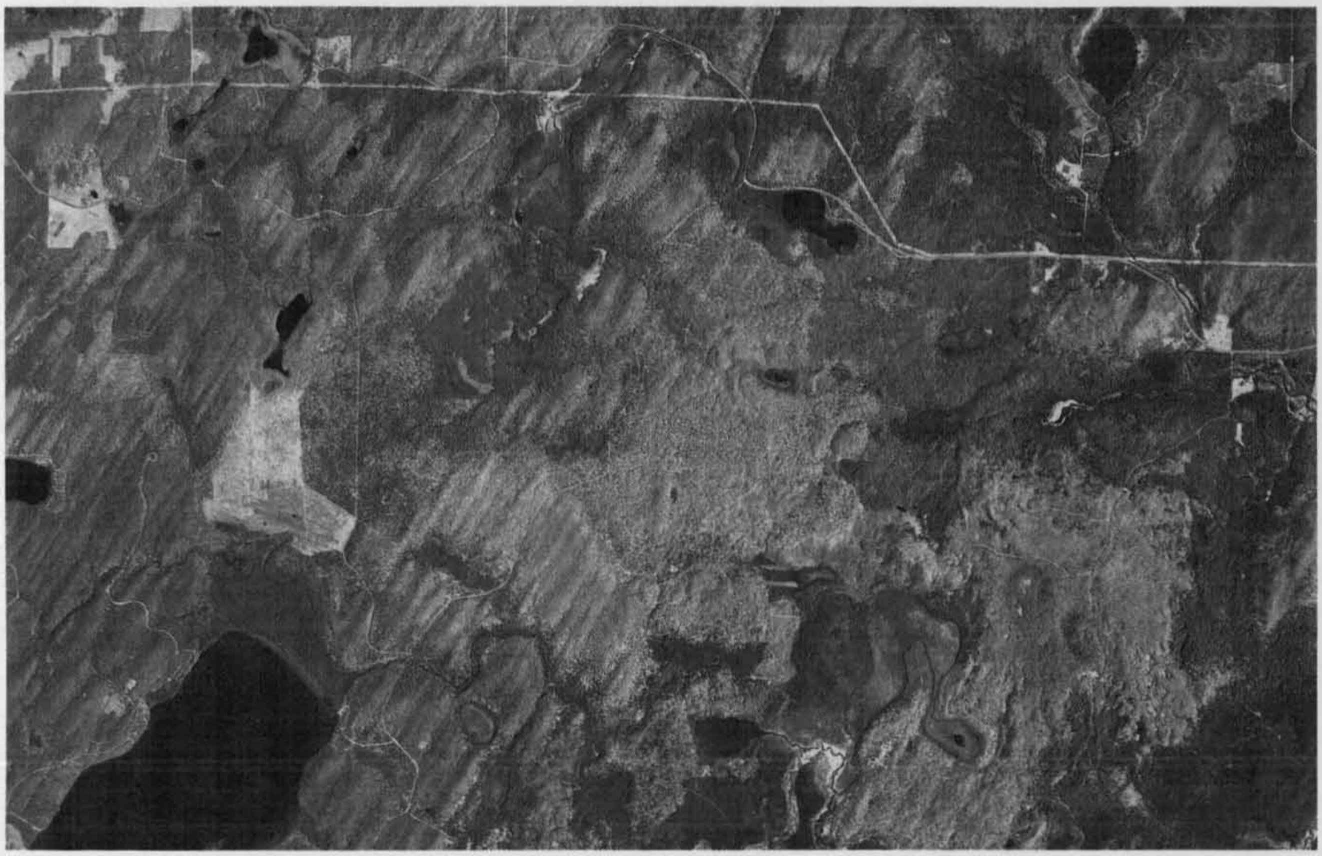
Pleistocene Geology of Vilas County, Wisconsin

John W. Attig



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A description and discussion of the nature and history of the Pleistocene materials and landforms in Vilas County, Wisconsin

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FOREWORD

This is the third in a series of reports and 1:100,000 maps that describe the Pleistocene geology of Wisconsin counties. The series is intended to provide basic geologic information which can be used to assist with resource and environmental planning and management including determining mineral resources potential; locating and protecting potential groundwater supplies; siting construction projects and waste disposal and material storage facilities; routing utilities such as pipelines and roadways; and a host of other purposes.

The Vilas County report consists of two parts–a map with cross sections that shows the distribution of Pleistocene materials and landforms, and a report that contains a description and discussion of the physical character, stratigraphy, origin, and history of these materials and landforms.

In Vilas County the Pleistocene material is up to 85 m thick and the underlying Precambrian rock is exposed at the surface in a few places. Aggregate for construction purposes is mined exclusively from the Pleistocene material, and nearly all of the water pumped from wells is derived from the Pleistocene material.

This report was prepared as part of a cooperative agreement between the Wisconsin Geological and Natural History Survey, the U.S. Geological Survey, and the Vilas County Board of Supervisors.

Dr. Meredith E. Ostrom
Director and State Geologist

Pleistocene Geology of Vilas County, Wisconsin

John W. Attig

ABSTRACT

In Vilas County, Wisconsin, up to 85 m of Pleistocene till, debris-flow sediment, and stream sediment overlie Precambrian igneous and metamorphic rock. Most of the Pleistocene sediment was deposited during the last part of the Wisconsin Glaciation when lobes of the Laurentide Ice Sheet advanced into north-central Wisconsin. Three members of the Copper Falls Formation are recognized in the Vilas County area.

The Wisconsin Valley lobe advanced into Vilas County from the north and deposited the reddish-brown, sandy Wildcat Lake Member at nearly the same time the Langlade Lobe advanced from the northeast and deposited the brown, sandy Nashville Member. A number of readvances or periods of ice-margin stabilization occurred as these lobes wasted. The Ontonagon Lobe then advanced over silty lake sediment, flowed into northern Vilas County and deposited the reddish-brown, silty Crab Lake Member.

INTRODUCTION

This report and the accompanying map and geologic sections (plate 1) describe the character, distribution, and history of Pleistocene sediment and landforms in Vilas County. In addition to providing insight into the glacial history and landscape development of Vilas county, this report contains information that will aid studies of groundwater and sand and gravel resources in the area. It is suggested that the reader make frequent use of plate 1 (in pocket) while reading this report.

Vilas County occupies about 2,250 km^2 in north-central Wisconsin adjacent to the Upper Peninsula of Michigan (fig. 1). The county contains many lakes as well as large areas of public land, most of which are in national and state forests. The area has been referred to as the Northern Highland Lake District (Black and others, 1963; Martin, 1965).

Surface water in Vilas County flows south and west to the Mississippi River, north to Lake Superior, and east to Lake Michigan. The Manitowish River drains much of west-central Vilas County, and the Wisconsin River and its tributary, the Tomahawk River, drain southern and eastern Vilas County. The water from these areas eventually reaches the Mississippi River. Surface water from the northern part of the county is drained to Lake Superior by the Presque Isle and Ontonagon Rivers. Surface water from a small part of eastern Vilas County drains eastward to Lake Michigan.

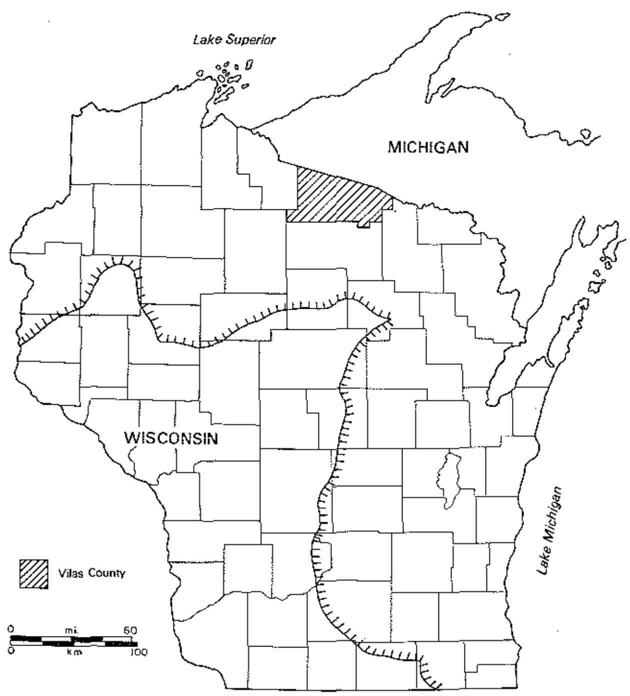

Figure 1. Location of Vilas County. Line with barbs shows maximum extent of ice during the last part of the Wisconsin Glaciation.

Elevations in Vilas County range from slightly over 560 m in the northeast corner (T. 42 N., R. 12 E.), to about 480 m near Shishebogama Lake (T. 40 N., R. 5 E.). Elevations generally decrease from northeast to southwest. A broad area of relatively high elevation, in excess of 520 m in many areas, trends north-south through the central part of the county. Local relief in Vilas County exceeds 50 m in some areas, but in most areas it is much less.

This report is based on data collected during 1981, 1982, and 1983, when a total of about seven months was spent in Vilas County. Field work was conducted using standard geologic field techniques including drilling with a power auger. The logs of the power-auger holes are listed in the appendix. Sediment samples were analyzed in the Quaternary Sediment Laboratory at the University of Wisconsin at Madison. The procedures used to analyze samples and the resulting data are listed by Attig (1984c).

This report has been improved by input from many people, especially David Mickelson and Lee Clayton who visited the study area and reviewed and commented on the manuscript a number of times. Special thanks go to my wife Cathy who assisted in the field, typed, drafted, and provided support throughout this project.

PRE-PLEISTOCENE GEOLOGY

Precambrian Rock in Vilas County

Precambrian rock is known to crop out in two areas in Vilas County. One, reported by Thwaites (1929), consists of a number of small outcrops of pink granitic rock in secs. 34 and 35, T. 43 N., R. 7 E. The other outcrop, in what have been described as possible prospect pits (M.G. Mudrey, verbal communication), in sec. 10, T. 40 N., R. 11 E., consists of white quartz and gray volcanic rock. Neither is clearly expressed topographically, and Precambrian rock probably crops out in other parts of forested eastern and northern Vilas County. Hanners (1941) reported five outcrops of rock in the county but he did not give locations.

Because of the small number of outcrops, what is known about the Precambrian rock of the area is known largely from logs of deep drill holes, geophysical data, and extrapolation from surrounding areas where there are more outcrops. Few water wells penetrate to Precambrian rock because a thick aquifer is present in the overlying Pleistocene material.

A summary by Morey and others (1982) shows the southern part of the county underlain primarily by Lower Proterozoic, mafic, metavolcanic rock (unit mm; fig. 2). Most of the northern part of the county is underlain by metasedimentary rock of the same age (unit qs; fig. 2) in which several bodies of Archean gneiss and amphibolite (unit ga; fig. 2) occur.

Topography on the Precambrian Rock

Elevations on the Precambrian rock surface in Vilas County range from about 413 m above sea level in the south-central area to about 512 m in the north-central and southeast areas. Maximum relief is about 100 m (fig. 3). The elevations shown on figure 3 are believed to be accurate within about 10 m. Figure 3, the surface elevation of the Precambrian rock, and figure 4, the

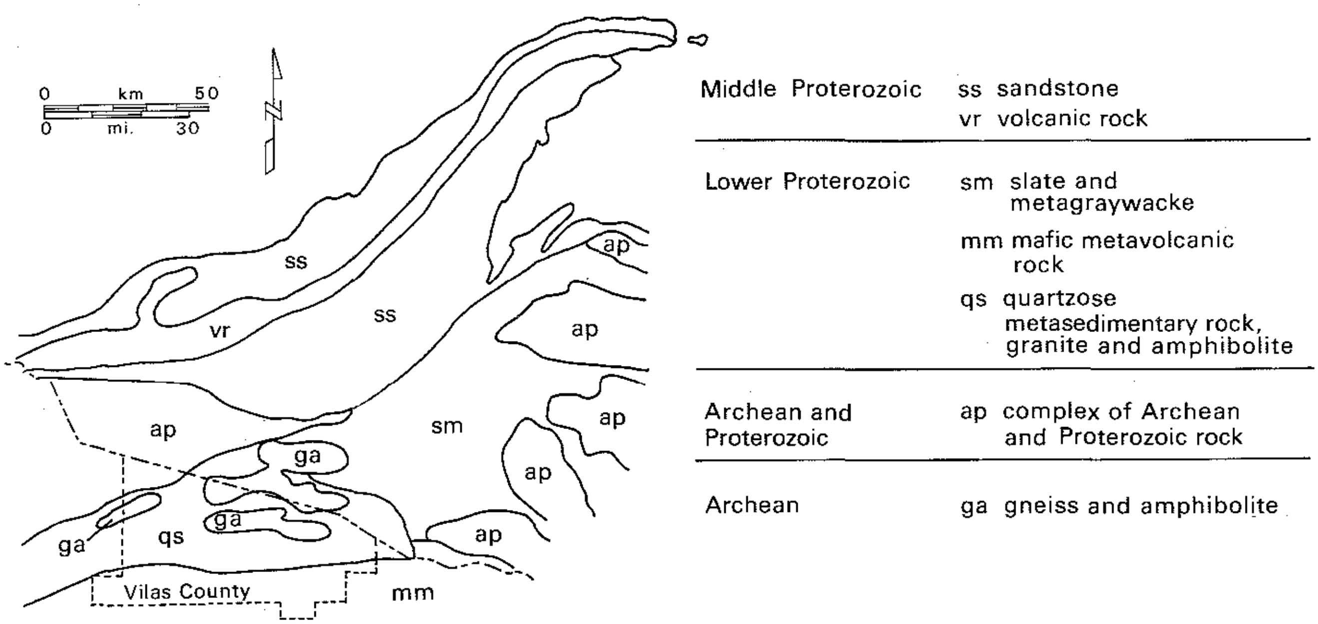

Figure 2. Map showing the distribution of rock types in Vilas County and some adjacent areas (modified from G. B. Morey and others, 1982).

