THE GLACIAL GEOLOGY OF A PORTION OF NORTH-CENTRAL WISCONSIN

BY

WILLIAM NILES MODE

A thesis submitted in partial fulfillment of the requirements for the degree of

MASTER OF SCIENCE
(Geology)

at the

UNIVERSITY OF WISCONSIN

1976

APPROVED: David M. Madden

DATE: 8/17/76

ABSTRACT

The stratigraphy of the extra-morainic drift in north central Wisconsin has been studied in Marathon County, and adjacent parts of Clark and Wood Counties. Four till units are distinguished on the basis of sand/silt/clay composition, clay mineralogy, color, and coarse sand fraction lithology. The four tills are informally called the Merrill, Bakerville, Edgar, and Wausau, in order of age from youngest to oldest. The Merrill and Wausau tills have been previously described and named in adjacent areas (LaBerge and Myers, 1971; Stewart, 1973). Based on radiocarbon dates from Stewart and Mickelson (1976) and on clay mineral weathering profiles, all four of the tills are pre-Woodfordian in age. The Wausau till may be Illinoian in age.

Extensive sand and gravel resources are limited in location to the major drainageways tributary to the Wisconsin River and in the Wisconsin River valley. In the Wisconsin River valley, these deposits exist as two Late Woodfordian terraces. These terraces are mapped on United States Geological Survey topographic maps which are kept on open file at the Wisconsin Geological and Natural History Survey.

ACKNOWLEDGEMENTS

For their help in the field, I would like to thank my wife, Cath Mode, and my sister, Cath Mode. Dr. Gene LaBerge of the University of Wisconsin - Oshkosh, the Haupt brothers of Haupt Well and Pump Company of Auburndale, and Mark Stewart are people to whom I owe thanks for their advice and help in the field. Mr. Marv Sherrill of the United States Geological Survey, Madison, also gave helpful guidance and provided drilling logs for holes in the area.

Special thanks goes to Mr. David L. Gasser who partially supported this work through the Gasser scholarships for research in the area of sand and gravel resources.

My graduate advisory committee members, Dr. John Steinhart, Dr. David Stephenson, and Dr. David Mickelson have provided insight and perspective throughout my years at the University. Dr. Steinhart and Dr. Stephenson critically read the manuscript. Dr. Mickelson is owed by far the greatest debt, and I wish to thank him sincerely for all that he has done.

TABLE OF CONTENTS

TABLE OF ILLUSTRATIONS

INTRODUCTION

The glacial drift outside of the mid-Woodfordian (Late Wisconsin) end moraines of northern Wisconsin has not been placed precisely in any time stratigraphic framework. (Appendix D contains the time stratigraphic framework used here.) Moreover, the rock stratigraphy of the area has not been well defined. In this study, four extra-morainic till units are defined, based upon differences in their texture, clay mineralogy, coarse sand fraction lithology, and color. The tills are the Wausau, Edgar, Bakerville, and Merrill tills. The Edgar and Bakerville tills are named and described for the first time, whereas the Wausau and Merrill tills were named earlier (LaBerge and Myers, 1971; Stewart, 1973; Stewart and Mickelson, 1976).

The area is in the western half of Marathon County and adjoining parts of Wood and Clark Counties (Figure 1), in central Wisconsin. It is dominated by gently rolling topography. At the eastern boundary of the area the Wisconsin River and its tributaries have deeply dissected the nearby landscape. Figure 2 shows the main streams that drain the area. The only recognizable glacial constructional feature in the area, the Marshfield moraine (Figure 14), is dissected by streams and little of the characteristic swell and swale topography of younger moraines is preserved. The area of the Merrill till (Figure 13) has somewhat poorly integrated drainage, and does contain some swell and swale topography.

Bedrock in the area consists of Precambrian crystalline rocks and Cambrian sandstone. The Precambrian crystalline rocks are dominantly

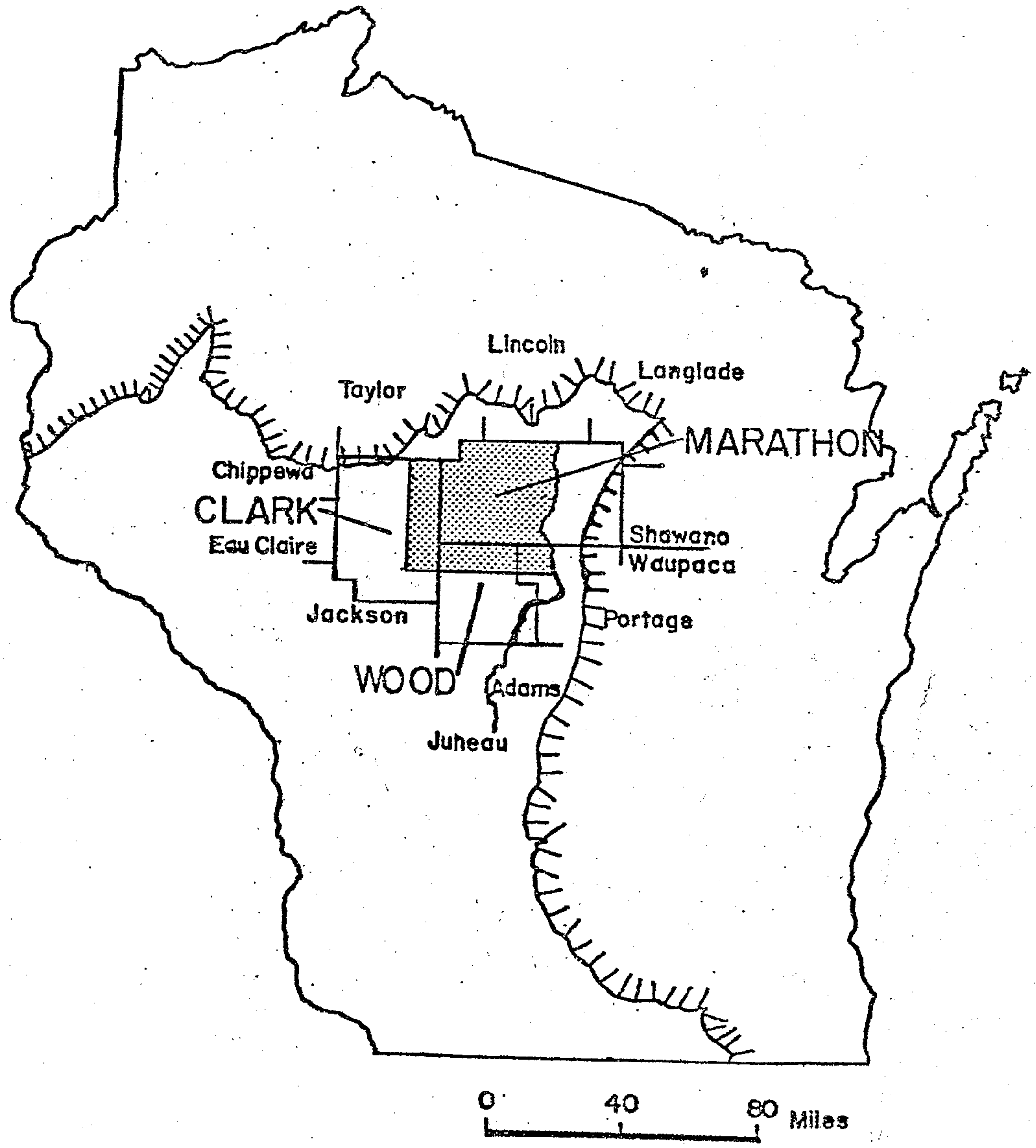


Figure 1. THE AREA OF STUDY (shaded). Adjacent counties and the Woodfordian end moraines (hatchured line) are also located.

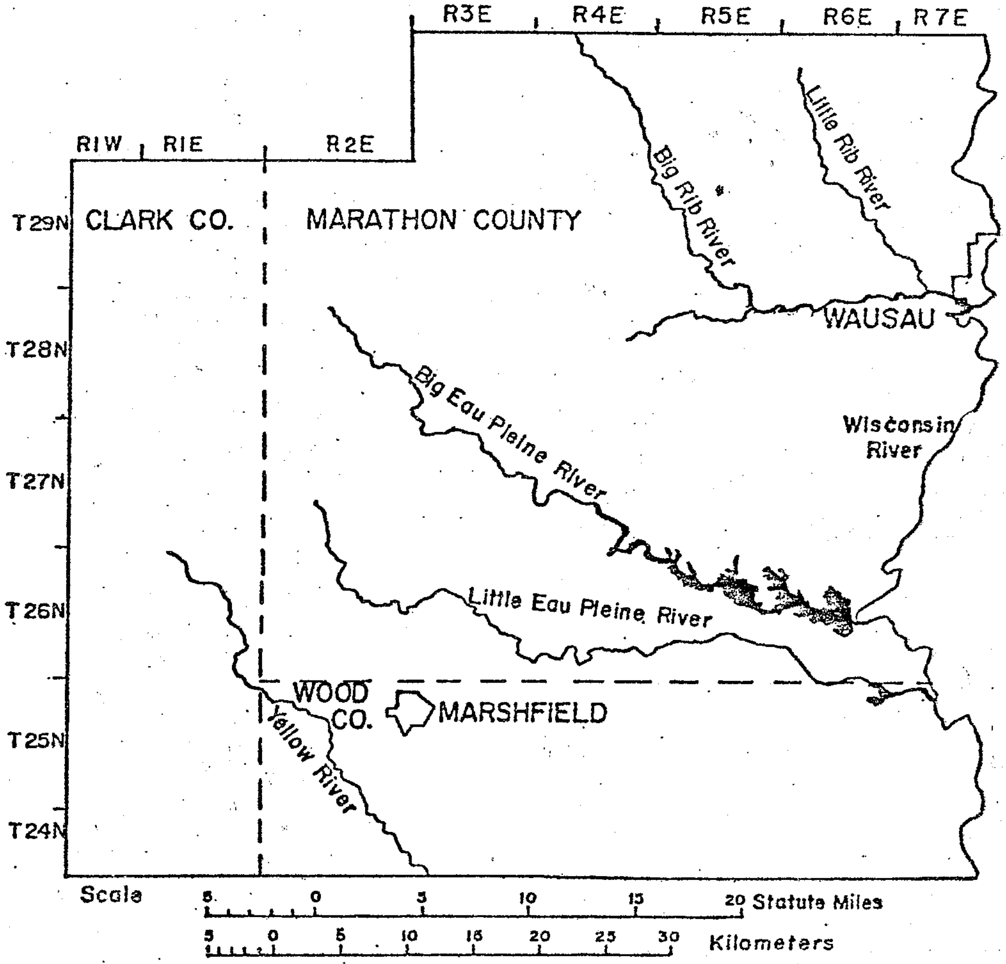


Figure 2. THE AREA OF STUDY AND THE MAJOR STREAMS THAT DRAIN IT.

granite and other granitic rocks. Also present are smaller areas of syenite, diorite, felsic flows, greenstone, and quartzite (LaBerge and Myers, 1971). These crystalline rocks are overlain by the Cambrian Mt. Simon sandstone in very few places in Marathon County. In the parts of Clark and Wood Counties included in the study area, the Cambrian sandstone is the dominant bedrock type underlying the drift.

Drift thickness gradually decreases from north to south in the study area, with the exception of the thickened drift in the Marshfield moraine. Drift also thins and disappears as the Wisconsin River is approached in the east. Drift thickness ranges from zero to 120 feet in the Marshfield moraine, and probably averages around 20-30 feet throughout the area.

A loess cap covers most of the landscape, even in areas where the drift has been stripped off the bedrock. This silt cap averages about 1.5 to 2 feet in thickness.

Much of the outwash which can be seen in the river valleys in the area, especially the Wisconsin River valley, is outwash that drained away from the Woodfordian ice when it stood just north of the study area. Only the Woodfordian age outwash terraces are continuous in the valleys of the major streams draining the area (Figure 2). Stratified deposits of sparse distribution can be found at elevations well above the Woodfordian terraces. These upland deposits are probably remnants of older terraces associated with pre-Woodfordian ice advances into the area.

Most upland soils in the area have their sola developed in the loess, with the lower parts of the B-horizon extending down into the till. Where these soils are developed above and in the loam tills (Edgar and Wausau tills), they are typically poorly to very poorly drained. Drainage of soils in and above the sandy loam tills (Merrill and Bakerville tills) ranges from well drained to poorly drained.

The purposes of this thesis are the following:

1. to describe and define the Quaternary stratigraphy of the area outside of the Woodfordian end moraines in Marathon County;
2. to reconstruct the Quaternary history of the study area on the basis of the stratigraphy; and
3. to apply information on surficial geology to natural resource data needs, especially sand and gravel resources. This purpose was secondary to the others, and most field work involved sampling till, not locating sand and gravel deposits. The information on sand and gravel resources that is reported here is directed toward the non-geologist.

PREVIOUS INVESTIGATIONS

I have developed an extensive literature review because it is necessary to have a historical perspective of the previous work that has been done in the study area. This is an especially critical need for this study because many workers have made many different interpretations of the age and stratigraphy of the extra-morainic drift.

Most previous work has utilized non-stratigraphic methods to distinguish different ages of drift (for example, Chamberlin and Salisbury, 1885; and Weidman, 1907). The thin scatter of erratics and drift in areas of well developed drainage is in sharp contrast to the landscape behind the mid-Woodfordian moraines (Weidman, 1907). The contrast is that of a stream eroded landscape to a glacially deposited landscape. This distinct topographic difference caused early workers (Chamberlin, 1883; Chamberlin and Salisbury, 1885; and Leverett, 1899) to be sure that the extra-morainic drift was of considerably greater age than the Wisconsin drift. However, the question of age was raised again when later workers (for example, Hole, 1943a, b) proposed the deposition of the extra-morainic drift by some sort of an unusual glacier. Hole felt that at least one, if not more, of the following characteristics was true of the ice that deposited the extra-morainic drift. The ice was short-lived in the extra-morainic area, thin, and relatively clean. This ice advanced and receded rapidly in Wisconsin time and did not stabilize anywhere until it had reached the present location of the prominent Late Woodfordian end moraines. The topography outside of these moraines is then largely pre-glacial and only slightly altered by the thin blanket of drift it would have received from such a glaciation.

Thwaites (1943) felt that the extra-morainic drifts were dissected to approximately the same degree as the Iowan Drift of Iowa, which was of Early Wisconsin age.

Besides degree of dissection, a number of other methods have been used to define the stratigraphy of the extra-morainic drift. Yet, the interpretation of the results has been as ambiguous as the interpretation of the topography. Some of the other charactertistics that have been used to define the stratigraphy and areal distribution of the extra-morainic drift are: 1.) depth of weathering; 2.) degree of weathering of constituent clasts; 3.) occurrence of erratics; 4.) color; 5.) soil development; 6.) texture; 7.) lithology, including methods such as pebble counts, calcite/dolomite ratios, and clay mineralogy.

The debate about the age of the extra-morainic drift continues. The lack of careful stratigraphic studies of this drift is probably one reason that so little is known for certain about it.

The purpose of this chapter is to review the work that has been done on the extra-morainic drifts. Later in this thesis, stratigraphic studies that I have done are interpreted in an attempt to clarify the stratigraphy of the extra-morainic drifts.

The earliest workers to publish a map showing the extra-morainic drift were Chamberlin and Salisbury (1885; Chamberlin, 1882, 1883) (Figure 3a). They mapped it as an Older Drift of the First Glacial Epoch, bounding the north side of the Driftless Area. They defined three types of glacial borders of

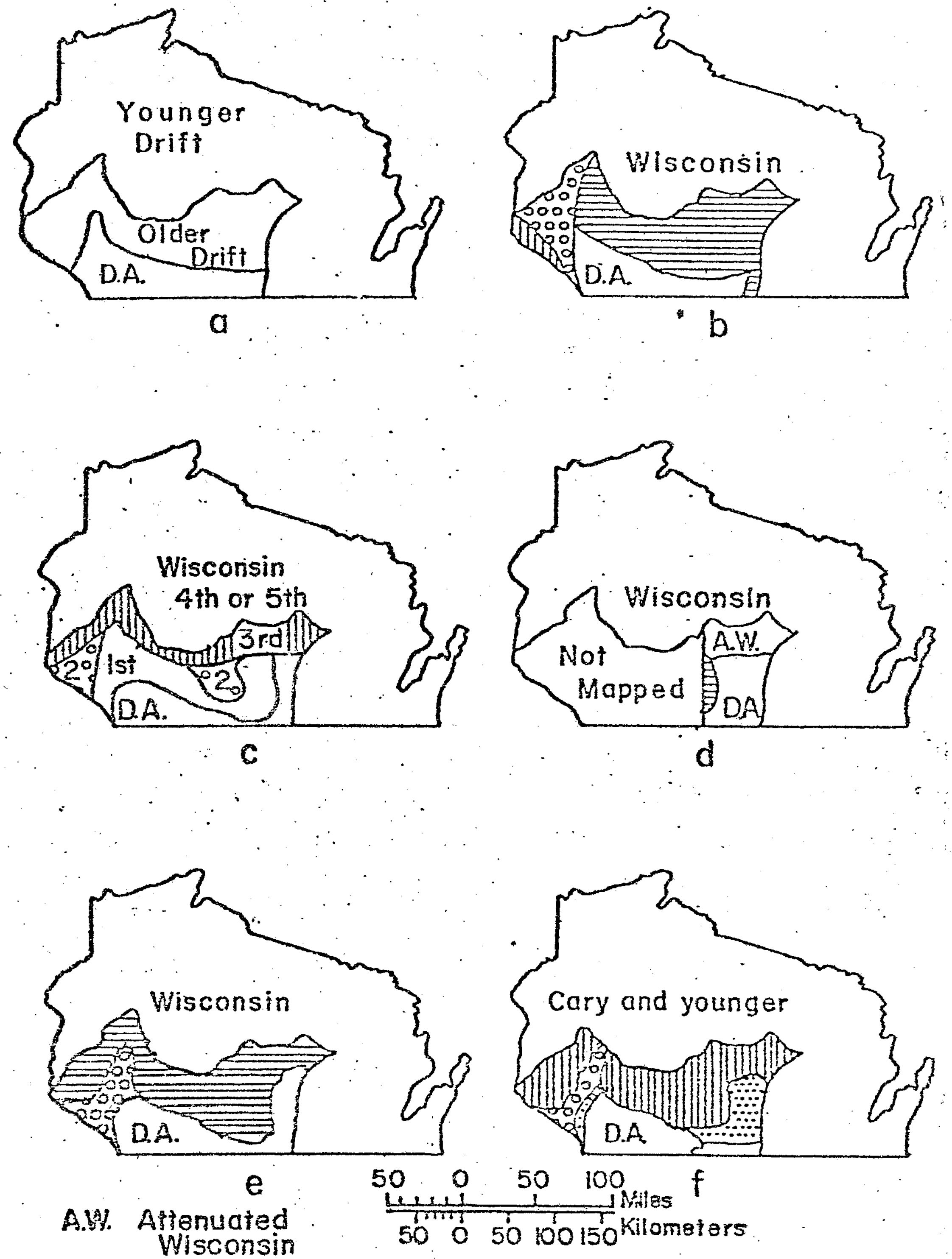


Figure 3. VARIOUS INTERPRETATIONS OF THE EXTRA-MORAINIC DRIFT. Past interpretations have ranged widely. a) Chamberlin and Salisbury (1885); b) Leverett (1899); c) Weidman (1907, 1913); d) Leverett and Taylor (1915); e) Leverett (1929); f) Thwaites (1955). Weidman's map (c) is the most similar to the results of the present study (Figures 12 and 13).

the Driftless Area of Wisconsin. These three glacial borders were: 1.) a morainic border, such as the prominent Late Woodfordian moraine that borders most of the eastern side of the Driftless Area; 2.) an "attenuated till and bowlder" border; and 3.) an "attenuated pebble" border. The latter two types of glacial borders are the types that Chamberlin and Salisbury mapped bordering the northern side of the Driftless Area. These borders are the southern limits of the extra-morainic drift of northern Wisconsin. Clearly, the main distinction for these workers between the Late Woodfordian drift farther north and the extra-morainic drift was thickness. Also noting the deep decay of pebbles in this thin extra-morainic drift, Chamberlin and Salisbury mapped this drift as "older" drift; that is, clearly older than the Late Woodfordian drift farther north.

Chamberlin (1882) opened the debate about the interpretation of the topography of the area of extra-morainic drift when he stated that the present topography was mainly pre-glacial and had only been slightly modified by the deposition of a thin blanket of drift. It appears that he did not feel this was the sole reason for the topography, however, because he was later cited by Weidman (1907; through personal communication) as having noted that the advanced state of erosion of the extra-morainic drift was comparable to that of the Kansan drift of Iowa.

