaging 7.5 m; the more sandy facies ranges from 0.5 to 6 m, averaging 1 m.

Origin.--Most of the Douglas Member is till deposited by ice of the Superior Lobe.

Age.--The Douglas till was probably deposited in earliest Holocene time, probably just after 9900 B.P.

Correlation.--The Douglas till has not been correlated eastward around the Bayfield Peninsula, but it presumably correlates with the upper till member of the Miller Creek Formation in the Ashland region, and it may make up the younger end moraines in the Saxon area, which contain wood dated 9730 $\pm$ 140 (I-5082) and 10,100 $\pm$ 100 B.P. (WIS-409). Clayton and Moran (1982) have correlated the Douglas Member with a unit in northern Michigan dated 9900 B.P.

Description of type section.--See description of Hanson Creek type section.

Person naming unit.--E. A. Need (1980), modified by Lee Clayton. This unit name was first used informally by Need (1980) and Johnson (1980).