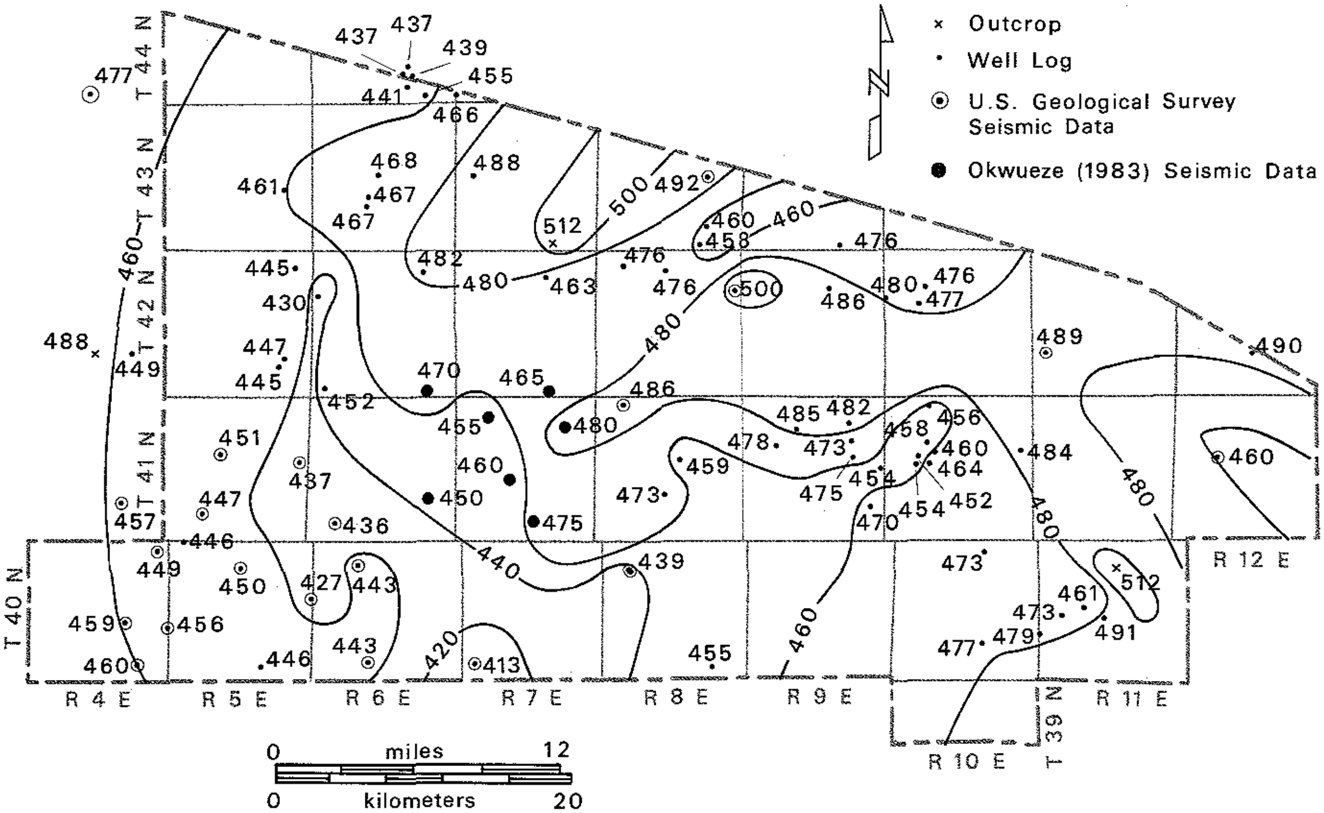

Figure 3. Elevation of the surface of the Precambrian rock in metres. Contour interval is 20 metres.

thickness of Pleistocene sediment, are based on data derived from five sources: logs of low-capacity wells on file at the Wisconsin Geological and Natural History Survey, records of diamond-drill holes constructed by the F.I. Carpenter Syndicate (on file with the U.S. Geological Survey in Madison, Wisconsin, or reported by Allen and Barrett, 1915), seismic data resulting from recent work by the U.S. Geological Survey and made available by Gary Patterson (1983, unpublished data), seismic data from Okwueze (1983), and two outcrops of Precambrian rock.

Both localities where Precambrian rock crops out are at an elevation of 512 m, and nearby well records show relief of at least 50 m. This indicates that the surface of the Precambrian rock is, at least locally, an irregular surface. Elevations generally decrease from the north and northeast to the south and southwest. Unfortunately the information is inadequate to evaluate the relationship between the location of Pleistocene landforms with respect to rock topography or to define small-scaled features on the Precambrian surface.

Thickness of Pleistocene Sediment

As shown in figure 4 the Pleistocene sediment in Vilas County ranges in thickness from 0 to about 85 m. The greatest known thicknesses, 85 and 82 m, occur in the south-central and eastern parts of the county. The thick Pleistocene sediment in the south-central part of the area occurs over the lowest Precambrian rock surface in the area, whereas the thick Pleistocene sediment in the eastern part of the area overlies a relatively high rock surface.

Precambrian Rock in Adjacent Areas

The distribution of pre-Pleistocene rock types north of Vilas County is different from that to the northeast. As shown by Morey and others (1982, fig. 2) immediately north of Vilas county Archean rock consisting of migmatitic gneiss, amphibole, granite, mafic volcanic, and cataclastic rock (unit ap; fig 2) occurs. This rock is interbedded with Proterozoic rock consisting of quartzose metasedimentary and metavolcanic rock, slate, metagraywacke, quartzite, mafic volcanic rock, and conglomerate. A narrow, discontinuous zone of Middle Proterozoic mafic volcanic rock and quartzite (not shown on fig. 2) separates the Proterozoic and Archean rock from the second major band of rock, a 10-to-15-km-wide zone of Middle Proterozoic sandstone (unit ss; fig. 2), which consists of quartzose and feldspathic sandstone and shale. A band, 5-to-10 km wide, of Middle Proterozoic basaltic and felsic volcanic rock (unit vr; fig. 2) lies north of the sandstone. This is the only volcanic rock in the area between Vilas county and Lake Superior that has a sufficiently low metamorphic grade to preserve

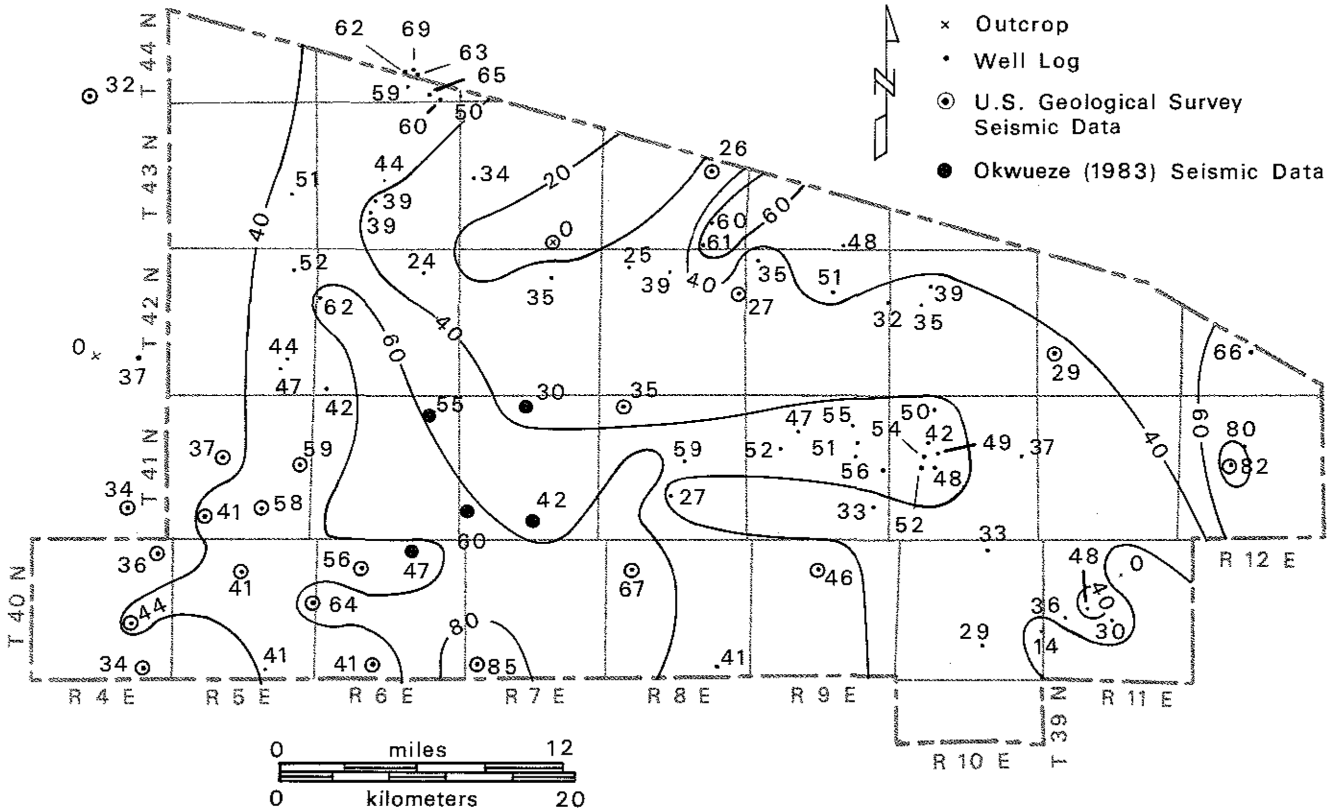

Figure 4. Thickness of Pleistocene sediment in metres. Contour interval is 20 metres.

primary features easily discernable in hand specimen (M.G. Mudrey 1983, verbal communication).

Between the volcanic rock, which crops out in a narrow band along the length of the Keweenaw Peninsula, and the south shore of Lake Superior is a band of red Middle Proterozoic sandstone (unit ss; fig. 2).

The sequence of rock types to the northeast of Vilas County differs from that described above. For about 15 km to the northeast the area is underlain by Lower Proterozoic quartzose metasedimentary rock (unit qs, fig. 2). Continuing to the northeast, a band up to 70 km wide is underlain predominantly by slate and metagraywacke (unit sm, fig. 2).

The closest area of sandstone is at least 100 km from Vilas County in a northeasterly direction as compared to approximately 20 km in a northerly direction. The volcanic rock that occurs about 40 km north of Vilas County does not occur (assuming the trend in the Keweenaw Peninsula continues beneath Lake Superior) for over 170 km in a northeasterly direction. As will be discussed in later sections, and as recognized by Leverett (1929), this difference is evident in the composition of the glacial sediment in Vilas County.

PLEISTOCENE GEOLOGY

The Vilas County area has probably been glaciated many times during the Pleistocene. Evidence has been found in Vilas County only for the last part of the Wisconsin Glaciation, which took place between about 25,000 and 10,000 years ago. South of the extent of late Wisconsin ice in north-central Wisconsin, sediment from earlier glacial advances has been described (Chamberlin, 1883; Weidman, 1907; Stewart, 1973; Mode, 1976; Stewart and Mickelson, 1976). These earlier glacial advances most likely covered the Vilas County area.