Leverett (1899) distinguished one pre-mid-Woodfordian drift in northern Wisconsin on the basis of color, clay content, pebble lithology, and degree of weathering (Figure 3b).

Samuel Weidman (1907) mapped three extra-morainic drifts in north central Wisconsin. His map (Figure 3c) shows how he numbered the drifts with the First Drift being the oldest and farthest south and the Fourth or Wisconsin Drift being the Late Woodfordian to the north. He used the following criteria to distinguish these drifts (after Hole, 1943a): 1.) grouping of moraines in relation to possible ice lobes; 2.) correlation of buried moraines; 3.) average thickness of ground moraine; 4.) average thickness of drift sheet borders; 5.) degree of weathering of drift shown by color, clay content, condition of included clasts, and depth of weathering; 6.) degree of compaction and cementation of drift; 7.) presence or absence of swamps and sag and swell topography; and, 8.) areal extent.

Weidman was one of the first workers to use the degree of weathering of the drift as a gauge of relative age of drifts. The question of how you measure the degree of weathering was to be discussed repeatedly through the years by one worker after another. Weidman made very little effort to quantify what he felt were clear differences between the degrees of weathering of the extra-morainic drift and the Wisconsin or Fourth Drift. He also saw some of the same differences when comparing the degree of weathering of the First, Second, and Third Drifts. He suggested that the brownish-yellow color of oxidized First and Second Drifts meant extensive "oxidation and disintegration of iron-bearing minerals of the drift" (p. 450). Oxidation to this extent is not seen in the Third and Fourth Drifts. The relatively high clay content, the high proportion of weathered clasts, and the high degree of compaction and cementation of the First and Second Drifts were also used to show the greater age of these units. The depth of weathering is also much deeper in the First and Second Drifts. Weidman did not measure depth of leaching, probably for two reasons. Only the First Drift is calcareous and it is often so thin as to be completely leached throughout.

Weidman addressed the question of the interpretation of the topography. He took the position that the topography in areas of extensive post-glacial stream valley trenching was no longer influenced by the older drifts, but in areas where streams were not deeply entrenched, the older drift did strongly influence the topography. Tied closely to this interpretation was his understanding of drift thickness. At the borders of the different drift units, he described zones of thickened drift which he called terminal moraines.

> In Marathon County, along the Wisconsin River, the deep valleys of the small streams, as well as the large ones seem to have no regard for the occurrence of the drift of this formation (First Drift), but in Wood and Clark Counties, along the divide between the Wisconsin and Black Rivers where the streams are not deeply intrenched, the terminus of this drift sheet appears to form the divide between some of the small streams. (Weidman, 1907, p. 447)

Other workers (Chamberlin and Salisbury, 1885; Hole, 1943) have suggested that the extra-morainic drift exhibits a continuous, gradual attenuation from north to south. Yet, Weidman's evidence for thickened terminal moraines bounding each of the older drifts comes from well records as well as field exposures and topography. These three different, distinct, terminal moraines and their relationships provided the main basis for distinguishing three different drift sheets of different ages, though Weidman went on to provide many more distinguishing characteristics. Other workers apparently have not found good evidence for this terminal thickening of the drifts.

Weidman found characteristic average ground moraine thicknesses for each of the drift units, with the Second Drift having the greatest at about 30 feet. First and Third Drifts have 8 and 5 foot thicknesses, respectively.

The Third Drift was distinguished from the First and Second Drifts on the basis of apparent age, also. Two elements showing this were the intermittent presence of "drift ridges and morainic topography" (p. 467) along the border of the Third Drift, as well as the decreased degree of weathering and erosion of the Third Drift. Thwaites (1926) and Leverett (1929) were later to include many of the areas of morainic topography within Weidman's Third Drift as outer moraines of the mid-Woodfordian ice, because they are areas of pitted outwash.

Along the St. Croix River, in Polk and St. Croix Counties in northwestern Wisconsin, and in adjacent areas of Minnesota, Rollin T. Chamberlin (1910) described two tills underlying the Wisconsin red drift in ravines and railroad cuts. The units he described are a lower, grayish black, calcareous, clayey till overlain by a pinkish red or reddish brown, sandy till that is sometimes calcareous. He presented pebble counts that showed that the lower till contained Manitoba materials while the upper unit contained Lake Superior rock types. He had a problem, as Weidman had with his calcareous First Drift, telling where the limestones came from in the red till which was otherwise composed of Lake Superior rock types. The age of these drifts was suggested to Chamberlin by several things. One was a deposit of lumps of humus and twigs above the red till and below red Wisconsin drift, which represented a "true interglacial horizon" (Chamberlin, 1910, p. 546). Another was the eroded and weathered upper surface of the grayish-black till. The yellow oxidized upper part of the grayish-black till was seen to be leached as deeply as five or six feet below its upper contact with the red till. He also noted the advanced degree of decay of pebbles in these older drifts. He correlated the lower grayish black-drift with Kansan, and the red drift above it as probably Illinoian.

In a map published in 1913 (Figure 3d), Leverett and Taylor called Weidman's First and Second Drifts both Illinoian, and did not distinguish them from each other. The map also shows Weidman's Third Drift as "Attenuated Drift, Wisconsin?".

Later in 1913, Weidman and Leverett agreed that there were five different drifts in Wisconsin (Leverett, 1913; Weidman, 1913). Probably only four of these five drifts were to be found in north central Wisconsin. Correlations with the four drifts he had defined earlier (Weidman, 1907) are not made clear by Weidman. My interpretation is that the First through Third Drifts are the same as in 1907, but the original Fourth Drift, the Wisconsin drift, has been moved back to Fifth. The new Fourth Drift is correlated with the Early Wisconsin drift in northeastern Illinois. This probably means that Weidman was attempting to place the extra-morainic drift in southern Wisconsin into the time stratigraphic framework which he had developed for north central Wisconsin. Weidman correlated the Second Drift with the Kansan of Iowa, and the Third Drift with the Iowan of northeastern Iowa.

Throughout the period of time already discussed, Weidman (1903, 1911), Whitson (1927; et al., 1916, 1917, 1918, 1923), Kellogg (1930) and others studied and mapped the soils of central Wisconsin. Kellogg stated that the soil profiles developed on the extra-morainic drifts were immature because little or no colloids were accumulated in the subsoil. This has been used as an argument for the youth of these drifts. However, Whitson (1927) stated that the main reason for the lack of colloidal materials was the generally poor internal drainage of the soils. This is because the unusual proportion of silt and clay in the soil inhibits the formation of shrinkage cracks. Whitson and later soil surveyors also felt that Weidman's driftless area near the Wisconsin River valley was not driftless, but had patchy deposits of older drift.

Leverett (1932) felt that there were Kansan and Illinoian drifts in southeastern Minnesota and northern Wisconsin (Figure 3e). He also felt that Nebraskan drift might be present. Leverett described the Nebraskan and Kansan drifts as nearly black tills often with plant macrofossils included. They are usually indistinguishable and together were called the old gray drift. He further noted the deep degree of decay of pebbles in these drifts and the deep yellowish-brown oxidized zone in the top. An average depth of leaching of Kansan till was given as six feet. The exposures that R. Chamberlin (1910) described across the St. Croix River from Polk County, Wisconsin, and in St. Croix County, Wisconsin, were described and re-interpreted. Leverett described three tills in the Woodville cut, St. Croix County. Two tills overlie a peat bed and a possible third till underlies the peat bed. The upper till is the old red drift, and composed of Lake Superior rock types. Underlying it is a bluish-black till, oxidized and leached in its upper part. The upper till would be Illinoian and the lower Kansan, with the weathering in its top representing the intervening Yarmouth interglacial. The peat was interpreted to represent a long period of accumulation of organic matter, presumably during the Aftonian interglacial stage.

Leverett also described the old red drift throughout the extra-morainic area as being scarcely 10 feet thick on the average, and as being draped over the landscape and over the eroded surface of the older drift like a blanket. It is thickened into a moraine in only one place, near Hampton, Minnesota (Ruhe and Gould, 1954). The old red drift has a much greater degree of weathering than is seen in the young red drift (Wisconsin) nearby. Leverett offered his third different interpretation of the age of Weidman's Second Drift, this one Illinoian. He compared the terminal moraine of this drift, the Marshfield moraine, to the Illinoian moraines of Illinois. He felt the erosion of the moraine and the decay of pebbles was quite like that in Illinois.

Martin (1932) took the side that favored one pre-Wisconsin drift in north central Wisconsin (Figure 4). However, he did follow Weidman's views on two things. His map shows the Wisconsin River valley as driftless and it also shows the Power's bluff boulder train indicating the direction of flow of the ice that deposited the extra-morainic drift.

Mathiesen (1938, 1940) mapped the extra-morainic drift in Barron County, south of the large re-entrant in the mid-Woodfordian end moraine (Figure 5). He indicated that the oldest drift was very patchy and never more than three feet thick. He correlated Weidman's First Drift with this oldest

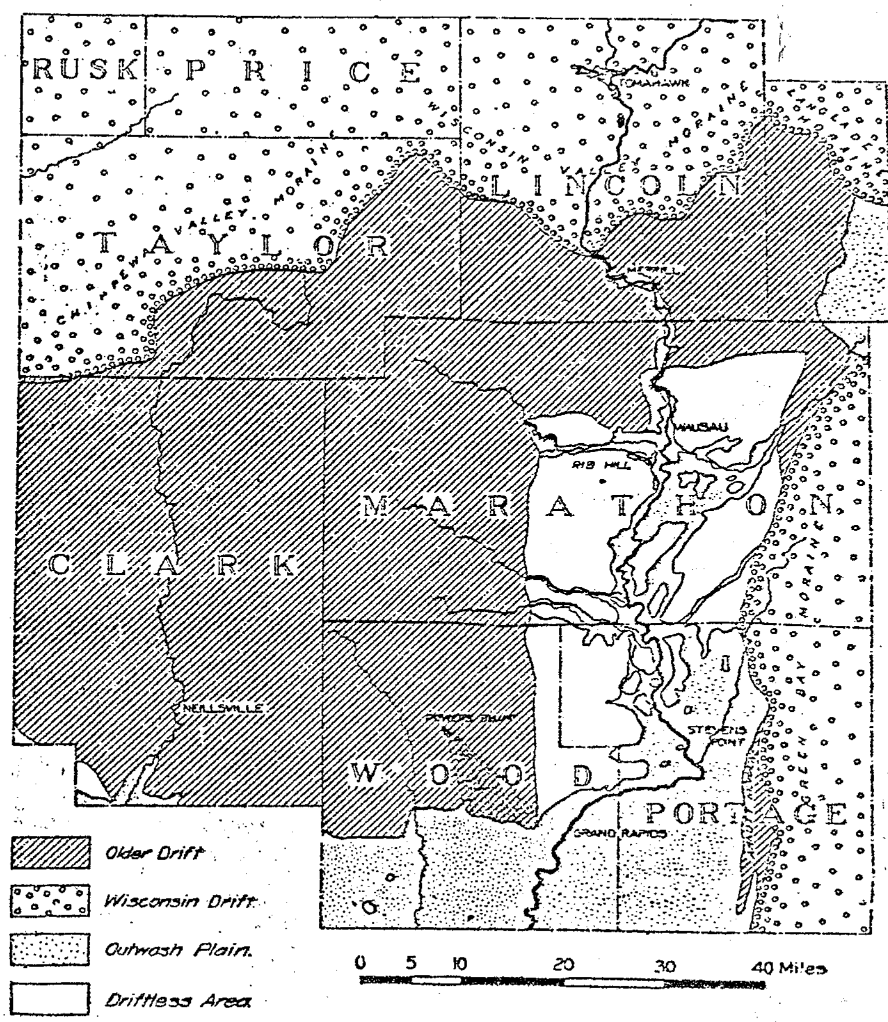


Figure 4. MARTIN'S (1932) MAP OF THE EXTRA-MORAINIC DRIFT IN NORTH CENTRAL WISCONSIN. He called it the older drift, and included the Power's Bluff boulder train, which indicates a southeastward flow direction of the ice which deposited the extra-morainic drift.

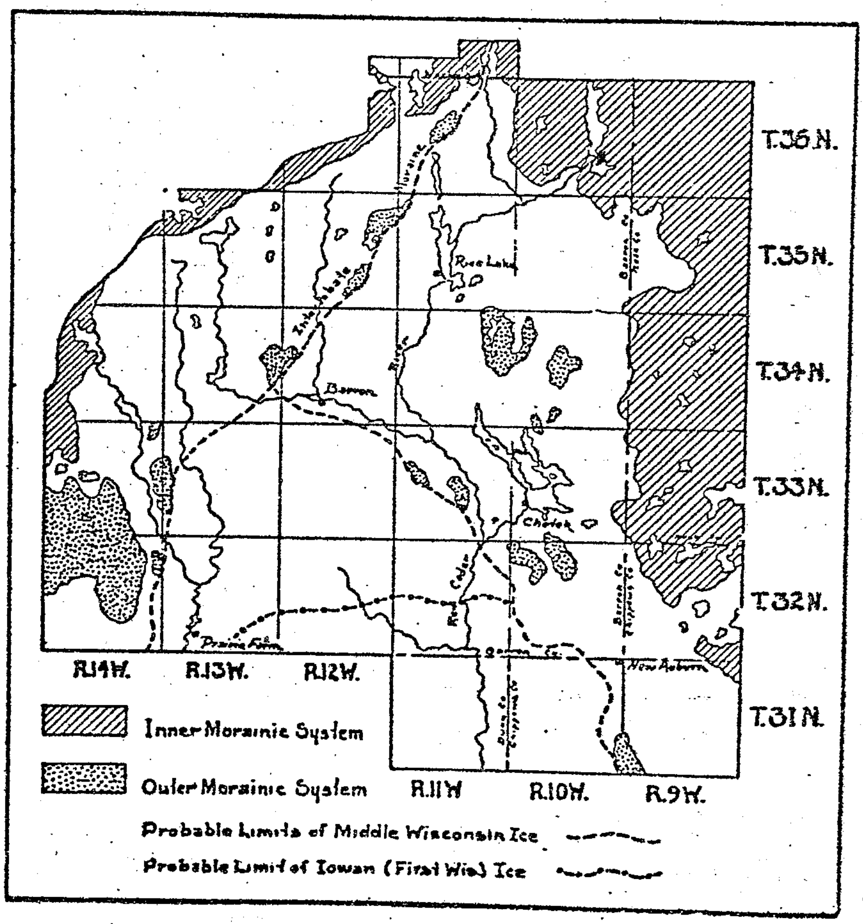


Figure 5. MATHIESEN'S (1940) MAP. He mapped Iowan (First Wisconsin) drift in parts of Barron, Dunn, and Chippewa Counties in western Wisconsin. This interpretation of the age of the extra-morainic drift in the area is the one which Thwaites (1955) followed (Figure 3e).

drift because of the advanced erosion and mature topography developed in it. A younger drift outside of the outer Woodfordian moraine was called Iowan or First Wisconsin and correlated with Weidman's Third Drift. This drift averaged 31 feet thick. Materials composing this drift were described as being nearly as unweathered as those in the Woodfordian end moraine.

Hole did his Ph.D. thesis studying the extra-morainic drifts of north central Wisconsin (1943a, b). He did depth of leaching measurements, mechanical analyses, chemical analyses, calcium carbonate equivalent determinations, and pebble counts. After careful review and refutation of all of Weidman's evidences for more than one extra-morainic drift, he concluded there was only one and that it was probably Wisconsin in age (Figure 6). Hole's six main arguments for one Border Drift follow.

1. The thickening of the Border drift from south to north is gradual and irregular. Such thickening could have been produced by the retreat of a single ice mass.
2. There are no Border drift terminal moraines. The Marshfield "moraine" is essentially a drift-veneered, discontinuous sandstone ridge. There may be a few indistinct moraines, but, if so, these are recessional moraines, which consist chiefly of kames.
3. No till has been found beneath buried soils. Sands, silts and gravels have been encountered beneath the Border drift.
4. Most of the erratics are equally unweathered throughout the Border drift. More weathering might have taken place in thin southern drift on sandstone than in thick northern drift on crystalline bedrock, in the same period of time. The glacier may have encountered a larger proportion of decomposed residuum in the south than in the north.
5. The silty texture of southern portions of the Border drift can be an expression of local material encountered by the glacier, rather than the result of great age. There are very stony and sandy masses of till as far south as

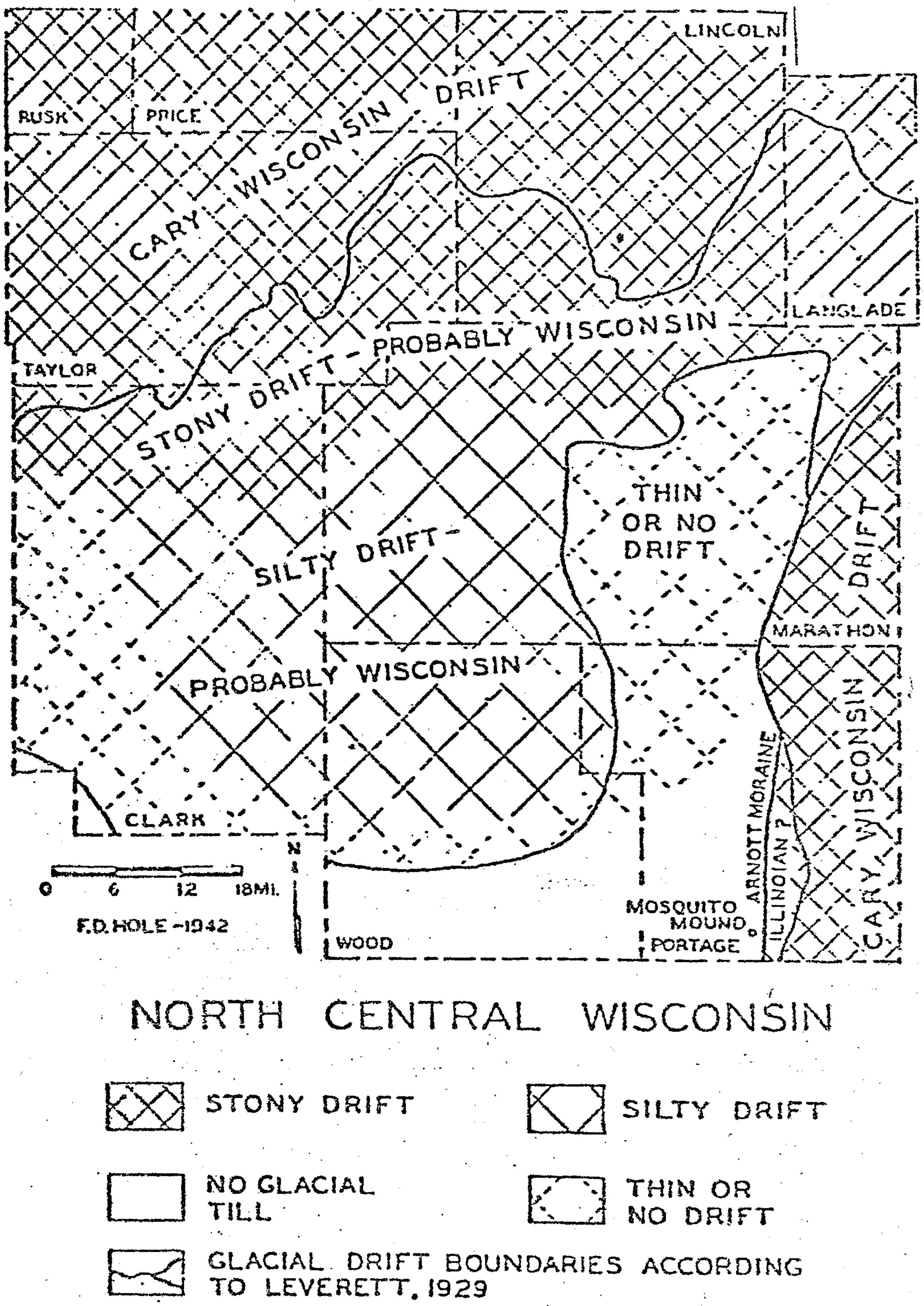


Figure 6. HOLE'S (1943a, b) INTERPRETATION THAT ALL OF THE EXTRA-MORAINIC DRIFT IN NORTH CENTRAL WISCONSIN IS A SINGLE DRIFT SHEET OF WISCONSIN AGE.

Marshfield. There is no definite and abrupt break in textural variation of the Border drift as one goes from south to north.

6. Red-brown drift occurs in the southern Border drift areas as well as in the north. This is another indication that the heterogeneity of the Border drifts does not give evidence of any zonal or regional discontinuities. (p. 100-101)

Hole did not commit himself firmly to an age for the Border drift, though he thought it was probably Cary (Late Wisconsin). He definitely ruled out Nebraskan and Kansan ages for the Border drift because of pollen evidence from a buried organic deposit on the Marshfield Experimental Farm. He listed the following reasons for a Cary age for the Border drift.

1. There is no significant, abrupt change in the character of the drift from the southern limit of the Border drift to the northern boundary of north central Wisconsin. Even the change in topography at the Cary moraine is gradual, locally, and that change does not necessarily involve a difference in age. (p. 104)
2. The majority of mineral particles throughout the Border drift are unweathered. If more decomposed debris actually does occur in southern north central Wisconsin than in northern north central Wisconsin, this, again, does not necessarily prove a difference in age of drifts, but rather a difference in kinds of materials encountered by the ice.
3. Field examination, mechnical analyses, and preliminary mineralogic examination yield no evidence in support of the view that the loess deposit north of the Cary moraine is not the same loess south of the moraine.
4. Chemical analyses and brief mineralogic examination indicate that the Border drift is almost as unweathered as the loess lying on it.
5. It is possible that Cary ice first advanced to the limit of the Border drift, and that the ice front then retreated rapidly, coming to a prolonged halt in the prominent morainal zone, before retreating farther north. (p. 105)

Hole mapped a substantial number of localities where highly calcareous till was located (Figure 7). Even though these localities are concentrated largely in one area, Hole did not view this as evidence of a till different from the rest of the Border Drift till.

Thwaites (1943) stated that the moderate amount of erosion and weathering and the immature soil profiles in the extra-morainic drift lead to the conclusion that this drift is of Iowan age. His map (1955) showed most of Wisconsin's extra-morainic drift as Iowan, but also some Kansan and Nebraskan drifts were present (Figure 3f).

Black (1959a, b) lumped the grayish-black, clayey till and the overlying reddish-brown sandy till of the Woodville railroad cut (Chamberlin, 1910; Leverett, 1932) together as Farmdale in age. This was because two radiocarbon dates of wood from the grayish-black till indicated an age of about 30,000 years B.P. In this scheme, the lower till was seen as a lodgement till and the upper till as an ablation till, both related to the same ice mass. Figure 8 is a map made after revision of time stratigraphy placed these 30,000 y. B.P. dates in late Altonian. Black (1962) coined the term Rockian for the period of glaciation in Wisconsin that began around 30,000 years B.P. In 1962, Black felt that there were no Pleistocene deposits in Wisconsin that were older than Rockian, and that it was the Rockian ice which glaciated the Driftless Area. He was later to agree with others that it was possible that there had been some pre-Rockian glaciation of the state (Frye, Willman, and Black, 1965; Black et al., 1965; Black and Rubin, 1968).

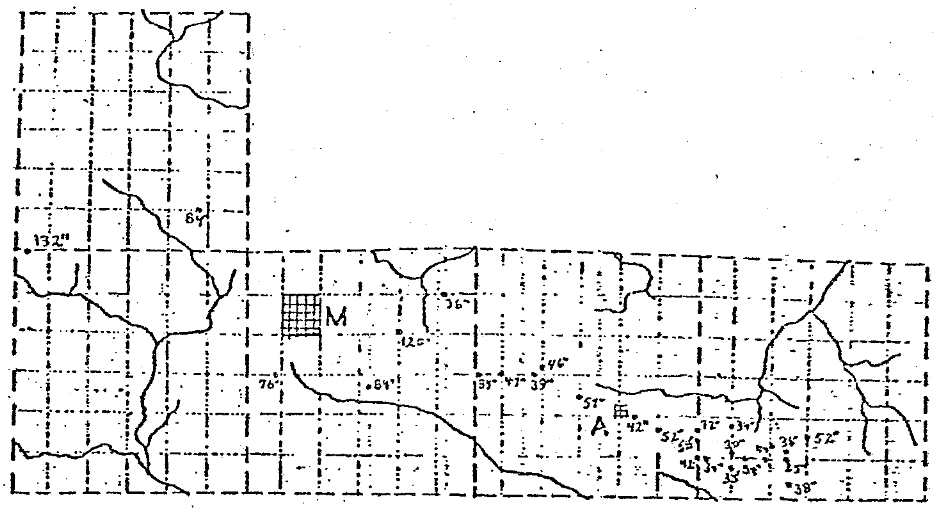


Figure 7. HOLE'S (1943a) MAP OF SITES WHERE CALCAREOUS DRIFT WAS FOUND. Depth of leaching in inches is indicated on the map. The M is Marshfield and the A is Auburndale. Hole felt that the carbonate had been locally concentrated in the till.

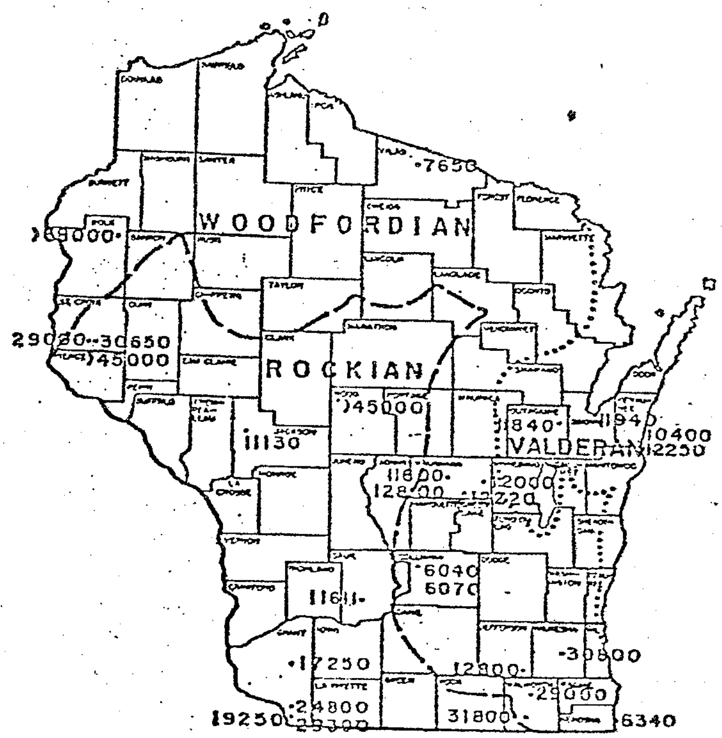


Figure 8. BLACK AND RUBIN'S (1968) MAP. The extra-morainic drift was mapped as late Altonian (Rockian). This was based on radiocarbon dates which are plotted on this map.

Akers (1961) studied the clay mineralogy of weathered and unweathered till samples of Rockian and Woodfordian age in west central Wisconsin. He stated that "there was nothing found in the clay-mineral content of the glacial deposits to indicate that more than one age of glacial deposits exists southeast of the St. Croix moraine of Cary age." (p. 3) Furthermore, his work did not support a radiometrically greater age for the Rockian till.

Olup (1969) worked in the northern part of Marathon County, an area including Weidman's First, Second, and Third drifts. He did mechanical analyses, qualitative clay mineralogy, coarse fraction petrography, pebble counts, calcium carbonate equivalent determination, and magnetic susceptibility measurement on unweathered till samples. Some of his conclusions follow.

1. The First Drift, Second Drift and Third Drift as defined by Weidman (1907) and Mathiesen (1940) are petrologically the same, and Black's (1959, 1962) proposal of one pre-Late Woodfordian (pre-Cary) surficial till is valid for Northern Marathon County.
2. It is tentatively suggested that the ice which deposited the Rockian till moved into the area from the northwest.
3. Because the Rockian till is very thin, it closely reflects the composition of the local bedrock.
4. The portion of the "Driftless Area" included in Northern Marathon County was glaciated by the same ice that deposited the Rockian drift.
5. The till is probably not as old as previously thought, and Black's age designation, Rockian (approximately 30,000 years B.P.), appears valid.
6. Based on mean values of sand, silt, and clay percentages and mean median diameters, the Rockian and Late Woodfordian (Cary) tills appear distinct; however, this is not definitely concluded because the Late Woodfordian (Cary) is only represented by two samples. (p. 49)
7. The tills of Northern Marathon County cannot be distinguished on the basis of coarse fraction composition nor on the basis of calcium carbonate equivalent due to the high degree of local bedrock control.

8. The Rockian drift of Northern Marathon County is correlative with the Rockian drift in the western part of Wisconsin. (p. 50)

LaBerge and Myers (1970, 1971) defined two extra-morainic drifts in eastern Marathon County, informally named the Wausau till and the Merrill till (Fig. 9). The Merrill till corresponds to Weidman's Third drift. The Wausau is found in Weidman's driftless area near the Wisconsin River. It is extremely thin and patchy in its distribution.

Stewart (1973) also worked in Marathon County as well as adjacent Lincoln and Langlade Counties. He, through about the same methods that Olup used, came to conclusions opposite those of Olup. Stewart found and distinguished the Wausau till and the Merrill till (Fig. 10). He distinguished the two by color, texture, and especially by semi-quantitative clay mineralogy. His results are summarized in Table 1. Unlike Olup or Akers, he was able to see differences between the clay mineralogy of the two different extra-morainic tills and also differences between these and the clay mineralogy of mid-Woodfordian tills. This is because Stewart's work was semi-quantitative, instead of simply quantitative, like the work of Akers and Olup. The Wausau and Merrill tills had much higher vermiculite (a weathering product) contents than the Woodfordian till. The Wausau till, which was found stratigraphically beneath the Merrill till, had very large amounts of smectites. These are clay minerals of advanced stages of weathering. More will be said about clay mineralogy below.

Stewart radiocarbon dated organic deposits on top of the Merrill till at 40,800 years B.P. $\pm$ 2,000 (IGS-256) (Stewart and Mickelson, 1976). Clearly,

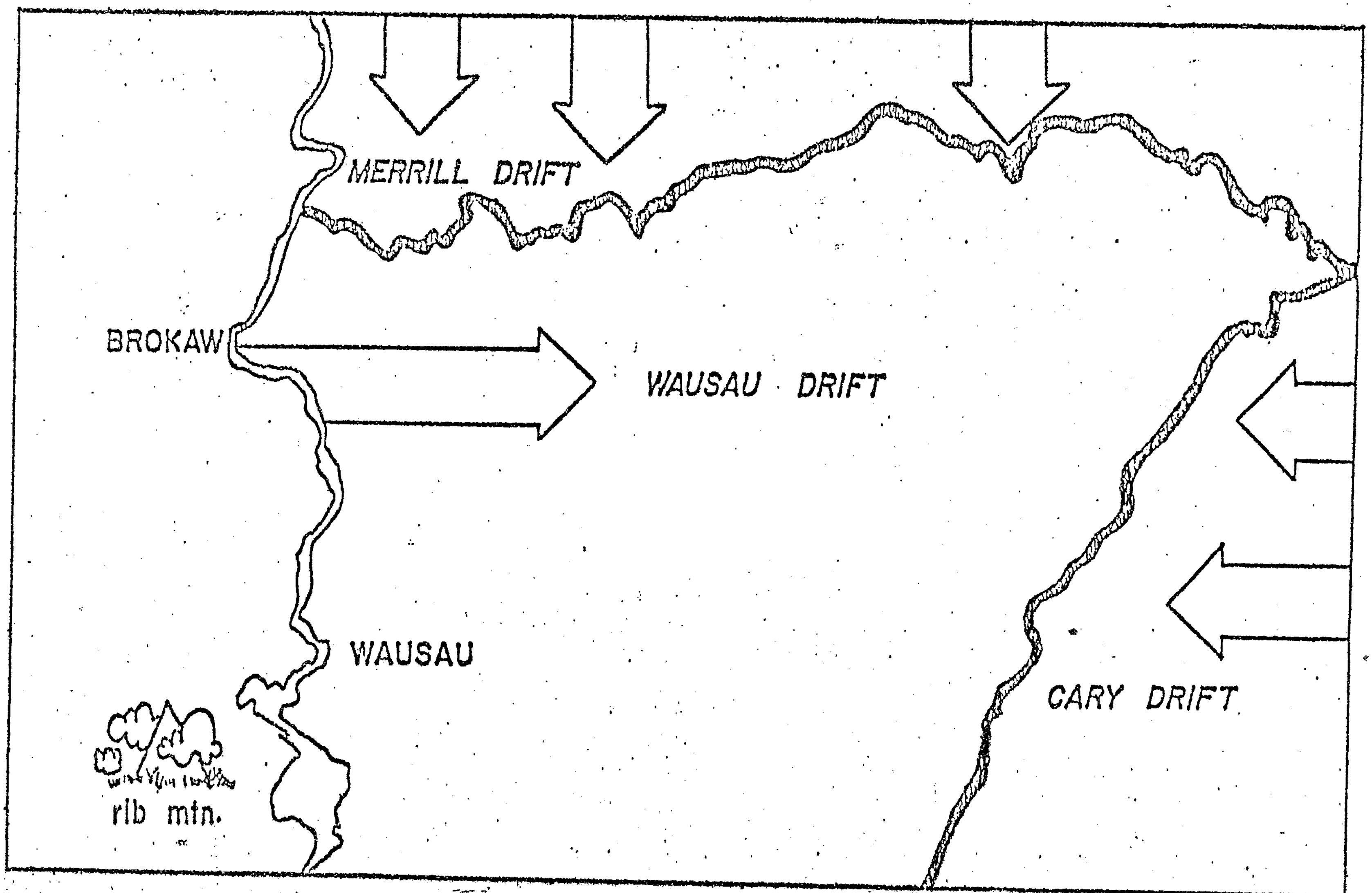


Figure 9. LABERGE AND MYERS'S (1971) MAP OF EASTERN MARATHON COUNTY. They first named and mapped the Merrill and Wausau tills in the extra-morainic area west and north of Wausau.

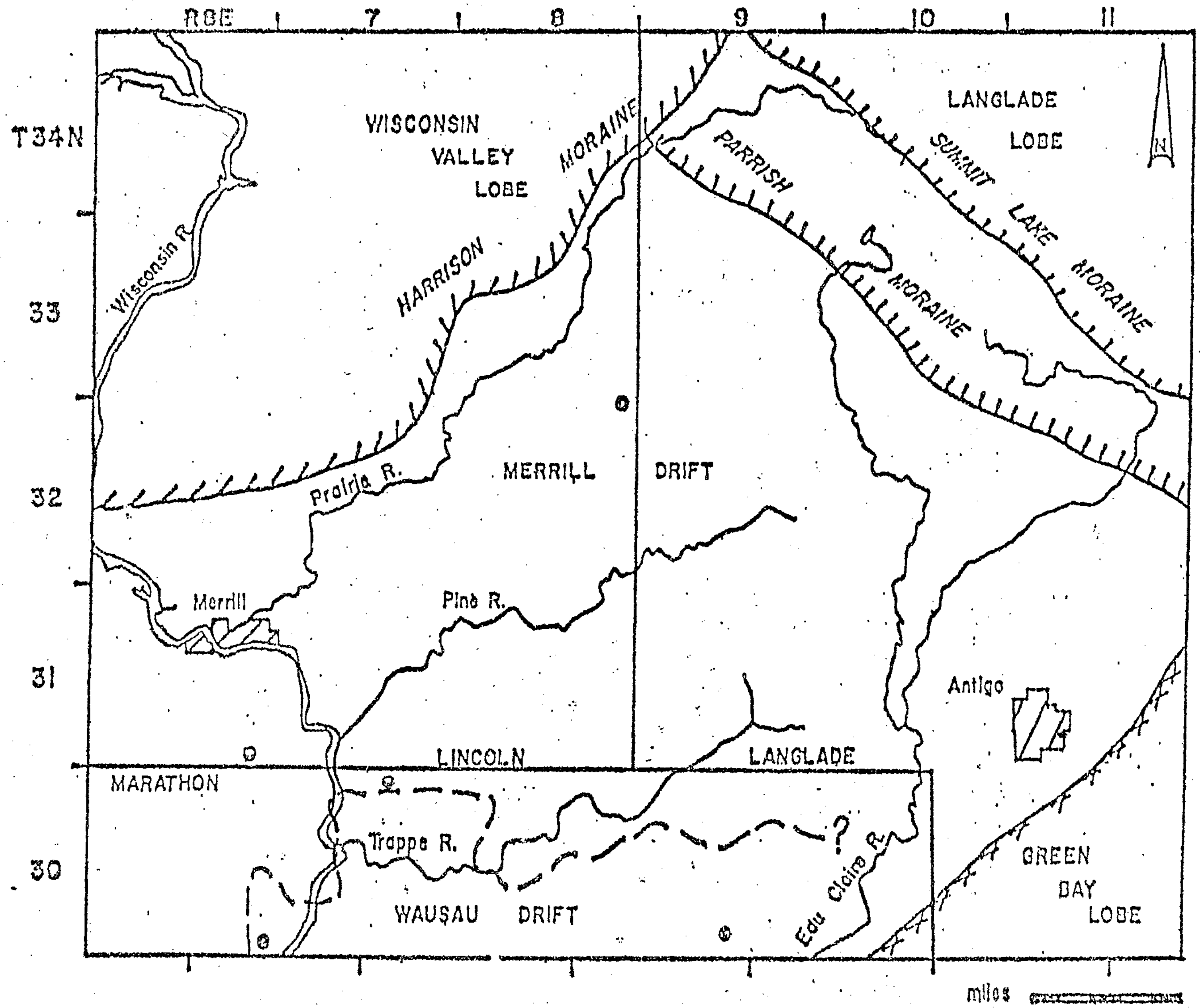


Figure 10. STEWART'S (1973) MAP OF THE EXTRA-MORAINIC DRIFTS. He mapped a boundary between the Merrill and Wausau tills in the area of the extra-morainic drift (southern part of the map). The boundary is similar to the one by LaBerge and Myers (1971) in Figure 9.

Table 1. STEWART'S (1973) MEAN SAND/SILT/CLAY AND CLAY MINERAL COMPOSITIONS FOR THE TILLS MAPPED IN FIGURE 10. The Merrill and Wausau tills are distinctively different from the Woodfordian tills. Their high content of weathering product clay minerals (vermiculite and smectite) indicates that the Merrill and Wausau tills are pre-Woodfordian in age.

TILL (Age)	TEXTURE			CLAY MINERALS (%)			
	Sand % (1/16-2 mm.)	Silt % (2 microns - 1/16 mm.)	Clay % (less than 2 microns)	Illite	Kaolin-Chlorite	Vermiculite	Smectite
Wisconsin Valley Lobe (Late Woodfordian)	78	17	5	66	21	2	12
Langlade Lobe (Late Woodfordian)	78	17	5	71	18	1	11
Green Bay Lobe (Late Woodfordian)	78	17	5	69	13	5	14
Merrill Till	60	30	10	51	9	23	16
Wausau Till	47	35	18	26	5	25	44

both the Merrill and Wausau tills are at least as old as Altonian. The advanced stage of clay mineral weathering in the Wausau till suggests it may be Illinoian in age.

An area adjacent to Stewart's was chosen for the present study with the goal of trying to extend knowledge of the glacial stratigraphy with the help of his work.

Bell and Sherrill (1974) state that during the process of drilling and logging about 180 auger holes in southwestern Marathon County and adjoining areas, they consistently saw two distinctly different tills. A clayey till was found underlying a sandy, gravelly till in many holes. I have been permitted to use the logs from the drilling done by Bell and Sherrill as an aid in my stratigraphic studies. They also published drift thickness maps which have also aided this study.

In summary, this literature review should demonstrate that there are still questions about the existence and nature of multiple extra-morainic drifts in north central Wisconsin. It is the main purpose of this thesis to answer some of these questions.

FIELD AND LABORATORY PROCEDURES

Field work was done in Marathon County during parts of the summers of 1974 and 1975. Surface materials were observed and the materials in the subsurface were sampled with the aid of hand and power augers. Munsell colors and field estimates of textural family were assigned to tills. Till samples from below the B-horizon were collected in air tight bags and returned to the laboratory for mechanical analyses, clay mineral analyses, and coarse sand fraction counts. Where the exposure permitted it, till fabrics were measured, using the orientation of the long axes of 50 pebbles. These orientations were measured as a dip angle and azimuth direction. Because of poor exposures, till fabrics were measured at only three localities in the study area. A computer program (Corbato, in Mickelson, 1971) was used to take the till fabric measurements and plot them on an equal area stereo plot.

Fifty-two till samples plus twenty-four samples of other types of materials were mechanically analyzed using standard techniques (Royse, 1970) of dry seiving and the Bouyoucos hydrometer method. Mechanical analysis results for the fifty-two till samples are plotted in Figure 11.