The geological evidence that does exist in Vilas County provides insight into ice-flow patterns during the late Wisconsin, the sequence of events during deglaciation, and the origin of the area's sediment and landforms. Primarily, it records events during deglaciation. The glacial deposits of Vilas County record a transition from a glacial to a postglacial environment. During this transition most of the landscape of Vilas County formed.

Sometime before 21,000 years ago ice advanced into the Lake Superior and Lake Michigan lowlands (Mickelson and others, 1983). As the ice advanced it formed lobes that flowed south-southwest and southwest across the northern peninsula of Michigan and into Vilas

County (fig. 5). Evidence for the advance and subsequent wastage of these lobes, the Wisconsin Valley and Langlade Lobes, is present in Vilas County. The long axis of drumlins and the orientation of pebbles in till show that the Langlade Lobe flowed into the area from the northeast and the Wisconsin Valley Lobe from the north-northeast. Following the wastage of these lobes deglaciation was interrupted by the advance of the Ontonagon Lobe into northern Vilas County. In the following sections the materials, landforms, and history of each of these lobes is discussed.

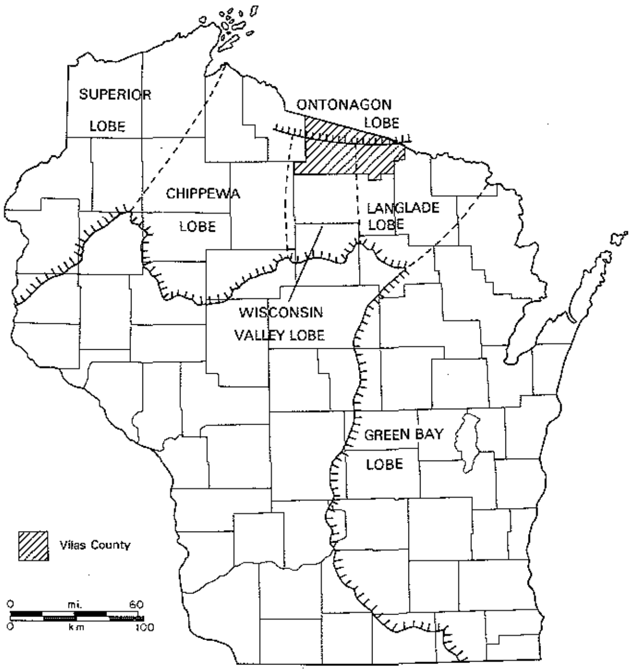

Figure 5. Ice lobes of northern Wisconsin. Arrows show ice-flow direction in the Vilas County area. Line with barbs shows maximum extent of ice during the last part of the Wisconsin Glaciation. Dashed lines show the approximate boundary between lobes.

Materials

The Copper Falls Formation (Mickelson and others, 1984) contains the late Wisconsin reddish-brown to brown sandy sediment of northern Wisconsin, including that in Vilas County. Three members of the Copper Falls Formation are recognized in Vilas County: the Nashville Member, informally named by Simpkins (1979) in adjacent Forest County and formally named by Mickelson and others (1984), and the Wildcat Lake and the Crab Lake Members (fig. 6), named by Attig (1984c).

Each member is defined on the basis of the physical properties of a till and each member contains associated debris flows and sediment deposited by streams on, under, and beyond the ice (table 1).

Till is interpreted to have been deposited by lodging and melting out of material from a thin, debris-rich layer at the base of the ice. Till in Vilas County is thin (typically less than 2 m), is uniform areally and vertically, is compact, generally lacks sedimentary structures or lenses of sorted sediment, and contains a strongly developed pebble fabric with the long axis of most pebbles lying parallel to ice flow and plunging upglacier. These characteristics are in general agreement with those cited as characteristic of lodgement and meltout till by Socha (1984), Lawson and Kemmis (1983), Shaw (1982), Dreimanis (1976), and Boulton and Paul (1976).

The debris flows consist of englacial debris that melted out at the upper surface of the ice and flowed to its present position as the underlying ice melted. The debris-flow sediment is more variable and is typically less compact than till. It has crude stratification, sedimentary structures indicating flow, abundant large clasts and weakly developed pebble fabrics typically having no relationship to ice flow. These characteristics agree with those noted by Lawson and Kemmis (1983), Eyles and others (1983), and Lawson (1979), as indicating debris-flow processes.

The supraglacial debris-flow sediment is relatively thin (typically less than 8 m) in Vilas County and nearly all of the debris released by melting out on the upper surface of the ice probably flowed. In some areas, where thick supraglacial sediment was lying over very debris-rich ice, debris-flow processes may not have reworked the debris after release from the ice and therefore the material may not be distinguishable from till.

Large clasts, those with an intermediate axis longer than 20 cm are found almost exclusively in the debris-flow sediment and are nearly lacking in till. This suggests that the large clasts were carried above the basal debris-rich zone and were released at the ice surface by melting out. This relationship is similar to that described by Johnson and others (1982) for sediment near the terminus of the Green Bay Lobe where sediment interpreted to have been carried above the basal debris-rich zone was found to contain more far-travelled rock types than till.

In addition to till and debris-flow sediment each member includes sand and gravel deposited by meltwater streams. These streams were confined in tunnels beneath the ice or were braided streams that wandered over broad plains. The streams in tunnels beneath the ice deposited sand and gravel along their beds. When the ice along the edges of the tunnel melted, this sediment was left in relief as elongate, somewhat sinuous ridges. These ridges are called eskers and are shown on plate 1 as units **Wgs, Ngs,** and **Cgs.**

The braided streams deposited sand and gravel in broad plains. Where this sediment was deposited mostly on solid ground the original depositional surface is preserved. Such areas are shown on plate 1 as units **Wgp, Ngp, Cgp** and **Ugp.** Small areas of these units are collapsed where sand and gravel was deposited on ice blocks that subsequently melted. In some areas most of the sediment deposited by braided streams was underlain by ice. In these areas the original depositional surface was destroyed by collapse as the underlying ice melted.

Table 1. Characteristics of Sediment types

	Till	Debris-flow Sediment	Fluvial Sediment Deposited in Sub-glacial Tunnels	Fluvial Sediment deposited by Braided Streams
Uniformity (<2 mm fraction)	Uniform	Variable	Variable	Variable near source, becomes more uniform with distance from source
Compaction	Compact	Variable	Typically not compact	Typically not compact
Pebble fabric	Strongly developed, in most cases parallel to ice flow	Weekly developed, no relation to ice flow	Not measured	Not measured
Stratification	Not stratified, contains a few small lenses of stratified sand and gravelly sand	Crude stratification, with some well-stratified lenses	Degree of stratification highly variable	Mostly well stratified, crudely stratified near source
Sorting	Very poorly sorted	Variable, poorly to well-sorted	Well sorted, but grain size changes abruptly	Mostly well sorted, very poorly sorted near source
Deformation features	Thrust faults and folds showing compression parallel to ice flow	Flow noses, flame structures	Normal faulting, common along ice-contact faces	Lacking except for normal faulting and other collapse features where deposited on ice
Abundance of clasts (> 30 cm)	Few	Common	Common	Absent except near the ice-contact face
Mode of deposition	Lodgement or melt-out from basal debris-rich zone	Debris flow as underlying ice melts	Streams in subglacial tunnels	Braided streams

These areas are shown on plate 1 as units **Wgc, Ngc, Cgc,** and **Ugc.** All of these units are discussed in more detail in later sections and are described in the explanation on plate 1.

Wildcat Lake Member

The till of the Wildcat Lake Member was deposited by the south-southwest flowing ice of the Wisconsin Valley Lobe during late Wisconsin time. It is the surface till in the west-central part of Vilas County (fig. 6), and crops out in drumlins southeast and northwest of Trout Lake (plate 1; map unit **Wtd**).

The till is slightly gravelly loamy sand or sandy loam. Analysis of sixteen samples resulted in an average sand:silt:clay ratio of 71:21:8 (fig. 7; table 2). The relative magnetic susceptibility (table 2) of these same samples (30 g of less-than-2 mm fraction) had an average of 14.8 (table 2). Field color is commonly reddish brown (5YR 5/4). Semiquantitative analysis of clay minerals in 11 samples gave an average expandable clay: illite:kaolinite plus chlorite ratio of 44:41:15 (fig. 8; table 2). The lithology of pebbles as determined by 12 counts of 100 pebbles (table 2) is 8 percent sandstone, 14 percent volcanic rock, 14 percent argillic, slaty, and quartz-rich metasedimentary rock, and 64 percent other igneous and metamorphic rock. The pebble fabric of the till could be measured at only one location. At this locality the till contained a strongly developed fabric (fig. 9) with the long axis of most pebbles lying parallel to regional ice flow and plunging upglacier. The till at this locality contains a number of pebbles and cobbles with well formed stoss-and-lee sides. The lee sides are on the

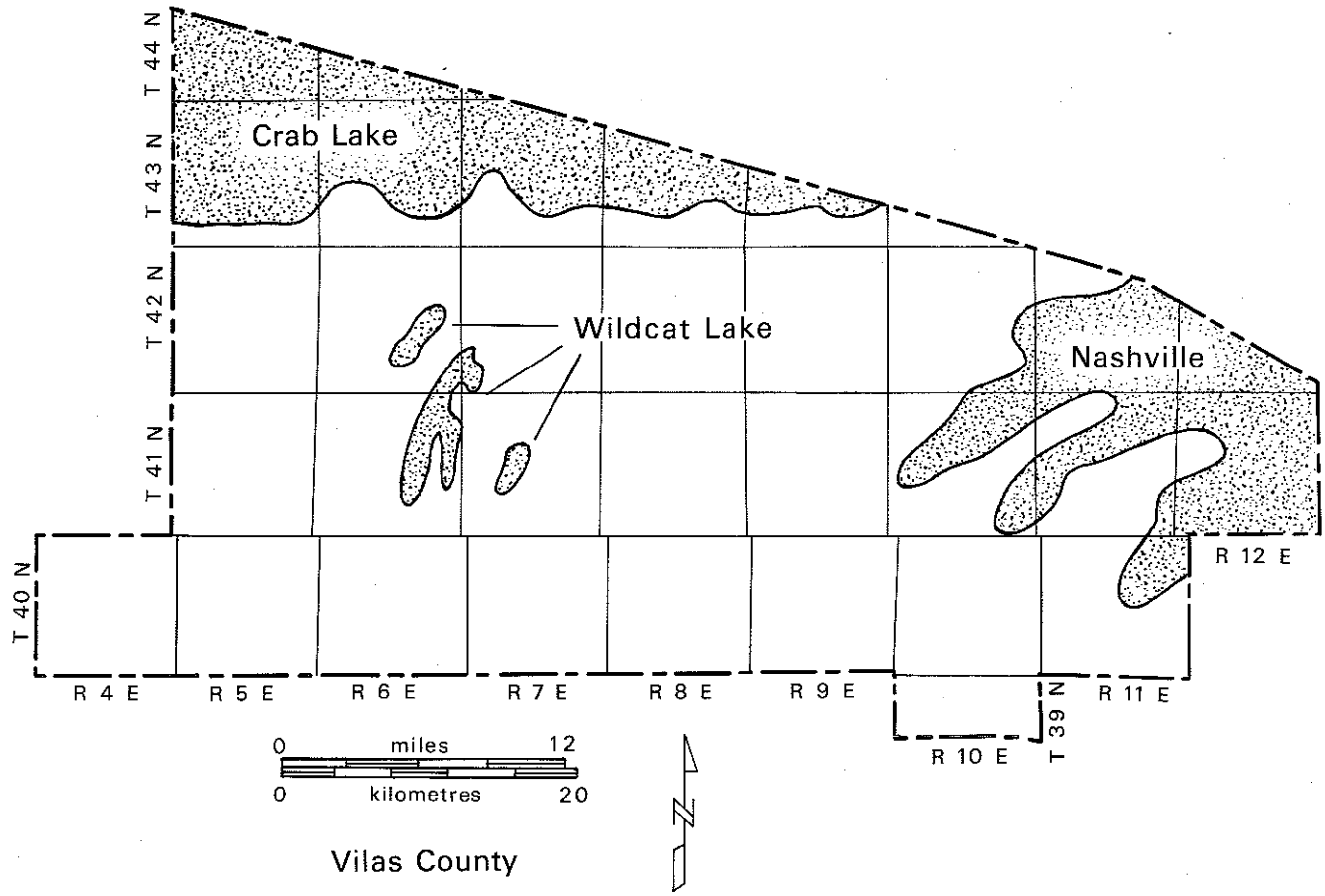

Figure 6. Map showing the surface distribution of till of lithostratigraphic members.

downglacier end on the upper surface of the clast and on the upglacier end on the lower surface. The long axis of all of these clasts is parallel to ice-flow direction. Clasts such as these have been interpreted to be indicative of subglacial lodging (Kruger, 1979; Boulton, 1974). The till reaches thicknesses of at least 6 m.

The supraglacial debris-flow sediment is gravelly sand to gravelly loamy sand. The average sand:silt:clay ratio of 43 samples is very similar to that of the till and is 75:20:5 (fig. 7; table 2). These average values show the supraglacial sediment to be slightly more sandy than the till and, as shown in figure 7, it is more variable. Relative magnetic susceptibility of the same 43 samples has an average of 11.9 (table 2). Field color is most commonly light brown (7.5YR 6/4) or light reddish brown (5YR 6/4). The semiquantitative analysis of clay minerals determined for seven samples yields an average expandable clay:illite:kaolinite plus chlorite ratio of 15:60:25 (fig. 8; table 2). Both the till and supraglacial sediment show considerable variability in clay mineralogy but little compositional overlap. Pebble lithology is similar for the two sediment types (table 2). Pebble fabrics in the supraglacial sediment are typically weak showing no relationship to regional ice flow direction (fig. 9). The supraglacial debris-flow sediment reaches thicknesses of at least 7 m.

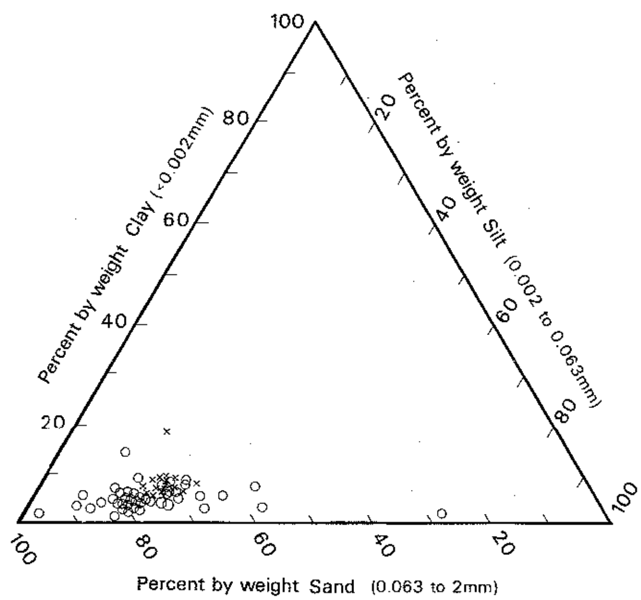

Figure 7. Grain-size distribution of the less-than-2 mm fraction of the till (x) and supraglacial debris-flow sediment (o) of the Wildcat Lake Member.

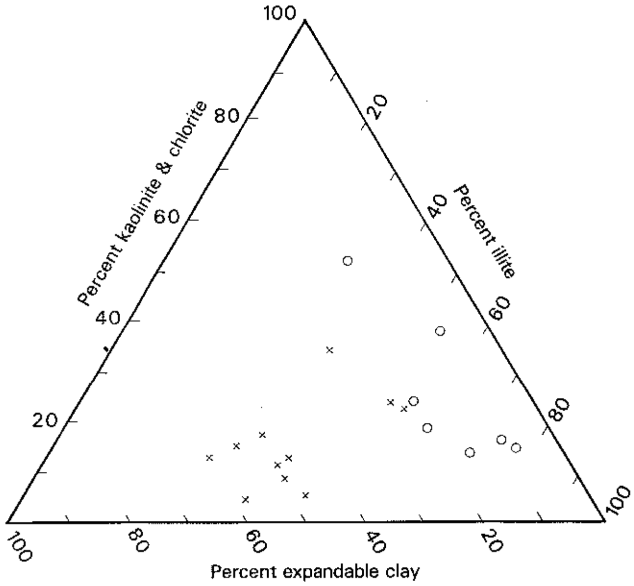

Figure 8. Clay mineralogy of the till (x) and supraglacial debris-flow sediment (o) of the Wildcat Lake Member.

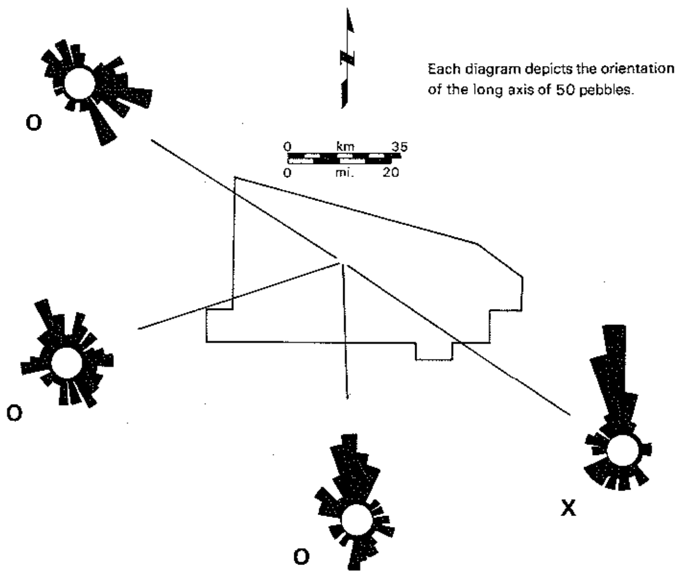

Figure 9. Pebble-fabric diagrams from the till (x) and supraglacial debris-flow sediment (o) of the Wildcat Lake Member.

The differences in clay mineralogy and magnetic susceptibility between the till and supraglacial sediment of the Wildcat Lake Member indicate that a difference in lithologic composition exists. This difference was not detected in examining pebble lithology. The incorporation of more far-traveled lithologies, incorporation of windblown material, or selective winnowing of clay minerals from the supraglacial sediment could account for the differences.

In addition to till and debris-flow sediment, the Wildcat Lake Member also includes stream sediment (plate 1, units **Wgs, Wgf, Wgp, Wgc**). The characteristics of the stream sediment are described in the explanation on Plate 1.

The till of the Wildcat Lake Member is probably nearly correlative with the till of the Nashville Member and is older than the till of the Crab Lake Member (both discussed below). Till of the Wildcat Lake Member is similar to the informally named Bass Lake till—the till of the Wisconsin Valley Lobe near its terminus (Nelson 1973). Samples from the Bass Lake till have an average sand:silt:clay ratio of 80:17:3 and are reddish brown (2.5 YR 4/4 to 5YR 4/4) (Nelson, 1973).

Locally the Wildcat Lake till overlies sand and gravelly sand (See appendix, 91 and 92). The thickness and extent of this older sediment is unknown and it is not included in the Wildcat Lake Member. The till is overlain by supraglacial debris-flow sediment and stream sediment. The upper and lower contacts of the till have only been encountered in drill holes and their nature is not well known. The till of the Wildcat Lake Member is not known to be in contact with till of any other member. In the northern part of the county, till, debris-flow sediment, and stream sediment of the Wildcat Lake Member are buried beneath sediment of the Crab Lake Member.

Nashville Member

The till of the Nashville Member was deposited in Vilas County by the southwest-flowing ice of the Langlade Lobe. It is the surface till in eastern Vilas County and is exposed there in drumlins (plate 1, map unit **Ntd;** fig. 6).

The till is uniform, slightly gravelly, loamy sand to sandy loam (fig. 10). The average sand:silt:clay ratio of 19 samples is 78:15:7 (fig. 10; table 2). The average relative magnetic susceptibility is 5.2 (table 2). Field color is commonly dark brown (7.5YR 4/4) to light brown (7.5YR 6/4). Semiquantitative analysis of clay minerals in 15 samples gave an average expandable clay:illite:kaolinite plus chlorite ratio of 6:59:35 (fig. 11; table 2). The average lithology of pebbles as determined by ten counts of 100 pebbles each is 4 percent sandstone, 4 percent volcanic rock, 39 percent argillic, slaty and quartz-rich metasedimentary rock, and 54 percent other igneous and metamorphic rock (table 2). A pebble fabric could be measured at only one location (fig. 12). It is a fairly weakly developed fabric. The maximum known thickness of the till is 4.5 m.

The supraglacial debris-flow sediment ranges from gravelly sand to gravelly loam. The average ratio of sand:silt:clay for 40 samples is 79:15:6 (fig. 10; table 2). Average relative magnetic susceptibility is 5.4 (table 2). Field color is most often light brown (7.5YR 6/4). Semiquantitative analysis of clay minerals of 12 samples gave an average expandable clay:illite:kaolinite plus chlorite ratio of 16:56:29 (fig. 11; table 2). Although the clay mineralogy is similar for both till and supraglacial sediment it is more variable in the supraglacial debris-flow sediment. Pebble lithology for the two sediment types is similar as shown in table 2. Pebble fabrics measured in

Table 2. Characteristics of lithostratigraphic members. Values represent the mean of the number of samples (n) indicated.

Member	Sediment Type	Grain-size distribution of the <2 mm fraction: n	Sand	Silt	Clay	Clay Mineralogy (%): n	Expandables	Illite	Kaolinite + Chlorite	Relative magnetic Susceptibility: n	
Wildcat Lake	Till	16	71	21	8	11	44	41	15	16	14.8
	Debris-flow sediment	43	75	20	5	7	15	60	25	43	11.9
Nashville	Till	19	78	15	7	15	6	59	35	19	5.2
	Debris-flow sediment	40	79	15	6	12	16	56	29	40	5.4
Crab Lake	Till	19	61	30	9	16	64	26	9	19	8.5
	Debris-flow sediment	61	60	32	8	22	47	40	13	61	8.6

Means of Counts of 100 Pebbles Each

Member	Sediment Type	n	Red Sandstone	Volcanic Rock	Argillic, Slaty, and Quartz-rich Meta-sedimentary rock	Other igneous and metamorphic rock
Wildcat Lake	Till	12	8	14	14	64
	Debris-flow sediment	11	10	20	8	62
Nashville	Till	10	4	4	39	54
	Debris-flow sediment	10	5	6	47	42
Crab Lake	Till	10	11	11	16	62
	Debris-flow sediment	10	13	8	14	65

the debris-flow sediment are weak and show no clear relationship to regional ice flow (fig. 12). The maximum known thickness of the supraglacial sediment is 6.5 m.

The relative magnetic susceptibility of the northeast-derived Nashville Member is low in comparison to that of the more northerly-derived Wildcat Lake and Crab Lake Members (table 2). Magnetic susceptibility is a measure of the relative content of magnetite and similar minerals in the sample. The relatively high magnetic susceptibility of the till derived from the north is probably directly related to the proximity of magnetite-rich, pre-Paleozoic source rock. Low-grade volcanic rock that locally

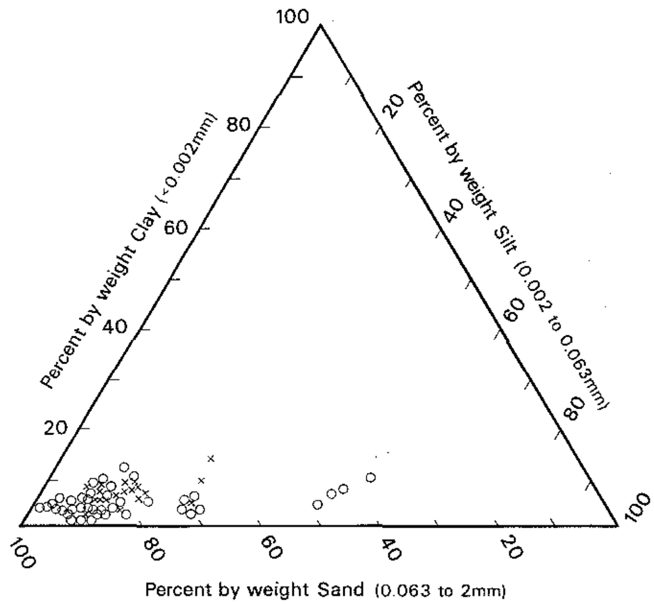

Figure 10. Grain-size distribution of the less-than-2 mm fraction of the till (x) and supraglacial debris-flow sediment (o) of the Nashville Member.