Coarse sand fraction counts were done on the 1-2 millimeter fraction after it was separated from the rest of the sands by dry seiving. Lithologies and minerals distinguished are listed in Table 2. Because LaBerge and Myers (1971) and Stewart (1973) noted differences in the amounts of non-local rock type in the different tills, it was hoped that the coarse sand fraction could be tested for this relationship. Because it would have been difficult to distinguish

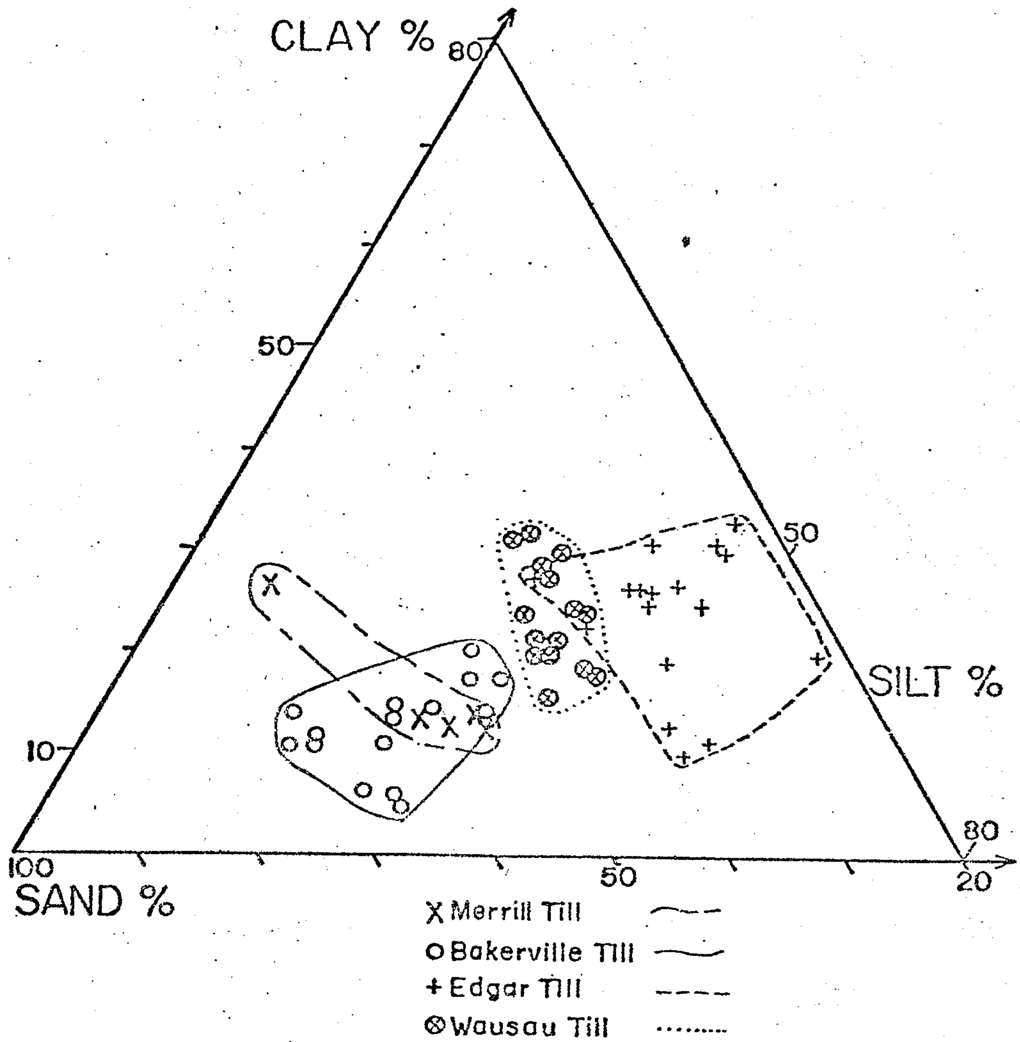


Figure 11. TRIANGULAR PLOT SHOWING THE SAND/SILT/CLAY COMPOSITIONS OF THE MERRILL, BAKERVILLE, EDGAR, AND WAUSAU TILLS. The Merrill and Bakerville tills are indistinguishable texturally, and there is a little overlap of the Edgar and Wausau tills.

Table 2. ROCK AND MINERAL TYPES THAT WERE COUNTED IN THE COARSE SAND FRACTION, AND THE RESULTS FOR EACH TILL. The total of the local rock types (asterisks) indicates that the Wausau and Edgar tills more strongly reflect the local bedrock.

Rock/Mineral Type	Percentage in Each Till			
	Merrill	Bakerville	Edgar	Wausau
Granitic*	28	25	33	32
Feldspar grains*	9	9	9	11
Angular quartz grains*	22	17	18	20
Rounded quartz grains*	2	12	7	9
Limestone	0	0	1	0.2
Dolomite	0	0	0	0
Rhyolite to intermediate	4	4	9	9
Gabbro	1	0	0.3	0.2
Diorite	6	4	2	2
Basalt	1	1	1	1
Vein quartz	0	0	0.2	0
Schist and Gneiss	2	2	3.5	3.3
Quartzite	9	7	3	2
Greywacke	3	4	4	3
Red Sandstone	7	10	7	5
Chert	0.5	1	0.7	0.4
Iron formation	1	1	0.7	1
Greenstone	3	2	0.8	1
Other	0	1	0.3	1
TOTAL	98.5	100	100.5	101.1
Unidentified weathered (Not in total)	6	7	5	4
TOTAL "LOCAL" (*) types	62	62	66	72

local from non-local grains of a given rock or mineral type, a somewhat arbitrary group of lithologies was selected to represent local rock types. Because granite and sandstone are the predominant local bedrock types (LaBerge and Myers, 1971), the percentage termed the total local rock types is defined as the total of the percentages of granite, feldspar, angular quartz, and rounded quartz. I am aware that all of the granite in these counts is not necessarily of local origin, and that all of the basalt is not necessarily erratic (LaBerge and Myers, 1971). However, it is hoped that the local rock type percentages are at least generally indicative of the amount of truly local types.

A number of lithologies are clearly erratic, and many of these point to the Lake Superior basin as a source for the ice which deposited the extramorainic tills. Some of these lithologies are iron formation, felsic to intermediate volcanics, and red sandstones. As Table 2 shows, all four of the tills contain Lake Superior rock types, so each of the four ice advances must have come through the Lake Superior basin.

The coarse sand fraction lithology counts were made with the intent of aiding in the definition of different stratigraphic units. My hypothesis is that the lower stratigraphic units will reflect more strongly the local bedrock. The younger units, having been deposited over a bevelled landscape of low relief, would not have the opportunity to incorporate as large a percentage of local rock types.

Procedures for semi-quantitative clay mineralogy determination were adopted mainly from Stewart (1973). The smear technique (Gibbs, 1965) was used to apply the less than two micron fraction of till samples to glass slides.

These slides were analyzed by X-ray diffraction on a Norelco diffractometer. They were run under three conditions, each with a one degree divergence slit, a scan rate of one degree two theta per minute, and a time constant of two. The three conditions under which each slide was run were dry air, water saturated air, and after glycerol treatment.

Diffraction pattern peak areas on a strip chart were used for the qualitative and semi-quantitative clay mineralogy. For the clay minerals, these peaks are from basal reflections. Using a method for semi-quantitative analysis developed by Johns, et al. (1954) and detailed by Darby (1971), peak areas of each characteristic basal reflection of each mineral are compared to that of illite (001) at 10 Å. In this scheme, peaks are measured for the clay minerals illite, kaolinite-chlorite, vermiculite, and smectite. For illite, the 001 reflection of 10 Å was measured on the water saturated air and the glycerol treated patterns. The 7 Å peak on the dry air pattern was measured as an index of kaolinite (001) and chlorite (002). No attempt was made to distinguish these two minerals. Vermiculite was quantified using the areas of dry air and glycerol treated 14 Å peaks. Because vermiculite collapses to 11-12 Å under dry air, the difference between the glycerol treated peak minus the dry air peak was used to quantify vermiculite. Smectite, a group of expandable minerals with a basal reflection of 17-18 Å after glycerol treatment, was quantified by using the glycerol treated 17 Å peak area.

The illite peak area is used as the standard for comparison. Because different clay minerals have different reflectives, any quantification scheme must account for these differences. This study adopts the reflectivity factors

(RF) developed for Stewart (Bailey, in Stewart, 1973). These are .25 for kaolinite-chlorite, .25 for vermiculite, and .22 for smectite. Hence, the equation for the relative percentage of one of the 4 clay minerals quantified is:

$$\text{relative \% of mineral Z} = \frac{\dfrac{\text{peak area Z} \times RF_Z}{10\ \text{Å illite peak area}}}{\text{sum of peak areas of all minerals quantified}} \times 100$$

In addition to the four clay minerals defined above, calcite peak heights in millimeters were measured from the strip charts.

There are two reasons why the semi-quantitative clay mineralogy of tills is important. One reason is that tills may be distinguished from each other if their clay mineral compositions are different. The other reason that clay mineralogy is important is that it can indicate the relative degree of weathering of each till. The degree of weathering can be used as an indicator of the relative ages of the tills (Stewart, 1973; Stewart and Mickelson, 1976; Willman, et al., 1965).

The four clay mineral groups quantified in this study were selected because in a closed system, weathering causes changes in their relative percentages. Illite and chlorite are altered and become vermiculite and smectite when weathered. Vermiculite also weathers to smectite. Kaolinite is a stable component, unaffected by weathering. Table 3 contains the mean clay mineral compositions of the four tills. The Wausau and Edgar tills have substantially higher percentage contents of weathering product clay minerals than the Bakerville and Merrill tills. If these differences are due to more extensive

Table 3. SAND/SILT/CLAY AND CLAY MINERAL COMPOSITIONS OF THE FOUR TILLS. They are shown with means (above) and ranges (below). The Merrill and Bakerville tills are quite similar. The Wausau and Edgar are also similar, but the Edgar till is siltier.

TILL	TEXTURE			CLAY MINERALS (%)				NUMBER OF SAMPLES
	Sand % (2-1/16 mm)	Silt % (1/16 mm-2 microns)	Clay % (less than 2 microns)	Illite %	Kaolinite-Chlorite	Vermiculite %	Smectite %	
Merrill	58 55-66	30 27-32	12 7-14	65 47-82	9 5-16	13 3-28	13 6-20	5
Bakerville	62 51-72	25 16-32	13 5-21	53 32-73	8 4-16	14 4-33	25 9-43	15
Edgar	33 23-43	43 30-58	24 10-33	44 30-59	6 1-10	17 10-27	33 23-49	17
Wausau	43 39-47	34 27-39	23 18-32	44 19-68	5 3-9	18 6-33	32 11-54	15

weathering of the Wausau and Edgar tills, it can be inferred that these two units are older than the Bakerville and Merrill tills.

A further refinement of the estimate of relative age can be made by comparing Table 3 to Table 1, which presents Stewart's (1973) clay mineralogy data for the Wausau and Merrill tills and also for three Late Woodfordian tills. Further discussion of the relative ages of the tills is found in the time stratigraphy section, which follows the detailed descriptions of the tills.

STRATIGRAPHY

Till Stratigraphy

Four different tills are distinguished in the study area. They are the Wausau till, the Edgar till, the Bakerville till, and the Merrill till. None of these are formal till stratigraphic units, and two of the names, Edgar and Bakerville, are new names for new tills described here.

The Merrill and Wausau tills were informally named by LaBerge and Myers (1971), Stewart (1973), and Stewart and Mickelson (1976). The tills are defined on the basis of their sand/silt/clay composition, clay mineralogy (Table 3), color, and coarse sand fraction lithologies (Table 2). Till fabrics for the Bakerville and the Edgar tills give additional information about ice flow direction in the area (Figures 15, 16, 18, and 19).

Figure 12 is a diagrammatic representation of the stratigraphy. The reason for the doubtful correlation of the Bakerville and Merrill tills is lack of information due to an inadequate sampling distribution, which can be seen in Figure 13. Where boundaries between surficial till units shown in Figure 13 were not well defined by sampling, Weidman's (1907) boundaries were used for guidance. No samples of the Wausau till were collected in the area where it is the surface till. In other areas the Wausau till was sampled where it underlays other tills or where it was exposed at the surface, but in the eastern third of the study area, the Wausau till has been largely removed by erosion.

Figure 14 shows the locations of auger holes drilled with the truck-mounted power auger. Figures 12, 13, and 14 will be referred to throughout

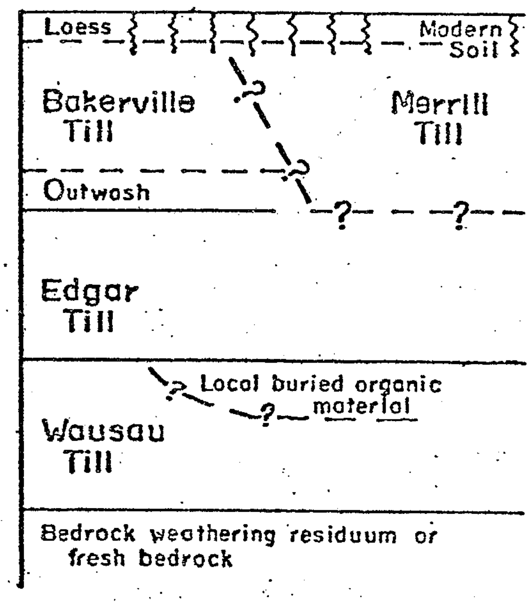


Figure 12. DIAGRAMMATIC REPRESENTATION OF THE STRATIGRAPHY OF THE EXTRA-MORAINIC DRIFTS. Although tills have been found in contact with each other, no one location shows all units.

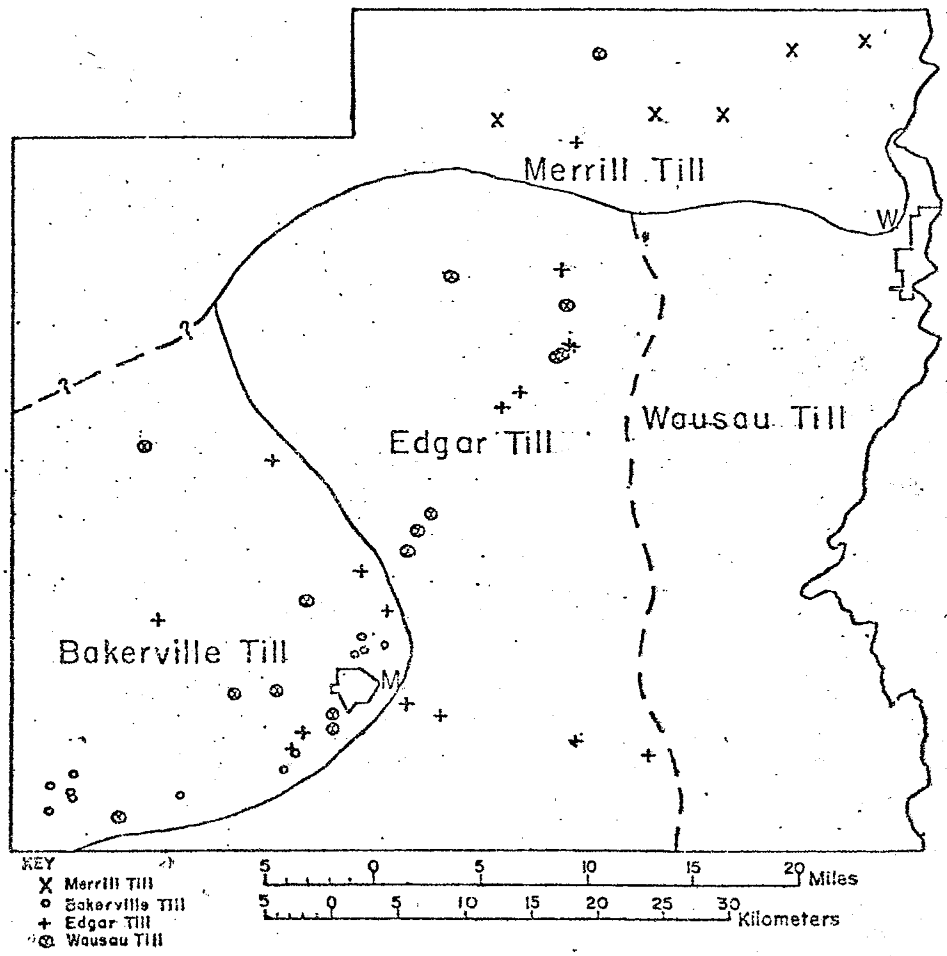


Figure 13. MAP OF THE DISTRIBUTION OF SURFACE TILL SAMPLES AND THE BOUNDARIES OF THE FOUR TILL UNITS. Where the contacts are dashed, Weidman (1907) has been relied upon for the approximate location. The Merrill and Bakerville tills may be correlative (Figure 12).

Bob Baker

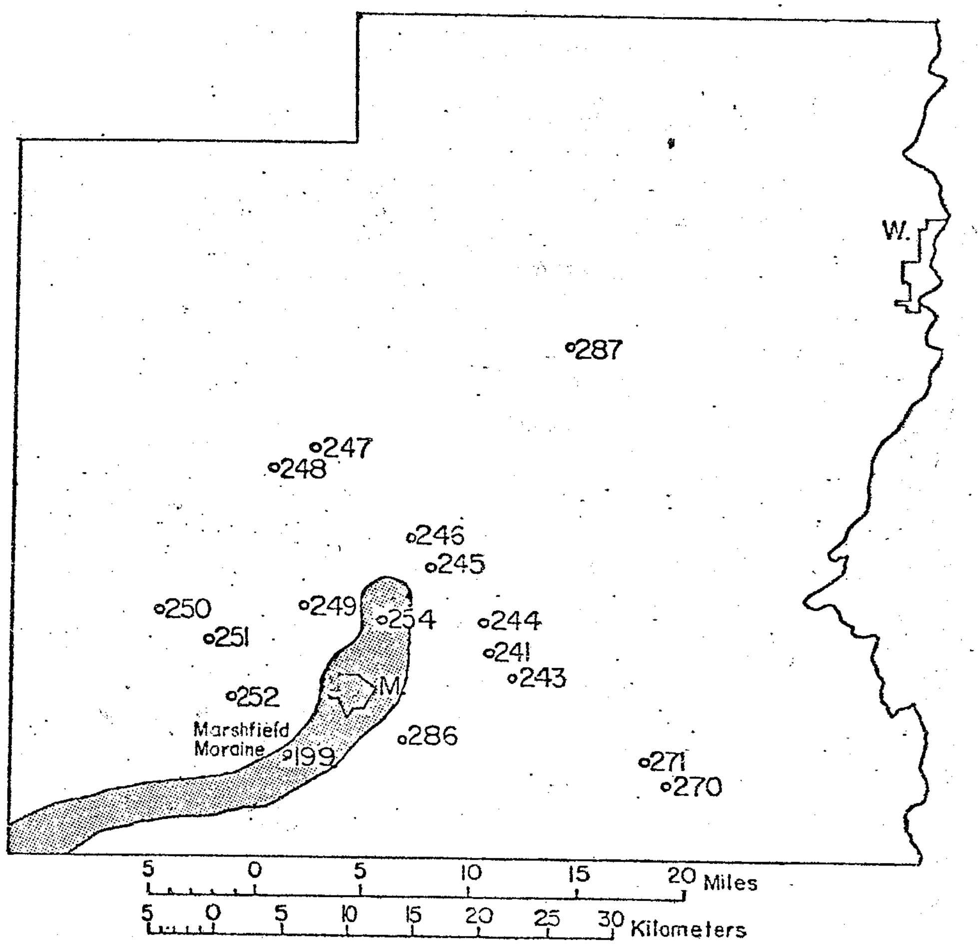


Figure 14. DRILL HOLE LOCATIONS AND THE MARSHFIELD MORAINE (shaded). Drill hole logs are in Appendix A. The Marshfield moraine cannot be traced northwest as a topographic ridge beyond where it is shown. However, as Figure 13 shows, the Bakerville till, which caps the moraine, is not overlain by the Merrill till until farther north (unless these two tills are equivalent).

the following discussion of stratigraphy.

Wausau Till

The data discussed below readily show that the Wausau till is demonstrably different from and older than the Merrill and Bakerville tills. These conclusions are not contradicted by drill hole stratigraphy. The clearest major distinctions between the Wausau till and the Edgar till are that the Edgar till is calcareous and always much siltier.

A large majority of the Wausau till samples are brown (7.5 YR 4/4). Though this till shows less variability in color than the Edgar till, it ranges from several samples of dull reddish brown, 5 YR 5/4, at the darkest, to dull yellowish brown, 10 YR 5/4, at the lightest. All these colors represent oxidized till samples.

Mean sand/silt/clay composition of the Wausau is 43/34/23 (Figure 11, Table 3). The ranges in these percentages are 39-47/27-39/18-32. There is a fairly clear break between this till and those with greater than 50% sand, the Merrill and Bakerville tills (Figure 11).