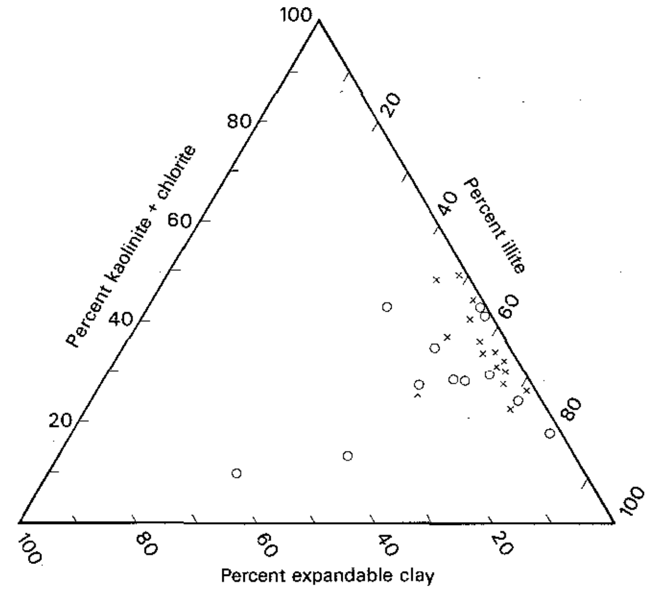

Figure 11. Clay mineralogy of the till (x) and supraglacial debris-flow sediment (o) of the Nashville Member.

contains abundant magnetite (M. G. Mudrey, 1982, verbal communication) crops out within 30 to 40 km north of the county. To the northeast, the same rock is about 170 km away and the intervening area contains high-grade metamorphic rock in which the primary magnetite has been altered (M. G. Mudrey, 1982, verbal communication). This difference in source area is also reflected in pebble lithology (table 2). The northeast derived till of the Nashville Member contains more pebbles of argillic, slaty and quartz-rich metasedimentary rock and fewer pebbles of sandstone and volcanic rock than the northern derived till of the Wildcat Lake and Crab Lake Members.

The Nashville Member in Vilas County is probably nearly the same age as the Wildcat Lake Member, is older than the Crab Lake Member, and is a westward extension of the Nashville Member defined in Forest County by Simpkins (1979). Considering that the ice flowing into Forest County was moving across a somewhat different pre-Pleistocene terrain from that flowing into Vilas County, the till of the two areas is remarkably similar. Field color for both is dark brown (7.5YR 4/4) with some reddish till near the Michigan border in Forest County. In till, the average ratio of sand:silt:clay is 78:15:7 for samples collected in Vilas County (table 2) and is 77:16:7 for samples collected in Forest County (Simpkins, 1979). Semiquantitative analysis of clay minerals following the method of Stewart (1973) yields a ratio of illite:kaolinite plus chlorite:vermiculite:smectite of 80:12:5:3 in Forest County (Simpkins 1979) and 66:12:21:0 in Vilas County. The pebble fraction in Forest County contains 5 percent sedimentary rock and 4 percent in Vilas County.

In Vilas County the till of the Nashville Member is overlain in many areas by stream-deposited sandy gravel and gravelly sand that is included in the Nashville Member or stream-deposited sand and gravelly sand included in the Crab Lake Member. The till of the Nashville Member overlies stratified sand and gravelly sand that is not included in the Nashville Member. The upper and lower contacts are typically sharp but have been observed at few localities. The till of the Nashville Member is not known to lie directly in contact with the till of the Wildcat Lake or Crab Lake Members.

The till of the Nashville Member is differentiated from that of the Wildcat Lake Member on the basis of its brown color, lower magnetic susceptibility, its relative lack of sandstone and volcanic rock and its relative abundance of metasedimentary rock in the pebble fraction, and by having less expandable clay (table 2).

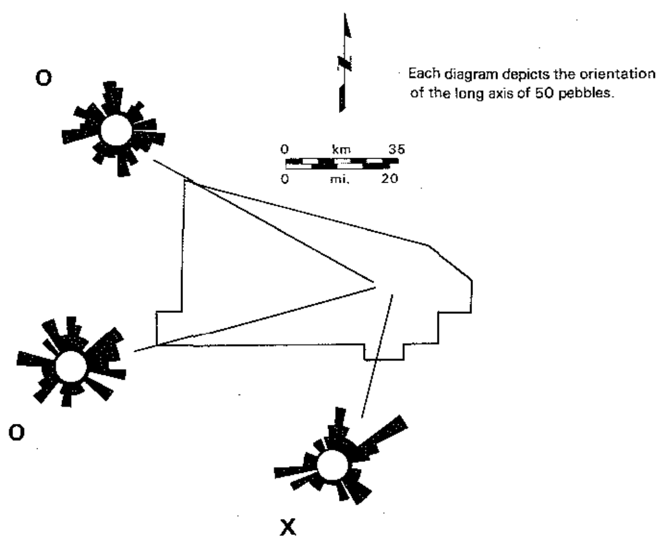

Figure 12. Pebble-fabric diagrams from the till (x) and supraglacial debris-flow sediment (o) of the Nashville Member.

Crab Lake Member

The till of the Crab Lake Member was deposited by the south-flowing Ontonagan Lobe during the late Wisconsin after wastage of the Wisconsin Valley and Langlade Lobes. The till of the Crab Lake Member is the surface till in Vilas County in and north of the Winegar moraine (plate 1, unit **Ctm**; fig. 6).

The till is slightly gravelly sandy loam (fig. 13). The average sand:silt:clay ratio of 19 samples is 61:30:9 (table 2). The average relative magnetic susceptibility measured on 19 samples is 8.5 (table 2). Field color is commonly reddish brown (5YR 4/4). Semiquantitative analysis of clay minerals in 16 samples of till gave an average ratio of expandable clay:illite:kaolinite plus chlorite of 64:26:9 (fig. 14; table 2). The average lithology of the pebble fraction as determined by ten counts of 100 pebbles each (table 2) is 11 percent sandstone, 11 percent volcanic rock, 16 percent argillic,

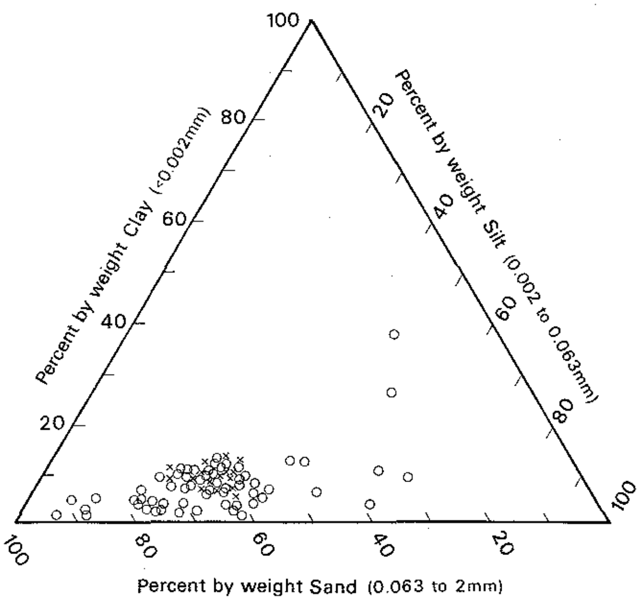

Figure 13. Grain-size distribution of the less-than-2mm fraction of the till (x) and supraglacial debris-flow sediment (o) of the Crab Lake Member.

slaty and quartz-rich metasedimentary rock, and 62 percent other igneous and metamorphic rock (table 2). Pebble fabrics from the till are strongly developed with the long axis of most pebbles plunging upglacier and lying parallel to the direction of ice flow (fig. 15). The maximum known thickness of the till is 8.5 m.

The supraglacial debris-flow sediment is gravelly sandy loam or gravelly loamy sand. The average ratio of sand:silt:clay of 61 samples is 60:32:8 (table 2). This ratio is similar to that of the till; but, as shown in figure 13, the supraglacial sediment shows more variability than the till. The average relative magnetic susceptibility of 61 samples is 8.6 (table 2). Semiquantitative analysis of clay minerals for 22 samples gave an average ratio of expandable clay:illite:kaolinite plus chlorite of 47:40:13

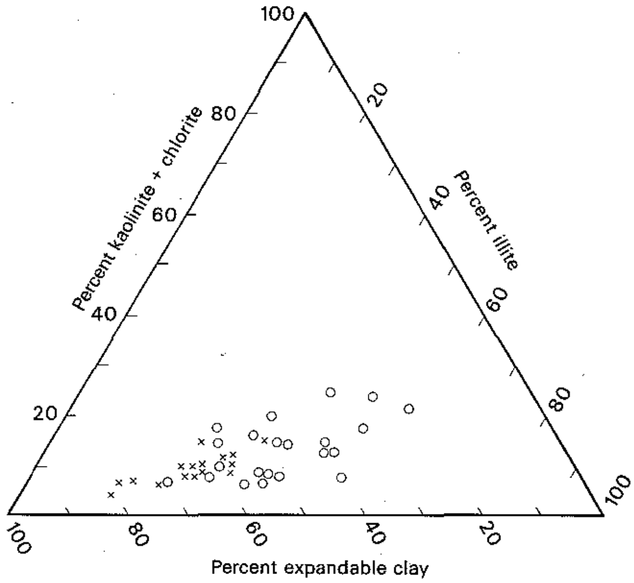

Figure 14. Clay mineralogy of the till (x) and supraglacial debris-flow sediment (o) of the Crab Lake Member.

(table 2). Pebble lithology is similar to that of the till and has an average value for ten samples of 13 percent sandstone, 8 percent volcanic rock, 14 percent argillic, slaty and quartz-rich metasedimentary rock, and 65 percent other igneous and metamorphic rock (table 2). Pebble fabrics from this material are weak and show no relation to regional ice flow (fig. 15). The maximum known thickness of this material is 13.5 m (See appendix, log 85).

The Crab Lake Member is younger than the Wildcat Lake and Nashville Members and is probably equivalent to the informally named Morse till of Iron County (Clayton, 1984). It is also equivalent to the sediment of

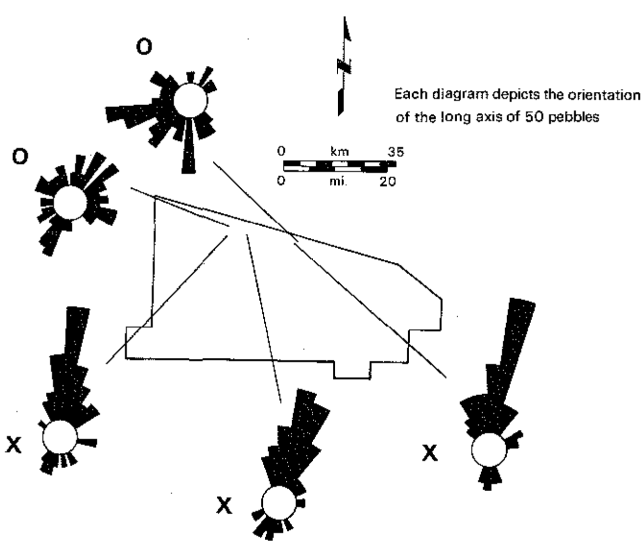

Figure 15. Pebble-fabric diagrams from the till (x) and supraglacial debris-flow sediment (o) of the Crab Lake Member.

the Winegar moraine in adjacent Michigan as described by Peterson (1982). The till of the Crab Lake Member is locally overlain by stream-deposited sandy gravel and gravelly sand that is included in the Crab Lake Member. The till also overlies stratified sand and gravelly sand. In some areas the underlying sand and gravelly sand is interpreted to belong to the Nashville or Wildcat Lake Members.

The till of the Crab Lake Member has a higher percentage of silt than the till of the Wildcat Lake and Nashville Members. It contains more magnetite, is redder, contains more pebbles of sandstone and volcanic rock, and has more expandable clay, than the Nashville Member. It has less magnetite and more expandable clay than the Wildcat Lake Member.

Calcareous Sediment

Calcareous sediment has been reported in the Vilas County area by several workers. Fries (1938) reported that a gray unit containing pebbles of gray dolomite, a large percentage of dark-colored minerals, and lenses of calcareous, gray clay was encountered in wells in western Vilas County. This gray, calcareous unit is reported to underlie the surface material in wells east of Crystal Lake, between Crystal and Muskellunge Lakes, along the shore of Trout Lake just south of Allaquash Creek, at Point Campsite on Trout Lake, and just north of Stephenson Creek. He suggested that this calcareous sediment was derived from an eastern source. Broughton (1941) described the surface material in the area as noncalcareous but also reported a calcareous unit encountered 14 to 27 m below the surface in wells at the Wildcat Lake Ranger Station and from 9 m to at least 15 m below the surface in a well at the Lake Tomahawk Community Hall in Oneida County. He said the calcareous unit contains dolomite pebbles, calcareous clay, and in the Lake Tomahawk well, pebbles containing colonial corals and brachiopods of possible Silurian age. Broughton (1941) estimated that the surface of the calcareous sediment has up to 50 m of relief.

The well record on file at the Wisconsin Geological and Natural History Survey for the well at the Ranger Station at Wildcat Lake was prepared by F. T. Thwaites in 1939 and makes no mention of calcareous material. The log of high-capacity well Vi-6 on file at the Wisconsin Geological and Natural History Survey, logged by Thwaites in 1953, records a well at the Lac Du Flambeau Public School that penetrated 34 m of pink and gray dolomite-rich till. Black (1966a) reported finding a red, calcareous material at the surface, 80 km north of Eagle River, Wisconsin, but he did not give the exact location. In northwest Wisconsin, Need (1980) reported that the Hansen Creek till and the Douglas till are slightly calcareous; however, the Jardine Creek till, which underlies the Douglas and Hansen Creek till units, is not.

The drilling and field work conducted during this study did not find evidence of a surface or buried calcareous unit in the Vilas County area. In conducting detailed groundwater studies in the Crystal Lake area, Galen Kenoyer (1984 verbal communication) also found no evidence for a calcareous unit. The largest amount of carbonate determined by gasometric analysis on the coarse silt fraction of any sample was 2.6% and this is very large by comparison to other samples (Attig, 1984c). Of 255 samples, 28 showed a reaction to 10 percent HCl. Each sample that showed a reaction was examined under a binocular microscope and in all samples the reaction was observed taking place on calcite cement in red sandstone and siltstone (Attig, 1984c).

One chert pebble with a poorly preserved coral was found at the surface in Vilas County, near the east shore of Wild Rice Lake (sec. 6, T. 41 N., R. 6 E.). Four chert pebbles containing moderately-well-preserved corals, bryozoans, and crinoid fragments were found on the south shore of Lake Superior about 1 km east of Little Girls Point. Klaus Westphal (1983, verbal communication) examined the fossils, determined they were not well enough preserved for precise identification but speculated that they were Silurian or Devonian in age. Drilling at the Lac Du Flambeau well site (See appendix, log 90), encountered 10 m of noncalcareous uniform, medium sand. The samples from the Lac Du Flambeau well archived at the Wisconsin Geological and Natural History Survey are calcareous, and it is believed that log Vi-6 may be based on mislabeled samples.

The new evidence neither confirms nor refutes the existence of buried calcareous sediment in parts of Vilas County and adjacent areas; however, some discussion of the possible source of such sediment is worthwhile. Precambrian sandstone contributes a small amount of calcite to the glacial sediment of the area. Precambrian dolomite, at least where exposed at the surface northwest of Vilas County, occupies low positions in the landscape and contributed little material to the glacial sediment. Any large amount of carbonate must have been derived from a Paleozoic source to the east in the Michigan basin (as suggested by Fries, 1938), to the north and northeast from the James Bay lowland, or from unknown Paleozoic outliers in north-central Wisconsin or the Upper Pennisula of Michigan.

No calcareous unit has been found in eastern Vilas County or adjacent western Forest County (Simpkins, 1979), and therefore an eastern or Green Bay Lobe source is unlikely. The pebbles of chert containing Silurian and Devonian fossils are common in the Nipigon area north of Lake Superior (Zoltai, 1965) and have been found on the south shore of Lake Superior, in Vilas County (this report), and Oneida County (Broughton, 1941). The transport of Paleozoic rock from the Hudson Bay and James Bay lowland to the Upper Peninsula of Michigan and north-central Wisconsin is believed to be the most likely source for these fossiliferous pebbles. This dispersal of rock from the James Bay area to northern Wisconsin is consistent with ice-flow paths suggested by Tyrrell (1898), Shilts (1982, 1980), and Shilts and others (1981, 1979).

No outliers of Paleozoic rock have been identified in north-central Wisconsin or adjacent Michigan; but the area is densely forested, Pleistocene sediment is thick, outcrops are few, and most of the area has not been studied in detail.

Use of Materials

The Pleistocene materials in Vilas County provide water to wells and are a source of construction aggregate. Groundwater supplies in volume sufficient for domestic use are available in most areas. The thick Pleistocene sand and gravel units are generally porous and permeable. In many areas of the county extensive units of sand and gravel are separated from lower units of sand and gravel by layers of till and debris-flow sediment (sections A to G, plate 1). Adjacent to many lakes, debris-flow sediment is interlayered with stream-deposited sand and gravel and silty lake sediment. In these areas, as well as in the Winegar Moraine, local conditions may greatly affect drilling conditions and the availability of water to wells.

Sandy gravel and gravelly sand deposited by braided streams is the major source of construction aggregate in the county (units ending in **gp** or **gc,** plate 1). In most areas this sediment is too well sorted and too fine to be of economic value. Commercial operations are typically located near the ice-contact source of the sediment. In these areas, the sediment is typically only crudely sorted and a wide range of particle sizes is available. Most active operations in Vilas County are mining sand and gravel from areas adjacent to the ice-marginal positions shown in figure 28, or adjacent to ice blocks that shed debris flows onto stream surfaces (figs. 22 and 23). In eastern Vilas County several aggregate operations mine till, debris-flow sediment, and stratified sand and gravel from drumlins.

Landforms

The distribution and morphology of glacial landforms such as drumlins, eskers, stream-deposited surfaces, and moraines along with the nature and distribution of the glacial materials allow the glacial history of the area (discussed in the next section) to be interpreted. In this section the distribution and morphology of the major landforms types in Vilas County are discussed. Where possible, landform development is also discussed.

Drumlins

Drumlins, subglacially streamlined hills, are a prominent part of the landscape in two parts of Vilas County. Drumlins occur northwest and southeast of Trout Lake in west-central Vilas County (plate 1, unit **Wtd**), and they are the most conspicuous landform in the eastern part of the county (plate 1, unit **Ntd**).

The drumlin topography in the Trout Lake area of west-central Vilas County is shown on plate 1 as map unit **Wtd,** and the drumlins are clearly shown on the Boulder Junction 7.5-minute topographic quadrangle (fig. 16). The long axis of each of these irregularly shaped drumlins is oriented south-southwest—north-northeast. These drumlins provide the best evidence for the advance of the south-southwest flowing ice of the Wisconsin Valley Lobe in the western part of the county. The irregular shape of the drumlins in this area may be due to the draping of thick supraglacial debris-flow sediment over a subglacially formed core or it may be due to pre-existing topographic irregularities that were not completely smoothed out by the last ice advance. The part of the drumlins exposed above the surrounding, younger, stream sediment is up to 2 km in length and about 0.5 km in width. Relief is about 40 m. The low-relief hummocky surface of these drumlins consists of cobble-rich and boulder-rich debris-flow sediment of the Wildcat Lake Member. Till was encountered in some power-auger holes (See appendix, logs 92 and 95). Evidence from one power-auger hole suggests that these drumlins are cored with stratified sand and gravelly sand (See appendix, log 91). Locally, as southeast of Trout Lake (secs. 20 and 17, T. 41 N., R. 7 E.), irregular ridges composed of crudely stratified and poorly sorted gravelly sand are draped over the drumlins (plate 1).

In the eastern part of Vilas County areas of drumlin topography dominate the landscape (plate 1, unit **Ntd**). The drumlins are clearly illustrated on the Pioneer Lake, Phelps, and Anvil Lake 7.5-minute topographic quadrangles (fig. 17). The long axis of each drumlin is oriented southwest-northeast. The orientation of these drumlins is the best evidence for the advance of the southwest-flowing ice of the Langlade Lobe over eastern Vilas Country. The drumlin areas in eastern Vilas County occur in southwest-northeast trending zones that are separated by southwest sloping stream-deposited surfaces (plate 1, units **Ngp, Ngc**). The elevation of the drumlins decreases from northeast to southwest, and at their western extent the drumlins are buried by braided-stream sediment. The part of the drumlins exposed above the surrounding younger stream sediment is up to 1.5 km in length and 0.5 km in width. Relief decreases from about 50 m in the northeast part of the area to 5 m or less in the southwest. The surface of these drumlins consists of smooth, to low-relief hummocky topography underlain by gravelly supraglacial debris-flow sediment of the Nashville Member.

Geologic sections D, E, F, and G, plate 1, show that the till and debris-flow sediment of the Nashville Member overlie stratified sand and gravelly sand in eastern Vilas County. As shown on section G the limited subsurface data available suggest that in the easternmost area the drumlins are composed of till and debris-flow sediment. Westward from there (sections E and F) the till and supraglacial sediment thins and becomes patchy; some drumlins north of Eagle River (sec. 20, 21, T. 41 N., R. 10 E.) are composed primarily of stratified sand and gravelly sand.

In the area near Spectacle Lake, T. 41 N., R. 12 E., (SE¼ Phelps 7.5-minute quadrangle) drumlin topography grades to the southwest into an area of topography

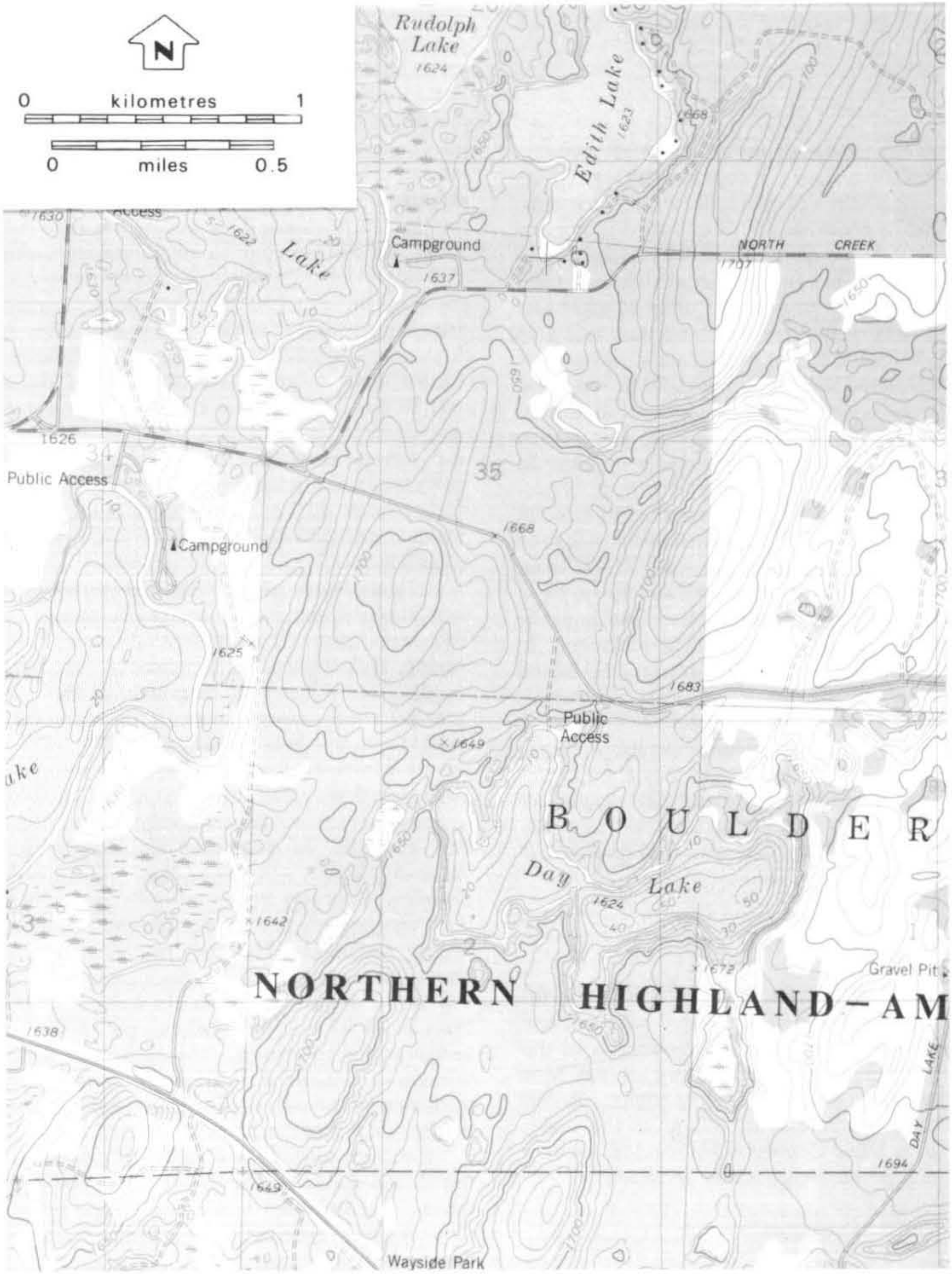

Figure 16. *Part of the Boulder Junction 7.5-minute topographic quadrangle showing drumlins northwest of Trout Lake (T. 42 N., R. 6 E.).*