There is a small amount of overlap in Figure 11 between the Wausau till and the Edgar till. It is possible that a small number of till samples that were composed of nearly equal amounts of sand and silt could be either Wausau or Edgar till, if they were non-calcareous. Hence, the area of overlap in Figure 11 represents an area in which some characteristic other than sand/silt/clay composition was used to determine if the till sample was Wausau or

Edgar till. Other characteristics used to aid in this determination were color, stratigraphic position, and presence of a calcite peak on the X-ray diffractogram.

A mean of 72% of the mineral and rock grains in the coarse sand fraction are local bedrock types (Table 2). Among individual Wausau till samples, this percentage ranged from 62% to 80%. This is a substantially higher percentage than that found in the Bakerville till (62%) or the Merrill till (62%). 66% is the proportion of local types in the Edgar till. These percentages suggest that the Wausau and Edgar tills lie closer to the bedrock than the other two tills, an interpretation which is supported by drill hole stratigraphy and road cuts.

The clay minerals in the less than two micron fraction of the Wausau till are quantitatively distinct from those of the Merrill and Bakerville tills, but not distinct from those of the Edgar till (Table 3). Relatively high mean percentages of vermiculite and smectite (18% and 32%, respectively), and low percentages of illite and kaolinite-chlorite (44% and 5%, respectively), all fit together to suggest that the Wausau is a more deeply weathered till than the Merrill or Bakerville. Ranges in the percentages of each clay mineral are: illite, 19-68%; kaolinite-chlorite, 3-9%; vermiculite, 6-33%; and smectite, 11-54%. Such variation in the clay mineralogy of a single till is largely due to various degrees of weathering. The variations appear to be the result of sampling at different depths, where weathering has been more or less active. This will be discussed again below.

Comparison of clay mineralogy of the Wausau till given here to that given by Stewart (1973) (Table 1), shows some difference between the two quantifications. This difference is probably due to individual differences in procedure, machinery, or sample condition. These types of variables are the reason why clay mineralogy is semi-quantitative and not purely quantitative. In a semi-quantitative sense, the two sets of data on the Wausau till are enough alike to conclude that they do characterize one till unit, and that this unit, the Wausau till, is substantially different from the Bakerville and Merrill tills.

Drill hole 252 (Figure 14; Appendix A) penetrated three tills. The surficial till is the Bakerville till which overlies the Edgar till, which in turn overlies the Wausau till.

In three drill holes (271, 286, and 287; Figure 14; Appendix A) relatively thick layers of black, organic sediment were found underlying the Edgar till. In hole 287, this organic material probably accumulated on and in the underlying Wausau till. Hole 271 has the same sequence, but there the organic matter has been reduced, and the sediment is bluish gray and greenish gray in color. In hole 286, the organic sediment is underlain by bedrock weathering residuum.

The Wausau till is generally quite thin (5-10 feet), and often is not present, even in the subsurface. As Figure 13 shows, the Wausau till is exposed at the surface by erosion throughout the study area. The Wausau till overlies the bedrock weathering residuum.

Edgar Till

Seven Edgar till samples were calcareous when tested in the field. Depth of leaching ranges from 3 to 10 feet, and averages about 5 feet. Texturally, the calcareous samples average to loam, but they approach the silty clay loam textural family. Sand/silt/clay composition percentages consistently have greater silt than sand content (Figure 11). The calcareous nature and the silty texture of the Edgar till distinguish it from the Wausau till.

A type locality is required for naming till units formally. Though the Edgar till is named informally, a type locality is still considered useful. The type locality I suggest for the Edgar till is in a Chicago and Northwestern railroad cut about one mile south of Edgar. Weidman (1907) described the cut as an example of the First drift. The cut exposes about 10 feet of calcareous Edgar till, and is located just south of Marathon County Highway N, in the SE 1/4, NE 1/4, NW 1/4, Sec. 24, T.28N., R.4E.

The most common color of the Edgar till is 7.5 YR 4/4-5/4, brown to dull brown. The range of color is from as dark as 5 YR 4/4 to as light as 10 YR 5/6. There are a significant number of Edgar till samples that are dark reddish brown (5 YR 4/4) and brown (10 YR 4/6). The Edgar till has the greatest color variability of all the tills samples and is not easily distinguished in the field by color alone.

Mean sand/silt/clay composition for the 17 Edgar till samples is 33/43/24. For the 7 calcareous samples, these percentages are 33/45/22. The ranges of these textural components are 23-43/30-58/10-33 (Figure 11).

An average of 66% of the lithologies/minerals in the coarse sand fraction are of local origin. The range is 52 to 87%. This is somewhat different from the percentages determined for the Merrill till (61%) and the Bakerville till (63%), and quite different from the percentage for the Wausau till (Table 2). The Edgar till is the only till which contains limestone sand grains. A pebble of this limestone from the Edgar till was thin-sectioned and examined. It consists of a fossil hash of Paleozoic fossil fragments. The fossil fragments are not coarser than sand-sized, but some of the types are recognizable as crinoid and bryozoan fragments. It is unclear what or where the source for Paleozoic limestones in this till might be. The source for limestone in drift that was deposited by ice that moved out of the Lake Superior basin has been indeterminate for some time (Hole, 1943a).

The mean percentages of clay minerals in the less than two micron fraction of the Edgar till are as follows: 44% illite, 6% kaolinite-chlorite, 17% vermiculite, and 33% smectite (Table 3). The ranges of the percentages are: illite, 30-59%; kaolinite-chlorite, 1-10%; vermiculite, 10-27%; smectite, 23-49%. The pattern formed by this assemblage of clay minerals suggests substantially more weathering than is shown by the clay mineralogies of the Merrill and Bakerville tills. Diffraction pattern peaks for calcite are consistently present only in Edgar till samples, even many of the ones that are leached.

The exposure mentioned above as a possible type locality of the Edgar till was deemed acceptable for measuring a till fabric. The location is mapped in Figure 15. The fabric (Figure 16) suggests that the ice which deposited the Edgar till was travelling in a south-southeasterly direction. Other evidence

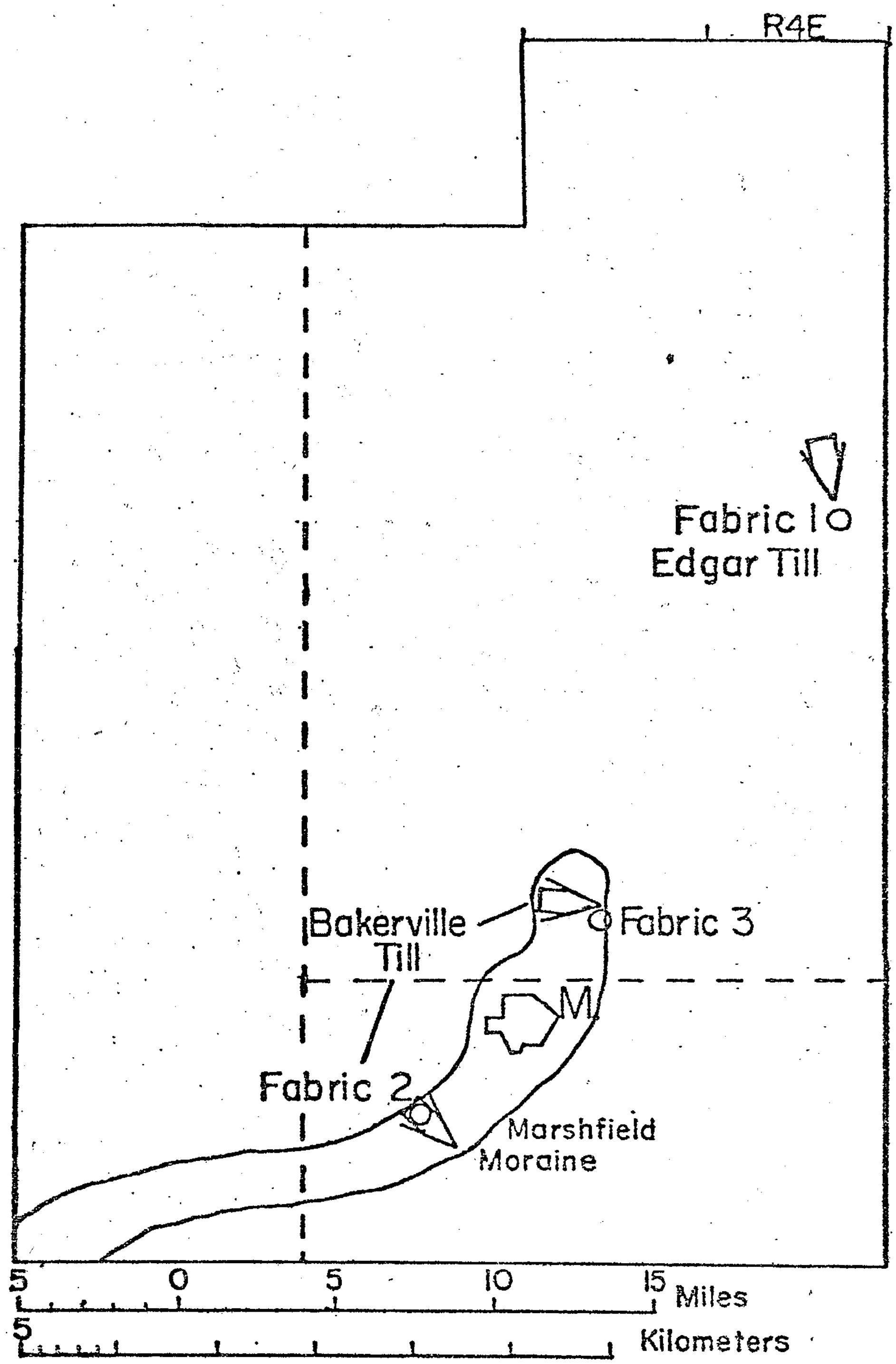


Figure 15. LOCATION OF TILL FABRICS AND THE ICE FLOW DIRECTIONS THEY INDICATE.

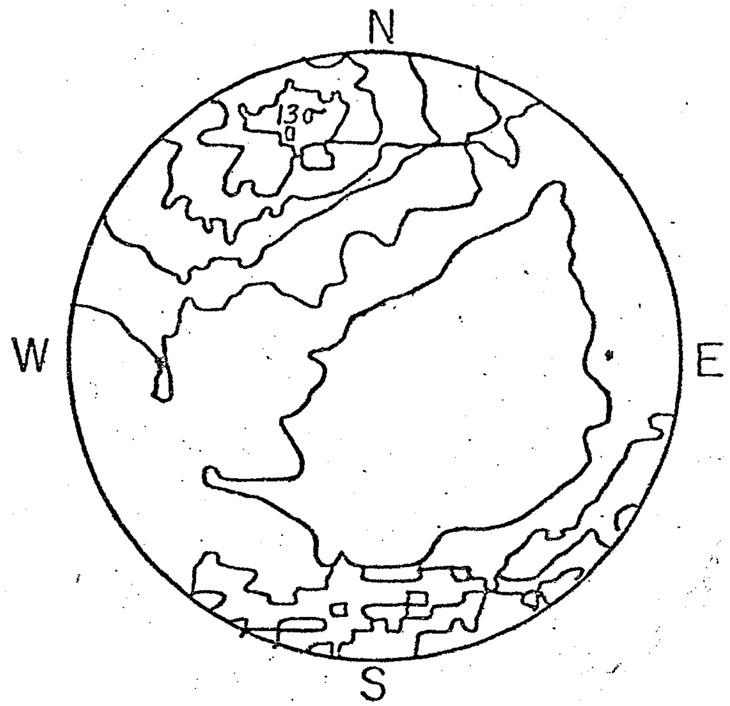


Figure 16. TILL FABRIC 1. It indicates a southward flow direction for the ice which deposited the Edgar till. Plotted are long axes of pebbles on a lower hemisphere, equal area net. The first contour is one sigma, and the contour interval is 2 sigma. Figure 18 and 19 are the same type of plot.

that supports this flow direction is the presence of Lake Superior basin rock types in the Edgar till, and all the tills, and the Power's Bluff boulder train shown in Figure 4.

The Edgar till is most often found as the surficial till in the central area of Figure 13. It is frequently found in the subsurface underlying the surficial Bakerville till to the west (drill holes 199, 252, and 254; Figure 14; Appendix A). It was found overlying the Wausau till, the black, organic sediment, and bedrock.

The Edgar till is typically quite thin, only about 5-10 feet in thickness. However, it is greatly thickened in a low ridge that runs east-southeastward from Marshfield. Hole's (1943a) map (Figure 7) shows this ridge, in which the Edgar till thickens to as much as 30 feet (drill hole 270, Appendix A; Figure 14).

Bakerville Till

The Bakerville till is defined here as a dark reddish brown, sandy loam till that caps the Marshfield moraine, and lies at the surface behind the moraine (Figures 13 and 14). All the characteristics discussed below will demonstrate that the Bakerville till is clearly distinct from the Edgar and Wausau tills. No significant difference is found between the Bakerville till and the Merrill till, but the Merrill till was defined considerably farther north. The spatial gap between the areas where the Merrill and Bakerville tills were sampled as surficial tills (Figure 13) has prohibited any correlation of the two units.

The Bakerville till is another newly named unit, and I would like to suggest a type locality for it. The type locality I suggest is my stop 199 (Figure 13; Appendix A) in a gravel pit, south of Wood County Highway B, one mile west of Bakerville. The location is SE 1/4, NW 1/4, NW 1/4, Sec. 26, T.25N., R.2E., and the property belongs to Mr. Arthur Woltmann. The photograph, Figure 17, shows the southeast wall of this pit, where about 10 feet of sand and gravel is overlain by about 25 feet of Bakerville till. Drill hole 199 (Appendix A) in the pit reveals five more feet of sandy outwash under the sand and gravel. Beneath this is thirteen feet of calcareous silt overlying seven feet of calcareous Edgar till.

The majority of Bakerville till samples collected were dark reddish brown, 5 YR 3/4 to 4/4. Colors range from as dark as 2.5 YR 4/4 to as light as 7.5 YR 7/6. Till samples with more yellow color in them were found further west, on and behind the Marshfield moraine. It is likely that this color change reflects the change in local bedrock type from granitic rocks to sandstone. The contact between the sandstone and the underlying granite runs approximately north-south along the county line between Clark County and Wood and Marathon Counties. West of this contact, very little of the Precambrian crystalline rock is exposed through the overlying Cambrian sandstone. Weathered sandstone bedrock being incorporated into the till probably imparts a lighter (less red, more yellowish) color than does weathered granitic rock in this area.

The mean sand/silt/clay composition of 15 samples of Bakerville till is 62/25/13 (Figure 11; Table 3). The ranges of these percentages are

Figure 17. PHOTOGRAPH OF THE GRAVEL PIT SUGGESTED AS THE POSSIBLE TYPE LOCALITY OF THE BAKERVILLE TILL. A gravel layer, about 10 feet thick, is being mined from beneath about 25 feet of Bakerville till. This pit is in the Marshfield moraine.

51-72/16-32/5-21. Sand content of the Bakerville till is markedly higher in Clark County (Figure 13), where it incorporated weathered sandstone bedrock instead of the crystalline rocks to the east.

An average of 62% of the lithologies/minerals in the coarse sand fraction of the Bakerville till are local rock types (Table 2). This percentage is about the same as the one for the Merrill till, and clearly different from those of the Edgar and Wausau tills. The range about the mean is from 53% to 80%. The smaller component of local rock types in the Bakerville till suggests a stratigraphic position overlying the Wausau and Edgar tills. This interpretation is supported by drill hole stratigraphy. The relatively high percentage of rounded sand grains in the Bakerville till (Table 2) must reflect the fact that this till was deposited in an area of dominantly sandstone bedrock which was incorporated into the till. The Bakerville till was seen in many exposures overlying sand and gravel, another source for the quartz sand in the till.

Mean clay mineral percentages for the Bakerville till show that it contains less illite (53%) and more smectite (25%) than the Merrill till (Table 3). The Bakerville till also has slightly less kaolinite-chlorite (8%) than the Merrill till, and slightly more vermiculite (14%) than the Merrill till. These differences are small ones, but they do form a pattern that could reflect greater weathering of the Bakerville till than of the Merrill till. These percentages clearly distinguish the Bakerville from the Wausau and Edgar tills. The ranges in the percentages of clay minerals in the Bakerville till are: illite, 32-73%; kaolinite-chlorite, 4-16%; vermiculite, 4-33%; and smectite, 9-43%.

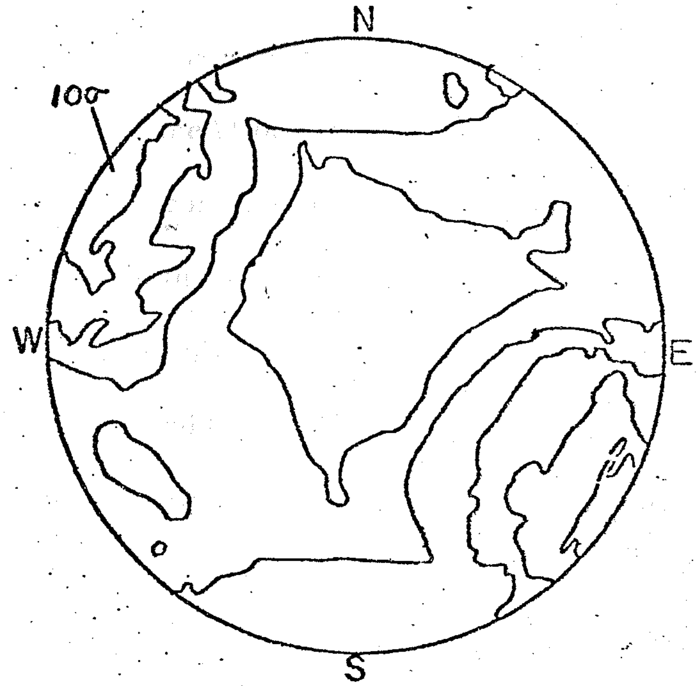
Two till fabrics were measured in the Bakerville till (Figures 18 and 19). Both were in gravel pits in the Marshfield moraine (Figure 15). These till fabrics tend to support the idea that the Marshfield moraine is the terminal moraine of the ice that deposited the Bakerville till. Both fabrics are nearly perpendicular to the trend of the morainic ridge. Though at least parts of the moraine are cored by sandstone bedrock ridges, the ridges were not deflecting the flow of the ice which deposited the Bakerville till in the two till fabric sites. Ice flow was out of the northwest and west-northwest in these two sites.

The thickness of the Bakerville till varies from nearly zero to about 100 feet (Bell and Sherrill, 1974). It is in the Marshfield moraine where this till is greatly thickened. The boundaries of this till are well-defined where the Marshfield moraine marks the former ice margin. However, where the moraine strikes to the north, in Figure 14, it is dissected by the Little Eau Pleine River and becomes impossible to trace farther north. The northern boundary with the Merrill till is somewhat in doubt. The lack of samples from that area prevents me from making any inferences about that relationship.

The Bakerville till was found directly overlying sandstone bedrock, the Edgar till, and substantial amounts of sand and gravel in different places.

Merrill Till

The Merrill till was named by LaBerge and Myers (1971) and later studied by Stewart (1973) in eastern Marathon, Lincoln, and Langlade Counties. The southern boundary of this till in Figures 9 and 10 is shown as roughly corresponding to that of Weidman's (1907) Third Drift. Stewart described the



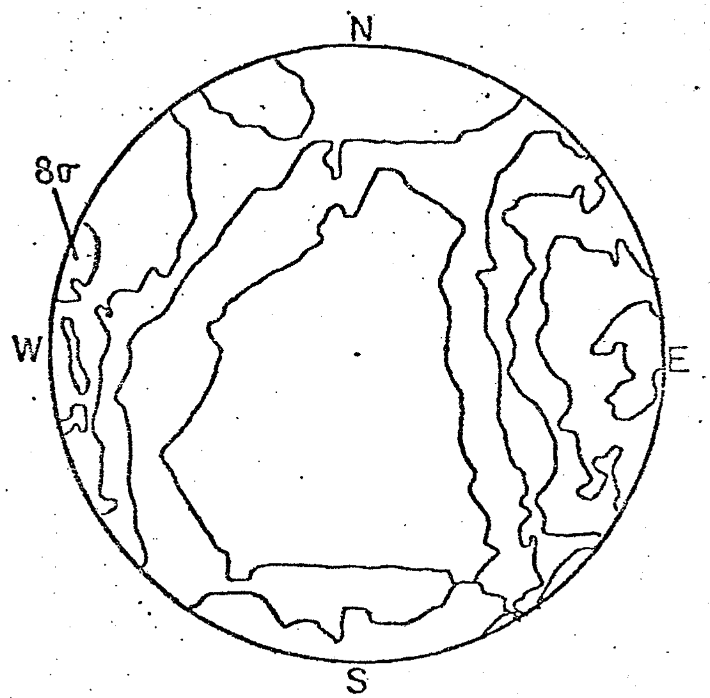


Figure 18 (top). TILL FABRIC 2. It was measured in the pit in Figure 17. The fabric indicates a southeastward ice flow direction.