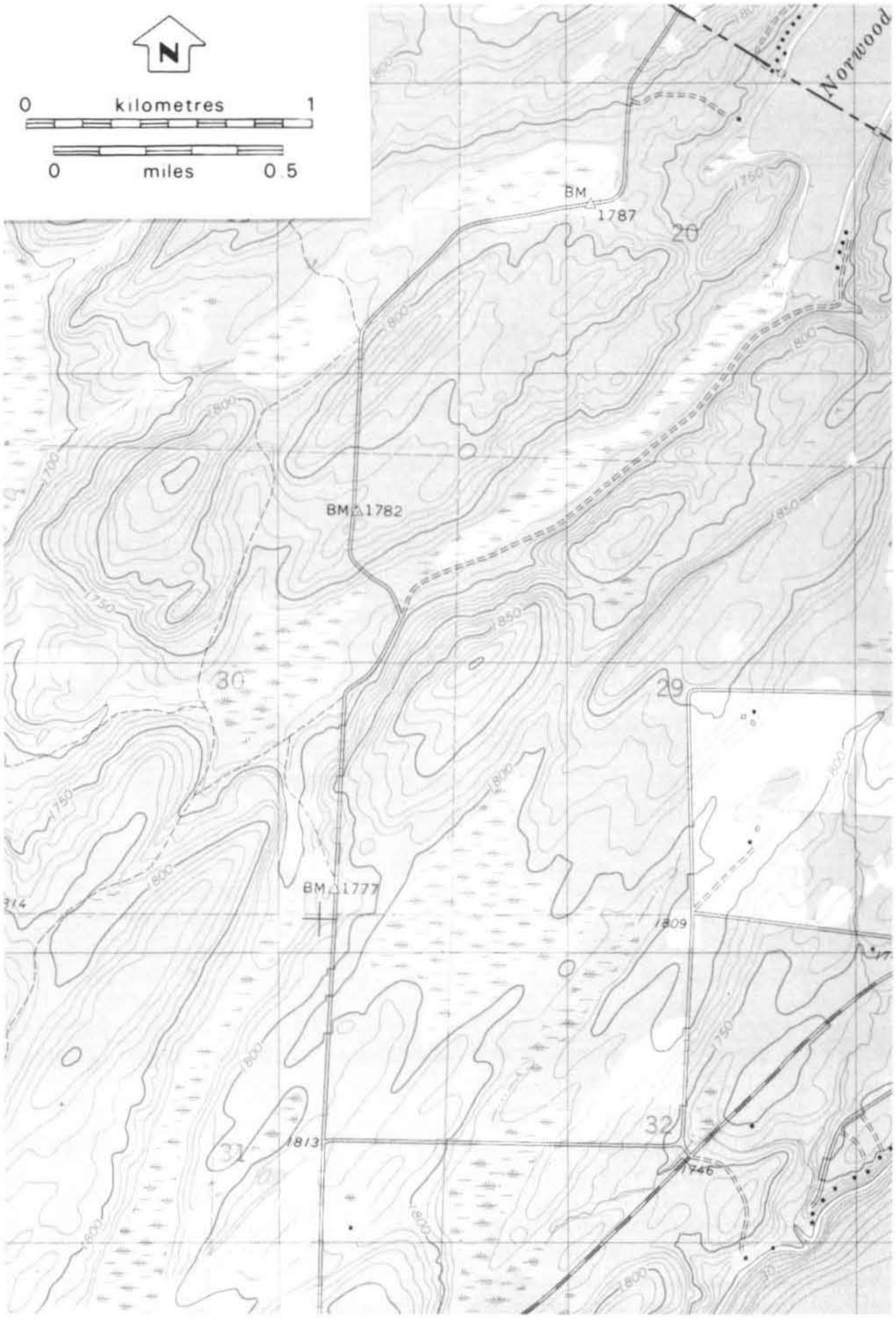

Figure 17. Part of the Phelps 7.5-minute topographic quadrangle showing drumlin topography northeast of the Town of Phelps (T. 42 N., R. 12 E.).

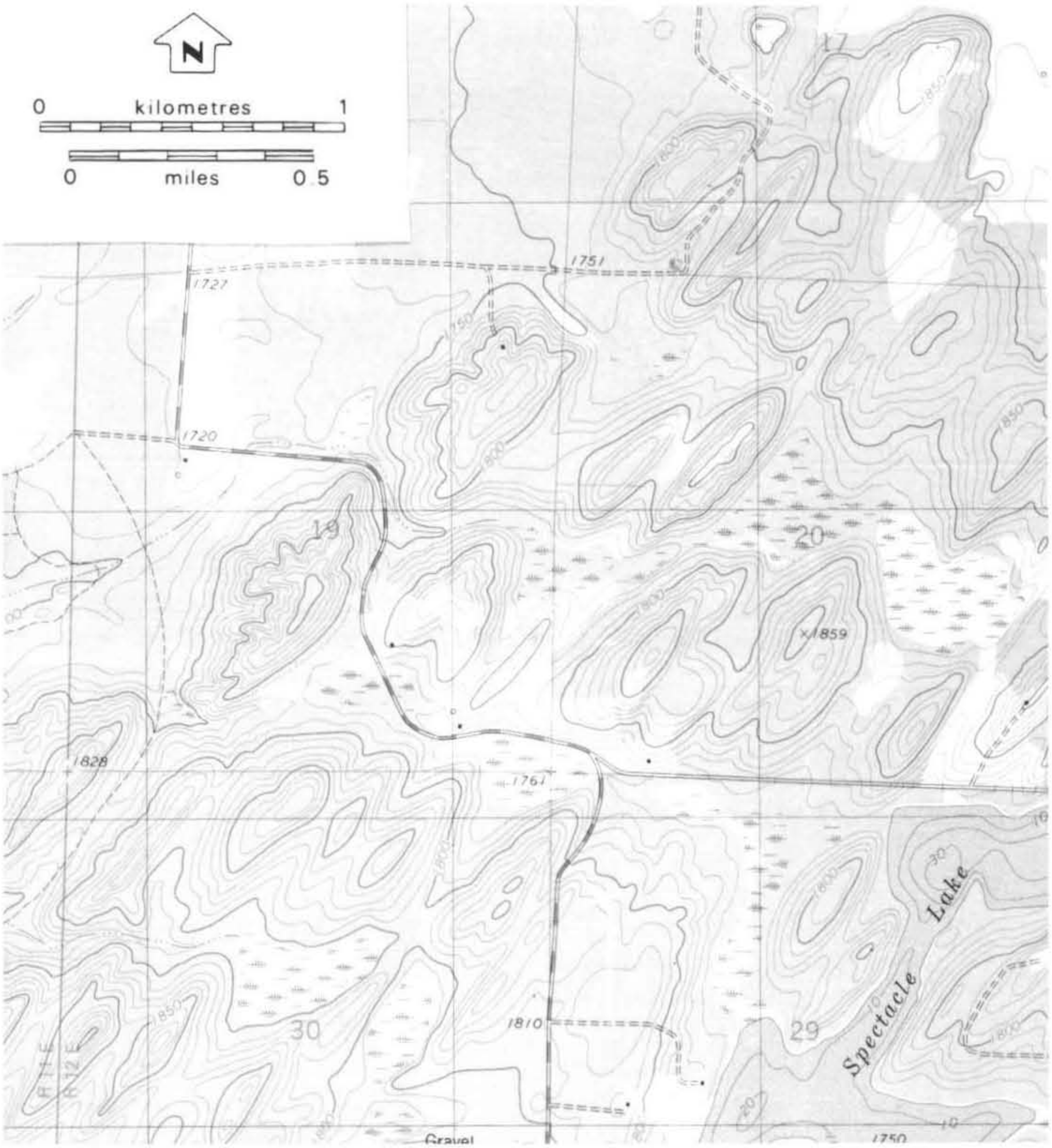

Figure 18. Part of Phelps 7.5-minute topographic quadrangle showing topography resembling Rogen moraine in the Spectacle Lake area (T. 41 N., R. 12 E.).

resembling Rogen moraine. Here the drumlins have very uniform length and width and are somewhat smaller than in surrounding areas. Individual drumlins have sharp crests, and groups of drumlins form arcuate ridges transverse to ice flow. The horns of the arcuate ridges point downglacier (figs. 18 and 19). This topography is similar to Rogen moraine in Sweden (Lundqvist, 1981, 1969), however, the drumlins and the transverse ridges are larger than those in the type area (Lundqvist, 1969· verbal communication, 1983.)

The area of Rogen-like topography is transitional to the northeast and northwest to drumlin areas that do not have the characteristics of Rogen moraine. This progression from drumlins to Rogen moraine is similar to that reported by Lundqvist (1969). In a downglacier direction the arcuate ridges become less evident southwest of Spectacle Lake and further southwest they are apparently buried beneath younger stream-deposited sediment.

Lakes lying transverse to ice flow and between arcuate ridges occur in the Spectacle Lake area (figs. 18 and 19) and are also shown on air photos from the area of transition from drumlins to Rogen moraine in Jamtland, Sweden (Lundqvist, 1969).

Little is known about the shape of the rock surface underlying eastern Vilas County and the internal structure of the drumlins or Rogen-like landforms. What is

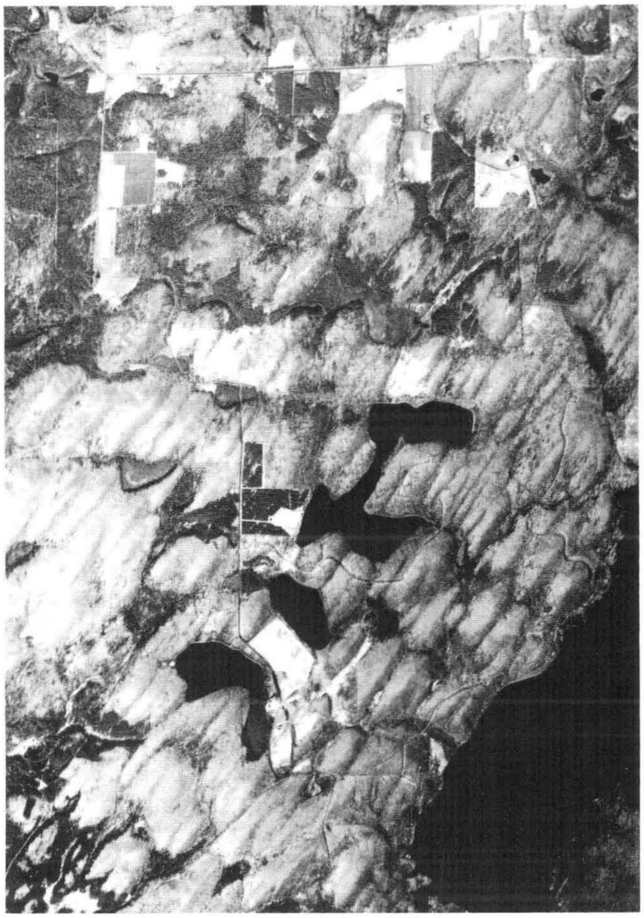

Figure 19. Air photo of the Spectacle Lake area showing topography resembling Rogen moraine. See Figure 18 for location.

known about the rock surface indicates that in eastern Vilas County drumlins occur over convex or high, nearly flat rock surfaces (fig. 20). The Rogen moraine topography appears to occur over a concave area where compressive-flow conditions probably existed near the base of the ice. In general this distribution agrees with that observed in Sweden by Lundqvist (1969) and with the model of Rogen-moraine formation postulated by Shaw (1979). However, because the till and supraglacial debris-flow sediment of the Nashville Member locally overlie stratified sand and gravelly sand (sections F and G, plate 1), the Langlade Lobe advanced over topography different than the rock topography.

Eskers

Eskers are composed of stream sediment deposited in subglacial tunnels. After melting of the bordering ice the deposits of sand and gravel are left in relief as elongate, somewhat sinuous ridges that are typically parallel to the direction of flow of the last ice to cover the area. Eskers deposited beneath the ice of the Wisconsin Valley, Langlade, and Ontonagon Lobes are shown on Plate 1 as map units **Wgs, Ngs,** and **Cgs.**

An esker that formed beneath the ice of the Wisconsin Valley Lobe occurs in secs. 10 and 15, T. 42 N., R. 6 E. (plate 1, unit **Wgs**). Here the esker is a north-south trending ridge about 1 km in length. A 10-m-high exposure in a gravel pit south of Highway K in the SW1/4 sec. 10, T. 42 N. R. 6 E. exposes the stratified sand and gravel in the esker. The degree of sorting and stratification is variable, and faults are common along the flanks of the esker. Only one esker segment that formed beneath the ice of the Langlade Lobe is recognized in eastern Vilas County. This esker located in sec. 29, T. 42 N., R. 10 E. (plate 1, unit **Ngs**) is oriented approximately northeast-southwest. It has a maximum length of about 2 km and numerous small roadcuts show it to be composed of stratified sand and gravelly sand. The distinction on Plate 1 between the small eskers that formed in tunnels beneath the ice of the Wisconsin Valley and Langlade Lobes and ridges formed by collapse of plains deposited by braided streams is not always clear. Many ridges composed of sand and gravelly sand occur throughout central and southwest Vilas County. These are interpreted to be ridges formed by collapse of broad stream-deposited plains rather than eskers.