Figure 19. FABRIC 3. It was also measures in the Bakerville till in the Marshfield moraine. It probably indicates an eastward ice flow direction. The westward direction that shows is probably caused by creep of the eastward facing gravel pit face where the fabric was measured.

Merrill till as being recognizable in the field by its dark reddish brown color and its mean sand/silt/clay composition of 60/30/10 (Table 1). The color is darker and more red than the Woodfordian tills to the north and the underlying Wausau till. The textural composition is sandier than that of the Wausau till, but less sandy than that of the Woodfordian tills (Table 1).

The area of the Merrill drift in the study area is considered to be the area within Weidman's Third Drift (Figure 13). Surficial till samples collected within this area proved to have colors, textures, and clay minerals that are similar to those given by Stewart for the Merrill till east of the Wisconsin River (Table 1). Hence, these samples were classified as Merrill till.

The average color of the samples of Merrill till collected is dark reddish brown, 5 YR 3/4. The colors ranged from 7.5 YR 4/4 to 2.5 YR 3/4. These colors are darker and redder than those of most samples of the other tills discussed in this thesis. Stewart (1973) stated that the majority of his Merrill till samples were dark reddish brown, 2.5 YR 3/3-4/3.

The Merrill till, a sandy loam, is sandier than the other tills in the area, except for the Bakerville till (Figure 11; Table 3). Mean textural composition of the Merrill till samples is 58/30/12. The percentages have the ranges 55-66/27-32/7-14. Along with being somewhat sandier, the Merrill till tends to contain more boulders, cobbles, and pebbles than are found in the other tills in the area. Hole (1943 a, b) viewed the decreasing coarseness of the Border Drift from north to south as a gradual facies change reflecting the incorporation of increasing amounts of older residual soils by the ice as it moved southward (Figure 6).

The percentage of local rock types in the Merrill till averages 62% (Table 2), with a range from 49% to 72%. LaBerge (1971) reported that the boulders in the rock piles in the area of the Merrill till show a lower correspondence to local bedrock outcrops than do the boulders in the area of the Wausau till. The coarse sand fraction also demonstrates this relationship. The two youngest tills, the Bakerville and Merrill, have substantially smaller local rock contents.

The mean clay mineral composition of the less than two micron fraction of the Merrill till is: 65% illite, 9% kaolinite-chlorite, 13% vermiculite, and 13% smectite (Table 3). The ranges of these percentages are: illite, 47-82%; kaolinite-chlorite, 5-16%; vermiculite, 3-28%; and smectite, 6-20%. Of the four tills discussed, the Merrill till has the highest mean percentages of vermiculite and smectite. The quantitative clay mineralogy of this till clearly distinguishes it from the other tills discussed here, except possibly for the Bakerville till, which has a somewhat similar clay mineral composition. The clay mineralogy established here for the Merrill till is similar to that defined by Stewart (1973) for the Merrill till (Table 1).

The Merrill and Bakerville tills have similar sand/silt/clay percentages (Figure 11), clay minerals (Table 3), color, and coarse sand fraction lithology (Table 2). It is possible that they are one till unit, but this was not established for several reasons. The Merrill till was never drilled in this study, and samples of the Merrill and Bakerville tills generally come from widely separated localities of the study area, with no connection between these two localities (Figure 13). Future work may demonstrate that the Merrill and Bakerville tills are correlative.

Of all four areas mapped with a different surficial till, only the Merrill till area does not have well integrated drainage. Stewart (1973) mapped a recessional moraine in the area of the city of Merrill that was built by the ice which deposited the Merrill till. Only the boundary of the Merrill till was found to have surficial stratified deposits consistently associated with it. This is not the case for any of the other till units.

Stratified Deposits

One of the goals of this study was to locate sand and gravel resources in Marathon County. The demand for this material is growing, but Marathon County is not as well endowed with these deposits as are counties in the state in which the late Woodfordian outwash was extensively deposited. Contractors go to great expense when they must transport sand and gravel a great distance.

The most recent volume of the Minerals Yearbook (United States Department of Interior, Bureau of Mines, 1973) shows that in 1970, 342 thousand short tons and in 1971, 495 thousand short tons of sand and gravel were mined from the ten active mines in Marathon County. This ranked the county about 21st out of 38 Wisconsin counties that reported data in 1971. With a population of about 97,000 in 1970, Marathon County ranks tenth of 72 counties in the state. Its rate of population increase of 9.66% between 1960 and 1970 ranks 26th of the 72 counties. (These figures are from Wisconsin Statistical Abstracts (1974)). Compared to these last two ranks, the county's relatively low rank in sand and gravel production suggests that some of this material must be imported from neighboring counties.

The sand and gravel supply problem in Marathon County is not just one of quantity, but also of distribution and quality. Much of the stratified material is of low quality because it is so sandy and clayey. Only the terraces in the Wisconsin River valley offer potential for large amounts of high quality aggregate. And this leads to the distribution problem. Marathon County is so wide, that the transportation expense involved in utilizing the Wisconsin River valley materials becomes prohibitive, and materials must be imported or lower quality aggregate substituted.

Appendix B contains locations and descriptions of sand and gravel deposits seen in the area. These localities can be located on United States Geological Survey (U.S.G.S.) topographic maps. In general, the outwash terraces in the Wisconsin River valley have the greatest potential for supplying aggregate demand. For this reason, I have mapped these terraces on U.S.G.S. topographic maps which are on open file at the Wisconsin Geological and Natural History Survey. Open file materials may be used by anyone who requests them of the Survey, and I hope these maps will be easily accessible to resource managers.

The bulk of sand and gravel produced in the county is mined from outwash terraces in the Wisconsin River valley. These terraces contain the greatest coarse aggregate (pebbles and cobbles) component of any of the sand and gravel sources in the county (for example, stop 275, Appendix B). There are two terraces that can be traced more or less continuously in the Wisconsin

River valley. At the northern boundary of Marathon County, the top of the upper terrace is at an elevation of about 1280 feet while the top of the lower terrace is about 1240 feet. Near the southern boundary of the county, the upper terrace level is about 1150 feet and at about 1130 feet is the top of the lower terrace. Knox and Johnson (1974) state that both of these Wisconsin River terraces can be traced to the Woodfordian end moraine. The lower terrace represents an adjustment by the river to reduced load that probably occurred as Woodfordian ice began to retreat. North of the study area, at Merrill, a third and higher terrace can be seen in the Wisconsin River valley. This terrace appears to have formed when the late Altonian ice, which deposited the Merrill till, stood for a time at Merrill and built two small morainal ridges there (Stewart, 1973). This terrace is not traceable downstream, where it is indistinguishable from the upper Woodfordian terrace.

Of the streams that drain the study area (Figure 2), only the Big Rib River has its headwaters at the Woodfordian end moraine to the north. The Big Eau Pleine River is separated by a drainage divide from the Woodfordian moraine. On the north side of this divide, the Black River drained the Woodfordian outwash westward. The Big Rib River valley over most of its length contains one outwash terrace, and in its lower reaches, a second, higher terrace is also present. These terraces are probably both Woodfordian. The other stream valleys in the area do not contain continuous outwash terraces, but terrace gravel and sand can be found at many places in these valleys (Appendix B). The Yellow and Little Eau Pleine Rivers head near the margin of the Bakerville till (Figure 13). Most of the outwash in these valleys was probably carried away from the ice which deposited the Bakerville till. The Big Eau Pleine and Little Rib Rivers both head near the margin of the Merrill till (Figure 13). Terrace deposits in these stream valleys were likely deposited during the deposition of the Merrill till in late Altonian time (for example, stop 70, Appendix B).

Significant amounts of pre-Woodfordian outwash were found interstratified with and underlying the Bakerville till. This outwash ranges from moderately sorted gravel to gravelly sand (for example, stop 199, Appendix B). This material is quarried largely in the Marshfield moraine, where the overlying Bakerville till can be easily removed and the outwash still lies well above the water table. There are a few places where this outwash can be located as the surficial material outside of the Marshfield moraine. Sandy deposits of it are seen in the Little Eau Pleine and Yellow River valleys (stop 225, Appendix B).

Stratified deposits were also found on the upland, well above modern stream valleys (for example, stop 289, Appendix B). There are few of these deposits, however. The greatest number of these were found near the margin of the Merrill till (Figure 13). They would be considered outwash aprons that were associated with the late Altonian ice.

The vast majority of the stratified material, outside of that of the Wisconsin River valley is mostly sand or pebbly sand. Coarser material is found in a few places, and these are generally near either the Bakerville till or Merrill till boundaries (Figure 13).

Discussion and Age of Deposits

Stewart (1973) made the case for the use of semi-quantitative clay mineralogy as a measure of the relative ages of the Merrill and Wausau tills. By showing that the vermiculite percentage of the Merrill till decreased with depth, he demonstrated that this vermiculite was being produced by weathering. He concluded that the large amounts of vermiculite and smectite in the Merrill and Wausau tills, relative to the Woodfordian tills, were produced by weathering, not by incorporation of pre-glacial soils. A similar demonstration can be made for the new tills named and discussed here. Figure 20 shows illite content of the less than two micron fraction of Bakerville till samples plotted versus depth. Weathering has reduced the amount of illite to a greater degree nearer the surface, where weathering processes are more effective.

Figure 21 is a plot of kaolinite-chlorite versus depth for the same Bakerville till samples. Kaolinite is not affected by weathering. However, chlorite is very rapidly weathered, altering to vermiculite. In Figure 21 there is little evidence for a weathering profile due to chlorite weathering. This is probably because chlorite is present in the Bakerville till (and the other three tills) only in a very small amount. Stewart (1973) stated that in the Merrill and Wausau tills about 10% of the total of kaolinite plus chlorite was chlorite.

Figure 22 is a plot of the total of vermiculite plus smectite, the clay minerals produced by weathering, versus depth in the Bakerville till samples. Clearly, in situ weathering, mainly of illite, has produced these minerals. Figures 23, 24, and 25 are plots of illite versus depth for the Wausau, Edgar,

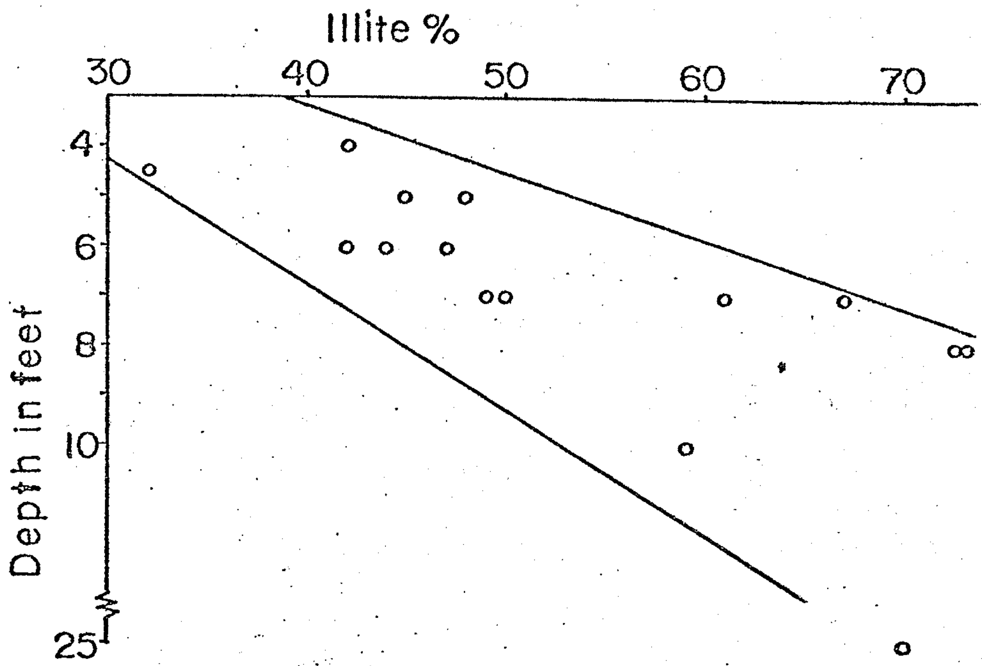


Figure 20. PLOT OF ILLITE VERSUS DEPTH IN BAKERVILLE TILL SAMPLES. It demonstrates that illite has been weathered in this till and a weathering profile has developed.

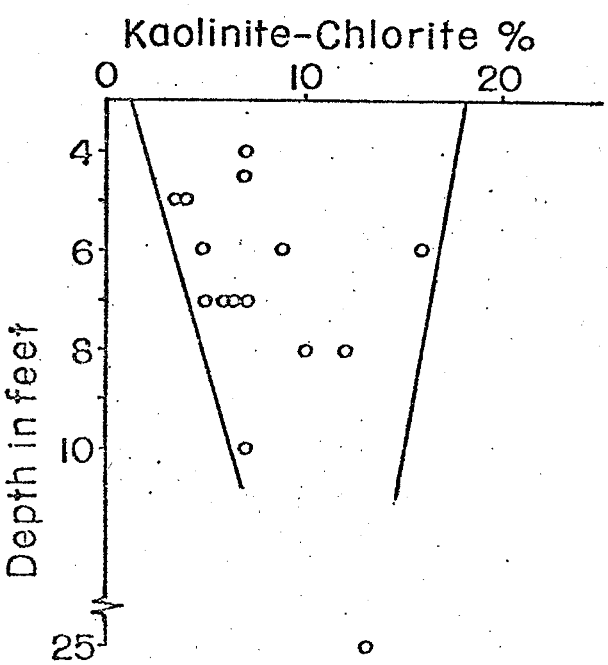


Figure 21. PLOT OF KAOLINITE-CHLORITE VERSUS DEPTH IN BAKERVILLE TILL SAMPLES. This plot shows that very little weathering of kaolinite-chlorite has occurred. Kaolinite is very stable, but chlorite weathers even more readily than illite. Thus it can be inferred that there is a very small proportion of chlorite in the kaolinite-chlorite sum, because if there were, a large amount of chlorite, this plot would look like Figure 20, a weathering profile.

and Merrill tills, respectively. These plots show that illite has been weathered in situ to some depth in these tills, also.

Figures 20 through 25 demonstrate that each of the tills has been subjected to extensive in situ weathering. This is the reason that there is so much range in clay mineralogy among samples of one till unit. Different degrees of weathering are seen in different samples as a function of depth.

The clay mineralogy of the tills can be used to give an estimate of age. Willman, et al. (1966) and Frye, et al. (1969) state that in Illinois, weathering has produced alteration of illite throughout the B-horizon in Altonian age tills. In the Sangamon Soil in Illinoian tills, this alteration of illite extends down into the leached zone of the C-horizon. Frye, et al. (1969) state that little or no alteration of illite has occurred in Woodfordian age tills of Illinois. Droste (1956) reported this same result for Woodfordian age tills in Ohio. Stewart's (1973) data (Table 1) for Late Woodfordian tills also indicates little weathering of illite. Assuming similar conditions for weathering, all four of the tills described here must be pre-Woodfordian in age, because illite has been weathered in them. It is possible that one or more of the tills is Illinoian in age. Figure 24 contains two Edgar till samples that are calcareous and yet have had illite weathered. Using the criterion cited above, weathering of illite below the leached zone indicates that the Edgar till may be of Illinoian age. The underlying Wausau till must be at least as old as Illinoian also.

Radiocarbon dates on samples collected by Hole (1943a, b), Black (1965), and Stewart (Stewart and Mickelson, 1976) help to put this till stratigraphy into a time stratigraphic framework. Infinite dates of greater than

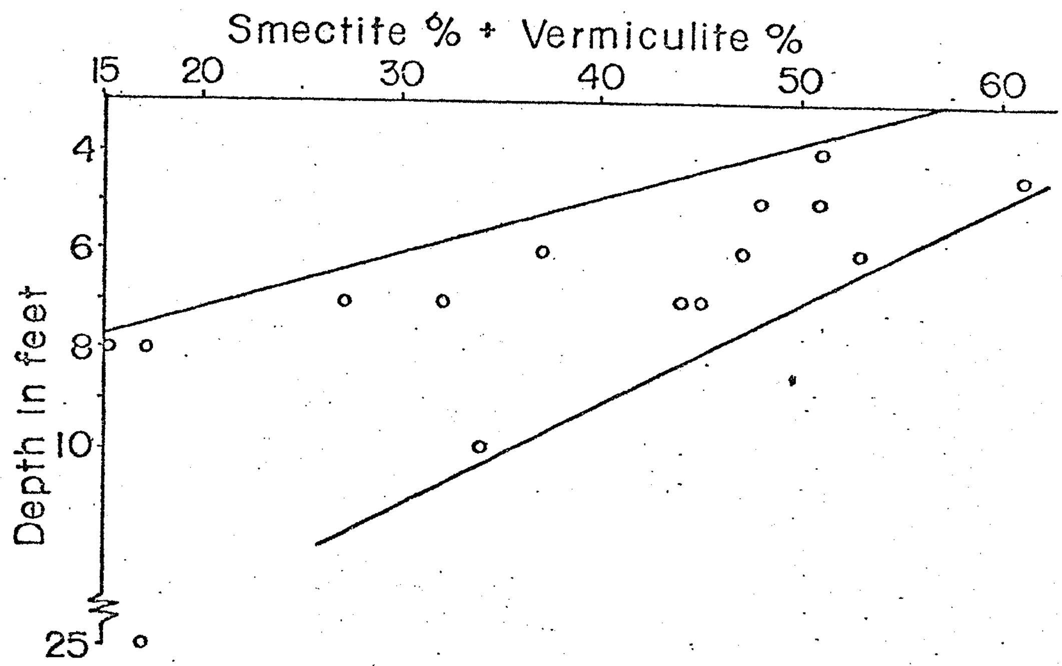


Figure 22. PLOT OF WEATHERING PRODUCT CLAY MINERALS (VERMICULITE PLUS SMECTITE) versus depth in samples of the Bakerville till. Again, a weathering profile can be seen. Illite (Figure 20) has weathered to vermiculite and smectite.

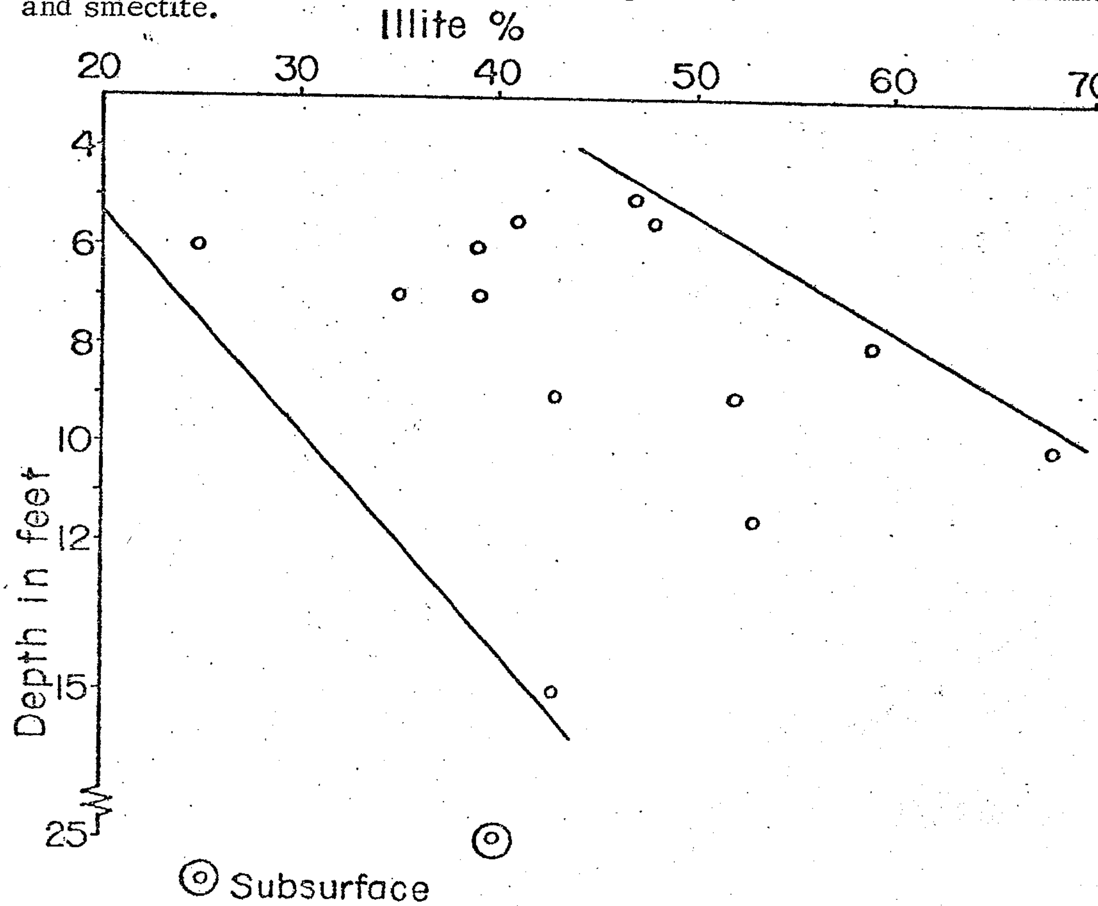


Figure 23. PLOT OF ILLITE CONTENT VERSUS DEPTH IN WAUSAU TILL SAMPLES. Illite again has been weathered, developing a weathering profile.

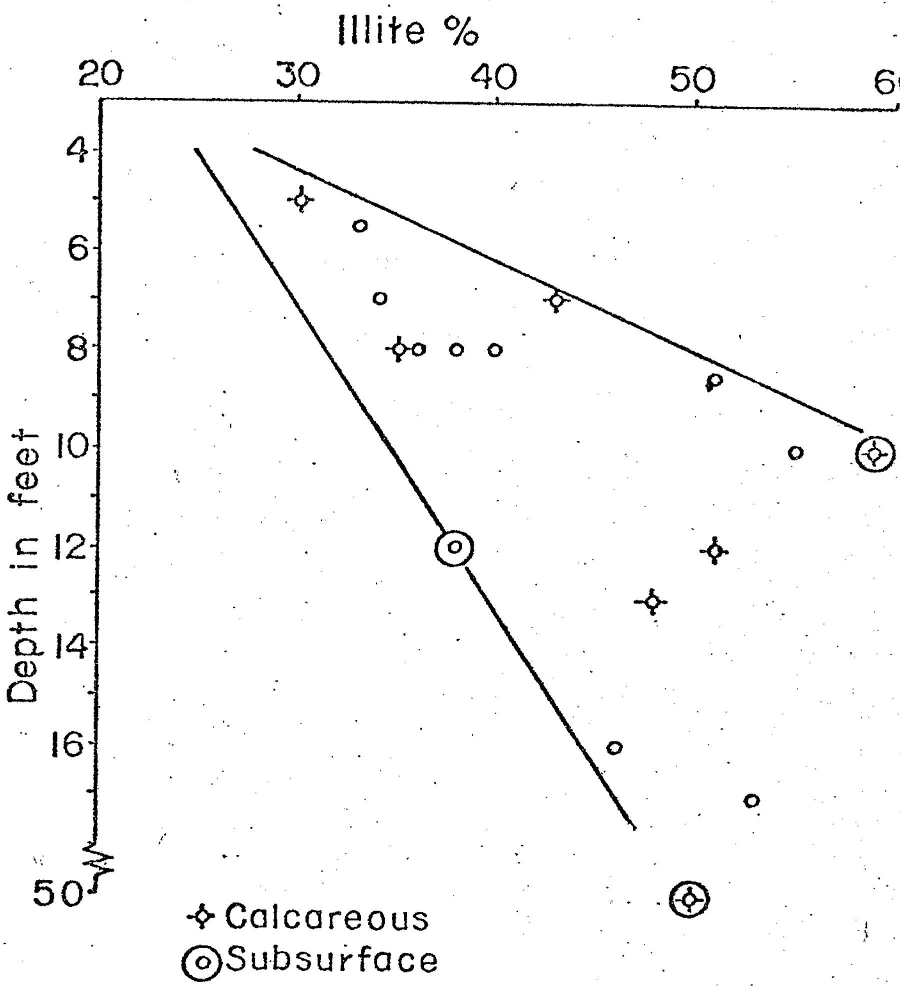


Figure 24. PLOT OF ILLITE VERSUS DEPTH IN EDGAR TILL SAMPLES. Again, a weathering profile can be be seen. Also, depth of leaching of this calcareous ranges from 5 to 17 feet.

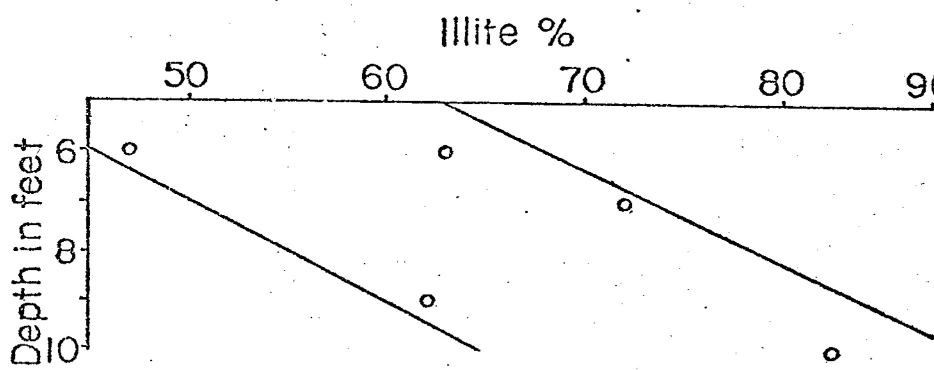


Figure 25. PLOT OF ILLITE VERSUS DEPTH IN MERRILL TILL SAMPLES. Another weathering profile can be seen.

33,000 years B.P. (W-1370) and greater than 45,000 years B.P. (Nuclear Science and Engineering Corp.) were given for samples containing disseminated organic matter in fine mud below a calcareous till (Black and Rubin, 1968). These samples were collected on the Marshfield Experimental Farm where I drilled auger hole 286 (Figure 14; Appendix A). The Edgar till is the calcareous till described by Hole (1943a, b) and Black (1965). I also found the underlying black organic sediment, which in this hole overlies a bedrock weathering residuum. However, in two other drill holes (Appendix A) where the organic sediment underlies the Edgar till, the Wausau till probably underlies the organic sediment (Figure 12). Hole (1943a, b) and Black and Rubin (1968) agreed that the overlying calcareous till was surely Wisconsin in age, though Hole thought it was likely of Cary (Late Woodfordian) age, while Black and Rubin favored a Rockian (pre-Late Woodfordian or Late Altonian) age for this till. However, these two infinite dates do not rule out the possibility that the Edgar and Wausau tills may be Illinoian in age.

Two dates, one finite and one infinite, reported by Stewart and Mickelson (1976) also aid the construction of a time stratigraphic framework. The dates are on organic rich silts and clays overlying the Merrill till in Lincoln County, Wisconsin. The dates are 40,800 years B.P. $\pm$ 2,000 (IGS-256) and greater than 36,800 years B.P. (IGS-262). The Merrill till is then greater than 40,800 years B.P. in age. Stewart (1973) concluded that the Merrill till is probably late Altonian in age, and that the underlying Wausau till may be as old as early Altonian or Illinoian.

I conclude that the Bakerville till is probably about the same age as the Merrill, late Altonian. The Edgar till is clearly older, at least early Altonian, possibly Illinoian in age. The underlying Wausau till is considered the best possibility of all the tills for an Illinoian age. The thick accumulation of organic sediment that appears to overlie it in places is reminiscent of the Sangamon accretion-gley described in Illinois (Willman and Frye, 1970).

It is not clear why Hole (1943a, b) called all these tills the same single drift. Probably, because he had no power drilling apparatus, he never saw more than one stratigraphic unit in one place. He probably never saw such a graphic demonstration of glacial stratigraphy as I saw at stop 199, described previously as a possible type locality for the Bakerville till (Figure 17). Weidman (1907) used well logs as one basis for multiple tills, and it is unclear why Hole (1943a, b) did not do the same.

Regarding the question of age, Hole (1943a, b) based his conclusion of Wisconsin age mainly from depth of leaching measurements where the till was calcareous. He gave an average depth of leaching for 32 sites of five feet, which is comparable to other such measurements in Wisconsin age drift. An Altonian (Early Wisconsin) age for the Edgar till would be likely for the depth of leaching and clay mineralogy that characterize it.

CONCLUSIONS

1. The four tills discussed, the Wausau, Edgar, Bakerville, and Merrill, are distinguishable lithologically and in their areal distribution. This conclusion is similar to Weidman's (1907) conclusion about the extra-morainic drift in north central Wisconsin.

2. Because the Merrill till is definitely pre-Woodfordian (Stewart, 1973), all four of these tills are at least as old as Altonian.

3. Intense weathering of the clay mineral illite in the Wausau and Edgar tills suggests that one or both of these tills is possibly as old as Illinoian. The Wausau till is more likely Illinoian in age. This is suggested by the presence of thick organic sediment underlying the Edgar till and apparently overlying the Wausau till. It is possible that this material is correlative to the Sangamon accretion gley described in Illinois (Frye, et al., 1966) and other places in the upper Midwest.

4. Stratified deposits are largely sandy outside of the Wisconsin River valley, and the best possibility for coarser deposits is along the margins of the Bakerville and Merrill tills. Except for those in the Big Rib River and Wisconsin River valleys, these terraces are pre-Woodfordian in age. The two Late Woodfordian terraces in the Wisconsin River valley contain

adequate coarse aggregate, and these terraces are fairly continuous in Marathon County. These have been mapped and the maps are on open file at the Wisconsin Geological and Natural History Survey.

REFERENCES CITED

Akers, R. H., 1961, Clay minerals of glacial deposits of west-central Wisconsin: unpub. M.S. thesis, University of Wisconsin, Madison, 82 p.

Antevs, Ernst, 1929, Maps of the Pleistocene glaciations: Geol. Soc. Amer. Bull., v. 40, p. 631-720.

Bell, E.A., and Sherill, M. G., 1974, Water availability in central Wisconsin--An area of near-surface crystalline rock: U. S. Geol. Surv., Water Supply Paper No. 2022, 32 p.

Black, R. F., 1959a, Glacial geology of west-central Wisconsin: mimeographed, 10th Annual Field Conf., Midwest Friends of the Pleistocene, 11 p.

__________________, 1959b, Friends of the Pleistocene: Science, v. 130, p. 172-173.

__________________, 1962, Pleistocene chronology of Wisconsin (abs.): Geol. Soc. Amer. Spec. Paper 68, p. 137.

__________________, Hole, F. D., Maher, L. J., and Freeman, J. E., 1965, The Wisconsin Quaternary, in, Guidebook for Field Conference C, Upper Mississippi valley: INQUA, 7th Congress, p. 56-81.

__________________, and Rubin, Meyer, 1968, Radiocarbon dates of Wisconsin: Wis. Acad. Science, Arts, and Letters, v. 56, p. 99-115.

Chamberlin, Rollin T., 1910, Older drifts in the St. Croix region: Jour. Geol., v. 18, p. 542-548.

Chamberlin, T. C., 1882, Superficial geology of the upper Wisconsin valley, in, Geology of Wisconsin, v. 4, part 8, p. 717-723.

__________________, 1883, Geology of Wisconsin, v. 1, p. 261-298.

__________________, and Salisbury, R. D., 1885, Preliminary paper on the Driftless Area of the upper Mississippi valley: U.S.G.S. 6th Ann. Rept., p. 199-322.

Darby, D. A., 1971, Carbonate cycles and clay mineralogy in Arctic Ocean cores: Ph.D. thesis, University of Wisconsin--Madison.

Droste, J. B., 1956, Alteration of clay minerals by weathering in Wisconsin tills: Geol. Soc. Amer. Bull., v. 67, p. 911-918.

Frye, J. C., Glass, H. D., Kempton, J. P., and Willman, H. B., 1969, Glacial tills of northwestern Illinois: Ill. State Geol. Surv., Circ. 437, 45 p.

__________________, Willman, H. B., and Black, R. F., 1965, Outline of Glacial geology of Illinois and Wisconsin, in The Quaternary of the United States, Wright and Frey, eds., Princeton University Press, p. 43-61.

Gibbs, R. J., 1965, Error due to segregation in quantitative clay mineral X-ray diffraction mounting techniques: Amer. Mineralogist, v. 50, p. 741-751.

Hole, F. D., 1943a, Correlation of the glacial border drifts of north central Wisconsin: unpub. Ph. D. thesis, University of Wisconsin, Madison, 137 p.

__________________, 1943b, Correlation of the glacial border drifts of north central Wisconsin: Amer. Jour. Sci., v. 241, p. 498-516.

Kellogg, C. E., 1930, Preliminary study of the profiles of the principal soil types of Wisconsin: Wis. Geol. & Nat. Hist. Surv., Bull. 77-A, Soil Series 54.

Knox, J. C., and Johnson, W., 1974, Late Quaternary valley alluviation in the Driftless Area of southwest Wisconsin, in, Late Quaternary Environments of Wisconsin, Knox, J. C., and Mickelson, D. M., eds.: AMQUA Third Biennial Mtg., p. 134-162.

LaBerge, G. L., and Myers, P. E., 1971, Progress report on mapping of Precambrian geology of Marathon County: University of Wisconsin-Extension, Wis. Geol. & Nat. Hist. Surv., open file report.

Leverett, Frank, 1899, The Illinois glacial lobe: U.S.G.S. Mon. 38, 817 p.

__________________, 1913, Iowan drift (abs.): Geol. Soc. Amer. Bull., v. 24, p. 697-698.

__________________, 1929, Moraines and shore lines of the Lake Superior region: U.S.G.S. Prof. Paper 154-A. 72 p.

__________________, 1932, Quaternary geology of Minnesota and parts of adjacent states: U.S.G.S. Prof. Paper 161, 149 p.

__________________, and Taylor, F. B., 1915, The Pleistocene of Indiana and Michigan and the history of the Great Lakes: U.S.G.S. Mon. 53, 529 p.

Martin, Lawrence, 1932, The physical geography of Wisconsin: Wis. Geol. & Nat. Hist. Surv. Bull. 36, 608 p.

Mathiesen, John T., 1938, The Pleistocene of part of northwestern Wisconsin: unpub. B.A. & M.A. thesis, University of Wisconsin, Madison, 83 p.

__________________, 1940, The Pleistocene of part of northwestern Wisconsin: Wis. Acad. Science, Arts, & Letters, v. 32, p. 251-272.

Mickelson, D. M., 1971, Glacial geology of the Burroughs Glacier area, southern Alaska: Ohio State Univ., Inst. of Polar Studies, Rept. no. 40, 149 p.

Olup, Bernard J., Jr., 1969, Petrology of glacial drift in northern Marathon County, Wisconsin: unpub. M.S. thesis, University of Wisconsin, Milwaukee, 70 p.

Royse, C. F., Jr., 1970, An introduction to sediment analysis: Tempe, Arizona State Univ., 180 p.

Ruhe, R. V., and Gould, L. M., 1954, Glacial geology of the Dakota County area, Minnesota: Geol. Soc. Amer. Bull., v. 65, p. 769-792.

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

__________________, and Mickelson, D. M., 1976, Clay mineralogy and relative age of tills in north-central Wisconsin: Jour. Sed. Pet., v. 46, no. 1, p. 200-205.

Thwaites, F. T., 1926, The origin and significance of pitted outwash: Jour. Geol., v. 34, p. 308-319.

__________________, 1927, The development of the theory of multiple glaciation in North America: Wis. Acad. Sci., Arts, & Letters, v. 23, p. 41-164.

__________________, 1943, Pleistocene of part of northeastern Wisconsin: Geol. Soc. Amer. Bull., v. 54, p. 87-144.

__________________, 1955, Outline of glacial geology: Edwards Bros., Inc., Ann Arbor, Michigan, 135 p.

United States Dept. of Interior, Bureau of Mines, 1971 Minerals Yearbook, v. 2, 1973: U. S. Govt. Printing Office, p. 783-793.

Weidman, Samuel, 1903, Preliminary report on the soils and agricultural conditions of north central Wisconsin: Wis. Geol. & Nat. Hist. Surv., Bull. 11.

__________________, 1907, The geology of north central Wisconsin: Wis. Geol. & Nat. Hist. Surv., Bull. 16, 697 p.

__________________, 1911, Reconnaissance soil survey of part of north central Wisconsin: Wis. Geol. & Nat. Hist. Surv., Bull. 24.

__________________, 1913, Pleistocene succession in Wisconsin: Geol. Soc. Amer. Bull., v. 24, p. 697-698.

__________________, Hall, E. B., and Musback, F. L., 1911, Reconnaissance soil survey of part of northwestern Wisconsin: Wis. Geol. & Nat. Hist. Surv., Bull. 23, 102 p.

Whitson, A. R., 1927, Soils of Wisconsin: Wis. Geol. & Nat. Hist. Surv., Bull. 68, Soil Series 49.

Whitson, A. R., et al., Reconnaissance soil survey of north part of north central Wisconsin: Wis. Geol. & Nat. Hist. Surv., Bull. 50, Soil Series 15.

__________________, 1917, Soil survey of Buffalo County, Wisconsin: Wis. Geol. & Nat. Hist. Surv., Bull. 54-A, 76 p.

__________________, 1918, Reconnaissance soil survey of south part of north central Wisconsin: Wis. Geol. & Nat. Hist. Surv., Bull. 52-A, Soil Series 16.

__________________, 1918, Soil Survey of Portage County, Wisconsin: Wis. Geol. & Nat. Hist. Surv., Bull. 52-C, Soil Series 18.

__________________, 1918, Soil survey of Wood County, Wisconsin: Wis. Geol. & Nat. Hist. Surv., Bull. 52-B, Soil Series 17.

__________________, 1923, Soil survey of Jackson County, Wisconsin: Wis. Geol. & Nat. Hist. Surv., Bull. 54-B, 85 p.

Willman, H. B., and Frye, J. C., 1970, Pleistocene stratigraphy of Illinois: Ill. State Geol. Surv., Bull. 94, 204 p.

Willman, H. B., Glass, H. D., and Frye, J. C., 1966, Mineralogy of glacial tills and their weathering profiles in Illinois: Ill. State Geol. Surv., Circ. 400, 76 p.

Wisconsin Department of Administration, 1974, Wisconsin Statistical Abstracts: Madison, 215 p.

APPENDIX A

Auger Hole Logs

Stop 199; SE 1/4, NW 1/4, NW 1/4, Sec. 26, T.25N., R.2E., Wood County; in gravel pit with 35 feet of Bakerville till and sand and gravel exposed in pit face above the hole.

0-5'	red sand
5-18'	reddish brown (5 YR 4/4) silt, calcareous
18-25'	reddish brown (5 YR 4/4) pebbly, silty loam till, calcareous (Wd 86, Edgar till)
25'	sandstone (?) bedrock refusal

Stop 241; SE 1/4, NE 1/4, NE 1/4, Sec. 32, T.26N., R.4E., Marathon County

0-8'	road fill into bedrock weathering residuum, varicolored to green

Stop 243; SW 1/4, NW 1/4, SW 1/4, Sec. 3, T.25N., R.4E., Wood County

0-13'	greasy, shiny, black-brown bedrock weathering residuum (like graphite)

Stop 244; SE 1/4, SW 1/4, SE 1/4, Sec. 20, T.26N., R.4E., Marathon County

0-8'	muscovite-rich, yellow, greasy bedrock weathering residuum

Stop 245; SE 1/4, SE 1/4, NE 1/4, Sec. 11, T.26N., R.4E., Marathon County

0-17'	Granite bedrock weathering residuum, yellowish brown

Stop 246; NE 1/4, NW 1/4, NW 1/4, Sec. 2, T.26N., R.3E., Marathon County

0-18'	brown (7.5 YR 4/4) loam till (Mr 92, Wausau till)
18-20'	yellow, sandy rotten granite
20'	granite bedrock refusal

Stop 247; SE 1/4, SE 1/4, SW 1/4, Sec. 12, T.27N., R.2E., Marathon County

0-23'	granite bedrock weathering residuum, sandy at bottom

Stop 248; SE 1/4, SE 1/4, SW 1/4, Sec. 15, T.27N., R.2E., Marathon County

0-10' reddish brown (5 YR 4/4), loam till, noncalcareous (Mr 97, Edgar till)
10-16' brown (7.5 YR 4/4), loam till, calcareous (Mr 98, Edgar till)
16-26' sandy outwash, noncalcareous
26-28' yellowish brown (10 YR 5/3), granite bedrock weathering residuum

Stop 249; NW 1/4, SW 1/4, NW 1/4, Sec. 24, T.26N., R.2E., Marathon County

0-6' fill and lake clays, blues and grays, reduced colors
6-8' grayish olive (5 YR 4/2), loam till (Mr 101, Wausau till)

Stop 250; NE 1/4, SE 1/4, NE 1/4, Sec. 27, T.26N., R.1E., Clark County

0-5' sandy loam till (Bakerville till)
5' sandstone bedrock refusal

Stop 251; SW 1/4, SW 1/4, SE 1/4, Sec. 30, T.26N., R.2E., Marathon County

0-6' till (?)
6' sandstone bedrock refusal

Stop 252; SW 1/4, NW 1/4, SE 1/4, Sec. 8, T.25N., R.2E., Wood County

0-6' reddish brown, sandy loam till (Bakerville till)
6-13' brown (7.5 YR), loam till (Wd 103, Edgar till, leached)
13-21' sand and gravel
21-23' yellowish brown (10 YR 5/4), loam till (Wd 104, Wausau till)

Stop 254; SE 1/4, SW 1/4, SE 1/4, Sec. 21, T.26N., R.3E., Marathon County

0-7' reddish brown, sandy loam till (Bakerville till)
7-8' sandy outwash
8-10' reddish brown, loam till (Edgar till, leached)
10-13' reddish brown (5 YR 4/4), loam till, calcareous (Mr 105, Edgar till)

Stop 270; SW 1/4, SW 1/4, NW 1/4, Sec. 35, T.25N., R.5E., Wood County

0-3' sandy outwash
3-5' greasy, bright red soapstone

Stop 271; SW 1/4, NW 1/4, SW 1/4, Sec. 27, T.25 N., R.5E., Wood County
0-6' brown (7.5 YR 4/6), loam till, noncalcareous (Edgar till, leached)
6-30' brown (7.5 YR 5/6), loam till, calcareous (Wd 112, Edgar till)
30-35' grayish blue, loam till (?)

Stop 286; NE 1/4, SE 1/4, NW 1/4, Sec. 22, T.25N., R.3E., Wood County
0-18' brown, loamy till, calcareous (Edgar till)
18-25' olive black (5 YR 3/1), organic clay (Wd 120 & 121)
25-30' olive black, granite bedrock weathering residuum

Stop 287; NW 1/4, NE 1/4, NW 1/4, Sec. 24, T.28N., R.4E., Marathon County
0-18' brown (10 YR 4/6), loam till, calcareous (Mr 123, Edgar till)
18-32' brownish black (10 YR 2/2), loam till (?), noncalcareous (Mr 124-131, Wausau till?)

APPENDIX B
SAND AND GRAVEL FIELD NOTES

Stops 3 & 50; SW 1/4, SE 1/4, SE 1/4, Sec. 13, T.29N., R.6E., Marathon County.

Stratified sand, with gravelly channels, 3' in depth, cut and filled in them; predominantly quartz, with 5% dark minerals, 10% reddish grains (orthoclase?); medium grained sand.

Stop 9; SW 1/4, SW 1/4, Sec. 20, T.28N., R.3E., Marathon County.

Massive sand, poorly sorted, with about 25% pebbles, 5% cobbles, and less than 5% boulders; 5-10' face has been worked in this gravel pit (now a sanitary landfill).

Stop 10; NE 1/4, NW 1/4, NE 1/4, Sec. 23, T.28N., R.3E., Marathon County.

Massive sand, poorly sorted, reddish brown.

Stop 12; NW 1/4, SE 1/4, SE 1/4, Sec. 14, T.28N., R.1E., Clark County.

Stratified sand and gravel in 20' face of gravel pit; about 50% of beds are moderately sorted sand, other beds are pebbles, cobbles, and boulders (less than 10%); northwest side of pit is massive thick beds of gravel with some sand; cross beds dip southeastward.

Stop 13; SW 1/4, NW 1/4, SW 1/4, Sec. 16, T.28N., R.1E., Clark County.

Stratified, slightly gravelly sand; numerous medium scale cross beds dipping south, east, and southeast.

Stop 14; SE 1/4, NE 1/4, NE 1/4, Sec. 17, T.28N., R.1E., Clark County.

Stratified gravelly sand, cross bedded, medium scale, cross beds dip south-southeast; 2-4' of massive cobbly, sandy gravel overlying the sand.

Stop 16; NW 1/4, SE 1/4, NE 1/4, Sec. 32, T.30N., R.7E., Marathon County.

Nearly massive, very poorly sorted sand, with gravel, cobbles, and boulders, reddish brown.

Stop 24; SW 1/4, SW 1/4, SW 1/4, Sec. 22, T.29N., R.5E., Marathon County.

Stratified sand, well sorted, medium scale cross beds.

Stop 30; SW 1/4, NW 1/4, NW 1/4, Sec. 10, T.29N., R.4E., Marathon County.

Stratified sand with some minor gravel beds, large scale cross beds dip south.

Stop 32; NE 1/4, NE 1/4, NW 1/4, Sec. 25, T.31N., R.3E., Taylor County.
Stratified sand and minor gravel, poorly sorted.

Stop 34; SW 1/4, NW 1/4, SW 1/4, Sec. 2, T.28N., R.6E., Marathon County.
Stratified sand and gravel in small roadside borrow.

Stop 36; NW 1/4, SW 1/4, NW 1/4, Sec. 6, T.28N., R.6E., Marathon County.
Stratified sand and gravel interbeds, about 50% gravel beds with 5% cobbles in the gravel.

Stop 37; SE 1/4, NE 1/4, NW 1/4, Sec. 1, T.28N., R.5E., Marathon County.
Stratified sand and gravel interbeds, medium scale cross beds dip east.

Stop 38; SE 1/4, SE 1/4, SW 1/4, Sec. 36, T.29N., R.5E., Marathon County.
Stratified sand and gravel, being actively worked.

Stop 70; SE 1/4, SE 1/4, SW 1/4, Sec. 11, T.29N., R.4E., Marathon County.
Stratified sand, especially in east side of pit, and gravel, large scale cross beds dipping north and east.

Stop 79; NE 1/4, NE 1/4, NE 1/4, Sec. 32, T.26N., R.7E., Marathon County.
Stratified sand and gravel, finer sand at top to bouldery gravel 20' below, predominantly gravel with about 25% sand and sand beds.

Stop 84; NE 1/4, NW 1/4, NW 1/4, Sec. 36, T.29N., R.5E., Marathon County.
Interstratified sand and gravel, about 40% of beds are sand, 50% slightly sandy gravel, and 10% cobbly gravel.

Stop 86; NE 1/4, NE 1/4, NE 1/4, Sec. 34, T.29N., R.5E., Marathon County.
Stratified gravel and sand, gravel beds are mostly pebbles, with less than 5% cobbles and less than 50% sand.

Stop 132; SE 1/4, SW 1/4, NW 1/4, Sec. 28, T.29N., R.7E., Marathon County.
Sand and gravel in roadcut.

Stop 134; W 1/2, SE 1/4, NW 1/4, Sec. 29, T.20N., R.7E., Marathon County.
Gravelly sand at 2 exposures along the road.

Stop 228; NW 1/4, SW 1/4, SW 1/4, Sec. 7, T.25 N., R.4E., Wood County.

Stratified sand and minor gravelly sand, west wall of pit cuts across the channel in which these were deposited and exposes many cross beds dipping east.

Stop 230; SW 1/4, SW 1/4, NW 1/4, Sec. 2, T.26 N., R.3E., Wood County.

Stratified sand, moderately well sorted, new sand pit.

Stop 233; NW 1/4, NE 1/4, SE 1/4, Sec. 23, T.25 N., R.2E., Wood County.

Sand, poorly exposed, deep red color.

Stop 253; NE 1/4, SW 1/4, NE 1/4, Sec. 33, T.26 N., R.3E., Marathon County.

Gravelly sand underlying Bakerville till, nearly 50% gravel, at least 14' exposed in pit face, decreases in grain size with depth.

Stop 257; NW 1/4, SE 1/4, SE 1/4, Sec. 32, T.26 N., R.3E., Marathon County.

Sand and gravel, about 30% medium and coarse gravel with 5% cobbles.

Stop 267; SW 1/4, NE 1/4, NW 1/4, Sec. 34, T.27 N., R.2E., Marathon County.

Cobbly, poorly bedded gravel overlying convoluted, faulted, stratified sand; overlying material as thick as 20' to absent in 30' pit faces.

Stop 273; NW 1/4, SE 1/4, SE 1/4, Sec. 24, T.30 N., R.4E., Marathon County.

Cobbly, sandy gravel, cross bedded with upper part trough cross bedded (3' wide and 1' deep troughs) and lower part tabular cross beds; 40% gravel and coarser.

Stop 275; NW 1/4, NW 1/4, NW 1/4, Sec. 33, T.31 N., R.7E., Lincoln County.

Stratified gravel and sand with about 50% gravel and small cobbles; grain supported, plane parallel, cobbly material with cobbles imbricated dipping north; up to 20' of this exposed in active faces of pit; some minor sand in places below gravel that is tabular cross bedded, 1-2' thick beds.

Stop 279; NW 1/4, SE 1/4, SW 1/4, Sec. 26, T.29 N., R.3E., Marathon County.

Sand and gravel in old, overgrown pits, very poor exposure.

Stop 289; NW 1/4, SW 1/4, NW 1/4, Sec. 33, T.30 N., R.7E., Marathon County.

Sand and gravel, upper gravel somewhat sandy with cross beds dipping northeast.

APPENDIX C

Sample Locations and Data

Till	Sample No.	Location (1/4, 1/4, 1/4)	Depth (ft.)	Color
Wausau	Mr47	NE, NW, NE, Sec. 11, T.28 N., R.4 E.	5 1/2	7.5 YR 4/6
	Mr48	SW, SW, SW, Sec. 24, T.28 N., R.4 E.	5 1/2	7.5 YR 4/4
	Mr50	NW, NW, NW, Sec. 25, T.28 N., R.4 E.	5	10 YR 4/2
	Mr54	NE, SW, NE, Sec. 35, T.27 N., R.3 E.	11 1/2	7.5 YR 4/4
	Mr55	NW, NE, NE, Sec. 10, T.26 N., R.3 E.	9	7.5 YR 4/4
	Mr58	SW, SE, SW, Sec. 10, T.27 N., R.1 E.	5	5 YR 4/4
	Mr66	SW, SW, SW, Sec. 8, T.30 N., R.5 E.	8	5 YR 4/4
	Ck74	SW, NW, NW, Sec. 9, T.24 N., R.1 E.	10	5 YR 4/4
	Wd79	SW, NW, NW, Sec. 19, T.25 N., R.3 E.	6	7.5 YR 5/4
	Wd80	NW, NW, SW, Sec. 18, T.25 N., R.3 E.	7	7.5 YR 4/4
	Wd82	SW, NE, SE, Sec. 11, T.25 N., R.2 E.	7	7.5 YR 4/4
	Wd92	NE, NW, NW, Sec. 2, T.26 N., R.3 E.	15	7.5 YR 4/4
	Wd101	NW, SW, NW, Sec. 24, T.26 N., R.2 E.	6	7.5 YR 4/4
	Wd104	SW, NW, SE, Sec. 8, T.26 N., R.1 E.	23	10 YR 5/4
	Wd118	NE, NE, NE, Sec. 1, T.28 N., R.3 E.	9	5 YR 4/4
Edgar	Mr24	SE, NE, NW, Sec. 24, T.28 N., R.4 E.	5	7.5 YR 6/4
	Mr45	SW, SE, SE, Sec. 35, T.29 N., R.4 E.	5 1/2	7.5 YR 4/4
	Mr52	SW, SW, SW, Sec. 24, T.28 N., R.4 E.	16	7.5 YR 5/6
	Mr53	NE, SE, NW, Sec. 4, T.27 N., R.4 E.	17	7.5 YR 4/4
	Wd77	NW, NE, NE, Sec. 15, T.25 N., R.3 E.	8	5 YR 4/4
	Wd81	SW, SW, NE, Sec. 23, T.25 N., R.2 E.	8	10 YR 6/4
	Wd86	SE, NW, NW, Sec. 26, T.25 N., R.2 E.	50	5 YR 4/4
	Mr97	SE, SE, SW, Sec. 15, T.27 N., R.2 E.	8	5 YR 4/4
	Mr98	SE, SE, SW, Sec. 15, T.27 N., R.2 E.	13	7.5 YR 4/4
	Wd103	SW, NW, SE, Sec. 8, T.26 N., R.1 E.	12	7.5 YR 4/4
	Mr105	SW, SW, SE, Sec. 21, T.26 N., R.3 E.	10	5 YR 4/4
	Wd110	SW, SE, SW, Sec. 24, T.25 N., R.4 E.	7	10 YR 4/6
	Wd111	NW, SW, SE, Sec. 13, T.25 N., R.4 E.	10	10 YR 4/6
	Wd112	SW, NW, SW, Sec. 27, T.25 N., R.5 E.	8	10 YR 5/6
	Mr113	SE, NE, NE, Sec. 1, T.29 N., R.4 E.	8 1/2	7.5 YR 5/4
	Mr119	SW, SE, SE, Sec. 8, T.26 N., R.2 E.	7	7.5 YR 4/6
	Mr123	NW, NE, NW, Sec. 24, T.28 N., R.4 E.	12	10 YR 4/6
Bakerville	Wd61	SE, NW, NW, Sec. 26, T.25 N., R.2 E.	4	5 YR 3/4
	Wd62	SE, NW, NW, Sec. 26, T.25 N., R.2 E.	10	2.5 YR 4/4
	Wd63	SE, NW, NW, Sec. 26, T.25 N., R.2 E.	25	5 YR 3/4
	Ck68	SE, NE, NE, Sec. 1, T.24 N., R.1 W.	8	7.5 YR 7/6
	Ck69	SE, SE, NE, Sec. 1, T.24 N., R.1 W.	6	5 YR 4/4
	Ck70	NE, NW, NE, Sec. 11, T.24 N., R.1 W.	7	5 YR 3/4
	Ck72	SE, SE, SE, Sec. 35, T.25 N., R.1 W.	8	5 YR 4/4
	Ck73	NE, NE, SE, Sec. 36, T.25 N., R.1 W.	7	7.5 YR 4/6
	Ck75	SE, NE, SE, Sec. 2, T.24 N., R.1 E.	4 1/2	7.5 YR 4/4
	Wd76	SW, SE, SE, Sec. 23, T.25 N., R.2 E.	5	5 YR 4/4
	Wd83	NE, NW, NE, Sec. 32, T.26 N., R.3 E.	7	5 YR 4/6
	Wd84	SE, NE, NE, Sec. 34, T.25 N., R.2 E.	6	7.5 YR 5/6
	Mr106	NE, SW, NE, Sec. 33, T.26 N., R.3 E.	7	2.5 YR 4/6
	Mr107	SE, SE, SW, Sec. 32, T.26 N., R.3 E.	6	5 YR 4/4
	Mr109	NE, SW, SW, Sec. 32, T.26 N., R.3 E.	5	5 YR 4/6

Till	Sample No.	Location (1/4, 1/4, 1/4)	Depth (ft.)	Color
Merrill	Mr57	NW, SW, NE, Sec. 9, T.30 N., R.7 E.	10	5 YR 3/4
	Mr64A	SW, SE, SW, Sec. 29, T.30 N., R.6 E.	6	2.5 YR 3/4
	Mr65	SE, SE, SW, Sec. 27, T.30 N., R.5 E.	6	7.5 YR 4/4
	Mr67	SE, SE, SW, Sec. 11, T.30 N., R.6 E.	7	5 YR 3/4
	Mr115	NW, NE, NW, Sec. 33, T.30 N., R.4 E.	8 1/2	5 YR 3/5

Till	Sample No.	Stop No.	Sand %	Silt %	Clay %	% Local Types in Coarse Sand	Illite %	Kao-Ch. %	Verm. %	Smec. %
Wausau	Mr47	181	46	34	20	75	48	8	17	27
	Mr48	184	43	38	18	67	41	9	10	40
	Mr50	185	42	27	32	72	20	7	20	54
	Mr54	189	40	37	24	69	53	5	16	26
	Mr55	191	47	31	23	66	52	3	15	29
	Mr58	197	43	27	29	72	47	5	19	28
	Mr66	205	41	36	23	68	59	3	12	26
	Ck74	218	42	30	28	62	68	4	6	21
	Wd79	231	46	33	21	78	39	4	26	31
	Wd80	232	45	34	21	73	35	6	13	46
	Wd82	236	42	31	27	80	49	7	33	11
	Wd92	246	46	34	20	71	43	6	19	33
	Wd101	249	47	37	16	79	25	3	25	36
	Wd104	252	39	31	30	79	40	3	24	33
	Mr118	278	43	39	18	69	43	5	18	34
Edgar	Mr24	29	37	52	11	68	30	5	15	49
	Mr45	180	31	38	30	87	33	5	27	35
	Mr52	186	38	48	14	65	46	3	23	28
	Mr53	188	35	41	24	78	53	2	17	29
	Wd77	227	34	39	27	52	30	8	22	30
	Wd81	234	34	41	25	77	38	4	17	41
	Wd86	199	30	46	24	56	50	10	15	24
	Mr97	248	41	37	22	72	36	5	15	44
	Mr98	248	37	45	19	77	48	5	12	34
	Wd103	252	35	38	27	75	38	4	26	31
	Mr105	254	43	30	27	55	50	10	15	24
	Wd110	262	25	45	30	60	43	6	15	37
	Wd111	266	26	43	31	74	55	7	14	23
	Wd112	271	23	44	33	53	35	7	20	37
	Mr113	195	23	57	20	73	51	8	10	30
	Mr119	285	31	42	27	52	34	4	21	31
	Mr123	287	39	51	10	52	51	5	15	29

Till	Sample No.	Stop No.	Sand %	Silt %	Clay %	% Local Types in Coarse Sand	Illite %	Kao-Ch. %	Verm. %	Smec. %
Bakerville	Wd61	199	65	29	6	53	42	7	22	30
	Wd62	199	61	24	15	53	59	7	15	19
	Wd63	199	61	25	13	59	70	13	7	10
	Ck68	209	70	19	11	77	73	12	8	9
	Ck69	210	53	30	18	65	42	5	16	37
	Ck70	211	64	26	11	61	50	5	14	30
	Ck72	216	51	28	21	61	73	10	6	11
	Ck73	217	72	17	11	80	67	6	14	13
	Ck75	222	70	19	11	57	32	7	19	43
	Wd76	224	58	28	14	54	48	4	10	38
	Wd83	237	67	26	7	54	49	7	33	11
	Wd84	240	70	16	14	64	47	16	4	34
	Mr106	253	54	32	14	66	61	7	18	14
	Mr107	255	51	32	17	66	44	9	14	33
	Mr109	257	65	30	5	56	45	4	10	41
Merrill	Mr57	193	55	32	14	66	82	9	3	6
	Mr64A	194	66	27	7	56	47	5	28	20
	Mr65	203	55	32	13	65	63	6	11	20
	Mr67	208	59	27	14	49	72	7	7	14
	Mr115	274	57	30	13	72	61	16	16	7

Till	Sample No.	Stop No.	Sand %	Silt %	Clay %	% Local Types in Coarse Sand	Illite %	Kao-Ch. %	Verm. %	Smec. %
Bakerville	Wd61	199	65	29	6	53	42	7	22	30
	Wd62	199	61	24	15	53	59	7	15	19
	Wd63	199	61	25	13	59	70	13	7	10
	Ck68	209	70	19	11	77	73	12	8	9
	Ck69	210	53	30	18	65	42	5	16	37
	Ck70	211	64	26	11	61	50	5	14	30
	Ck72	216	51	28	21	61	73	10	6	11
	Ck73	217	72	17	11	80	67	6	14	13
	Ck75	222	70	19	11	57	32	7	19	43
	Wd76	224	58	28	14	54	48	4	10	38
	Wd83	237	67	26	7	54	49	7	33	11
	Wd84	240	70	16	14	64	47	16	4	34
	Mr106	253	54	32	14	66	61	7	18	14
	Mr107	255	51	32	17	66	44	9	14	33
	Mr109	257	65	30	5	56	45	4	10	41
Merrill	Mr57	193	55	32	14	66	82	9	3	6
	Mr64A	194	66	27	7	56	47	5	28	20
	Mr65	203	55	32	13	65	63	6	11	20
	Mr67	208	59	27	14	49	72	7	7	14
	Mr115	274	57	30	13	72	61	16	16	7

APPENDIX D. Time stratigraphy used in this thesis (Willman and Frye, 1970).

TIME STRATIGRAPHY			
QUATERNARY SYSTEM	PLEISTOCENE SERIES	HOLOCENE STAGE	
		WISCONSINAN STAGE	VALDERAN SUBSTAGE
			TWOCREEKAN SUBSTAGE
			WOODFORDIAN SUBSTAGE
			FARMDALIAN SUBSTAGE
			ALTONIAN SUBSTAGE
		SANGAMONIAN STAGE	
		ILLINOIAN STAGE	JUBILEEAN SUBSTAGE
			MONICAN SUBSTAGE
			LIMAN SUBSTAGE
		YARMOUTHIAN STAGE	
		KANSAN STAGE	
		AFTONIAN STAGE	
		NEBRASKAN STAGE	