The eskers deposited beneath the ice of the Ontonagon Lobe during the Winegar Phase are prominent, extensive landforms. Three large north-south trending eskers are present in northern Vilas County. These eskers are located from west to east in secs. 22 and 27, T. 44 N., R. 5 E.; in secs. 19, 30, and 31, T. 44 N., R. 6 E.; and in secs. 2, 11, 12, 13, 24, and 26, T. 43 N., R. 7 E.; and are shown as map unit **Cgs** on plate 1. All three eskers end at or just north of the Winegar ice-margin position (fig. 28). The westernmost of these eskers is

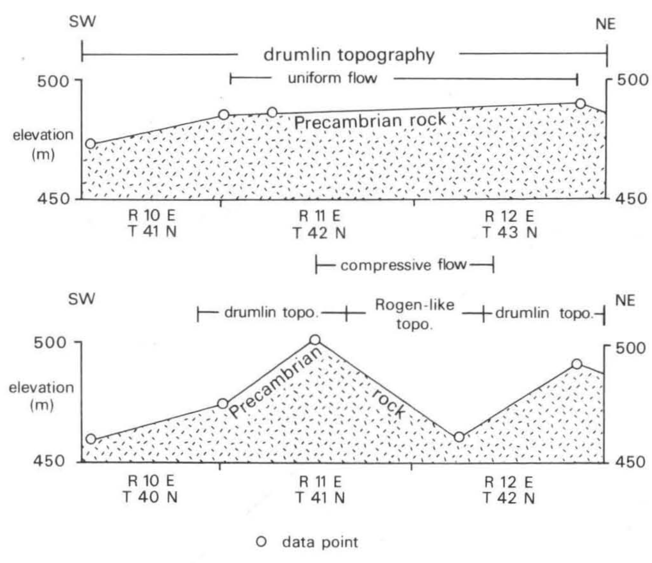

Figure 20. Cross-sections parallel to glacier flow showing the approximate Precambrian rock surface and the location of drumlins, topography resembling Rogen moraine, and areas of possible uniform and compressive flow.

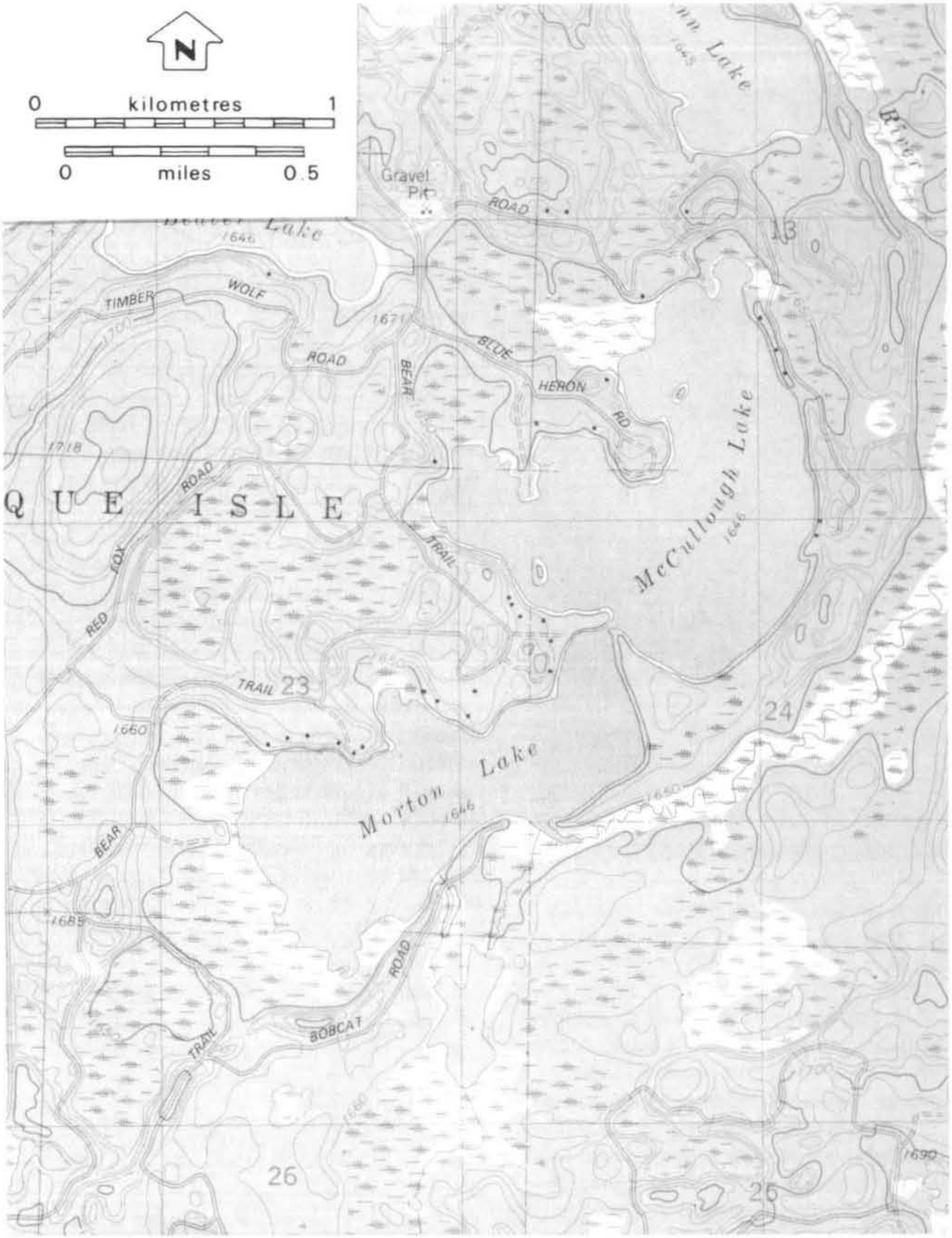

Figure 21. Part of the 7.5-minute Tenderfoot Lake topographic quadrangle showing a north-south trending esker formed beneath the Ontonagon Lobe during the Winegar event (T. 43 N., R. 7 E.). The esker lies along the east and southeast sides of Morton and McCullough Lakes.

about 3 km long in Vilas County and up to 0.4 km wide. It is not clearly expressed topographically north of Vilas County. The esker in T. 44 N., R. 6 E. consists of two parallel ridges about 2.5 km long in Vilas County. The eastern ridge consists of three segments each 0.5 to 0.75 km long. This esker is traceable northward about 20 km as a series of discontinuous ridges to the Marinesco ice-margin position (Peterson, 1982). The easternmost esker (fig. 21) is traceable for about 9 km from the border between Michigan and Wisconsin southward to near the former Winegar ice margin, where it ends east of Wildcat Lake (plate 1; west-central part of the Tenderfoot Lake 7.5-minute topographic quadrangle). This esker is also traceable northward in Michigan to near the Marinesco ice-margin position.

The sediment contained in eskers deposited beneath the Ontonagon Lobe is exposed in only a few small logging road exposures where it consists of sand and gravelly sand that is well-to-poorly sorted and well-to-crudely stratified. Locally debris-flow sediment has been draped over the eskers.

Stream-Deposited Surfaces

The most extensive deposits in Vilas County are those that consist of well-to-poorly sorted, well-to-poorly stratified sandy gravel and gravelly sand deposited by braided streams. This stream sediment becomes better sorted and better stratified with distance from the source area. In many areas the elevation, distribution, or slope of the original depositional surface allows the source of the sediment to be identified. This sediment is included in a specific lithostratigraphic unit on plate 1. In other areas the original depositional surface has been destroyed by collapse and the elevation and distribution of deposits do not provide clear evidence of source. This sediment is shown on plate 1 as belonging to an undifferentiated lithostratigraphic unit.

Braided-stream sediment occurs in three morphologic settings in Vilas County. It underlies extensive plains that contain some depressions (plate 1, units **Wgp, Ngp, Cgp,** and **Ugp**) where the original depositional surface is recognizable in most areas. It underlies relatively small, ice-marginal fans (plate 1, units **Wgf** and **Ngf**) that contain some collapse depressions, have flat surfaces, and clear ice-contact faces. It also underlies extensive hummocky areas where the original depositional surface has been destroyed by collapse (plate 1, units **Wgc, Ngc, Cgc** and **Ugc**). All of these landforms show at least some evidence of having been deposited over or adjacent to ice.

Plains deposited by braided streams (plate 1, units **Wgp, Ngp, Cgp,** and **Ugp**) are common in many parts of Vilas County. These areas have planar surfaces that are locally disrupted by depressions (kettles) that resulted from the melting of ice that was buried during deposition of the plain (Thwaites, 1926) and persisted until braided-stream deposition ceased. Melting of the ice resulted in collapse of the overlying sediment. These depressions are typically floored and surrounded by well-sorted sand or gravelly sand.

In western Vilas County the fluvial plain deposited in front of the Winegar ice margin (fig. 28; see next section) can be traced over broad areas (plate 1, unit **Cgp**). In this area, however, the depressions in the plain are commonly surrounded by slightly hummocky topography underlain by poorly sorted sand, gravelly sand and silty gravelly sand. This material is interpreted to be debris-flow sediment. This is in contrast to the planar surfaces underlain by relatively uniform sand that occur a short distance away from the depressions. The coarse, poorly sorted sediment is most common along the south and southeast margins of depressions but commonly is found surrounding depressions. It is in these locations where most commercial gravel operations are located.

The surface slope of the stream-deposited surface (unit **Cgp,** plate 1) is commonly steeper adjacent to depressions than in other areas. The depressions formed when debris-laden ice blocks melted after braided streams that deposited unit **Cgp** ceased flowing. If they melted prior to that time, the depressions would have been filled in. The coarse poorly-sorted sediment surrounding the depressions was deposited as debris-flow sediment derived from debris-laden ice blocks that stood in relief above the surrounding plain. The ice blocks were local sources of debris and meltwater that contributed to streams flowing from the Winegar ice margin (fig. 28). Two such local sources are shown in figures 22 and 23.

Map units **Wgc, Ngc, Cgc,** and **Ugc** (plate 1) contain braided-stream sediment deposited on top of extensive ice masses. The subsequent melting of the ice resulted in the collapse of the material and the destruction of the original depositional surface. In some places the elevation and distribution of this sediment along with the preservation of the original depositional surface in small areas allows assignment of the material to a specific lithostratigraphic unit on Plate 1.

In most areas these units consist of very hummocky topography underlain almost entirely by stratified sand and gravelly sand (fig. 24). Around depressions, especially some larger ones, coarse, poorly-sorted sediment is commonly present suggesting that, at least locally, debris-rich ice projected through the stream sediment and was supplying coarse, poorly-sorted debris-flow sediment to surrounding areas.

Map units **Ngf** and **Wgf** (plate 1) contain relatively small, fan-shaped areas of stream-deposited sand and gravelly sand. A very conspicuous proglacial fan in eastern Vilas County is shown in figure 25 and on plate 1 as unit **Ngf.** The fan shown in figure 25 was deposited in contact with the receding margin of the Langlade Lobe. Its northern and eastern margins have a conspicuous ice-contact face. As can be seen in figure 25, the surface of this fan slopes to the southwest, away from the ice-contact face. Other conspicuous fans occur in southwestern Vilas County (plate 1, unit **Wgf**).
Wgf).

Moraines

Two types of moraines, till and other sediment that accumulated at the margin of active glacial ice, occur in Vilas County. In the north-central and northwest parts of the county a broad east-west trending 5-to-10 km-wide band of high-relief hummocky topography underlain by till and supraglacial debris-flow sediment is the dominant feature in the landscape (fig. 26). The southern limit of this feature, (plate 1, unit **Ctm**), is a narrow discontinuous ridge.

As discussed by Attig (1983, 1984c) and Attig and others (1983), the hummocky topography in this feature, the Winegar moraine, is interpreted to have formed in at least three ways. Some hummocks are the result of the collapse and redistribution of a thick cover of supraglacial debris-flow sediment as underlying ice melted. Others are due to stacking of till, stream sediment, and supraglacial debris-flow sediment by minor fluctuations of the ice margin, and some are the result of the melting of ice that was buried in the sand and gravelly sand that is older than the till and supraglacial sediment deposited during the Winegar phase. The type of sediment in the narrow ice-marginal ridge and the mode of genesis of the

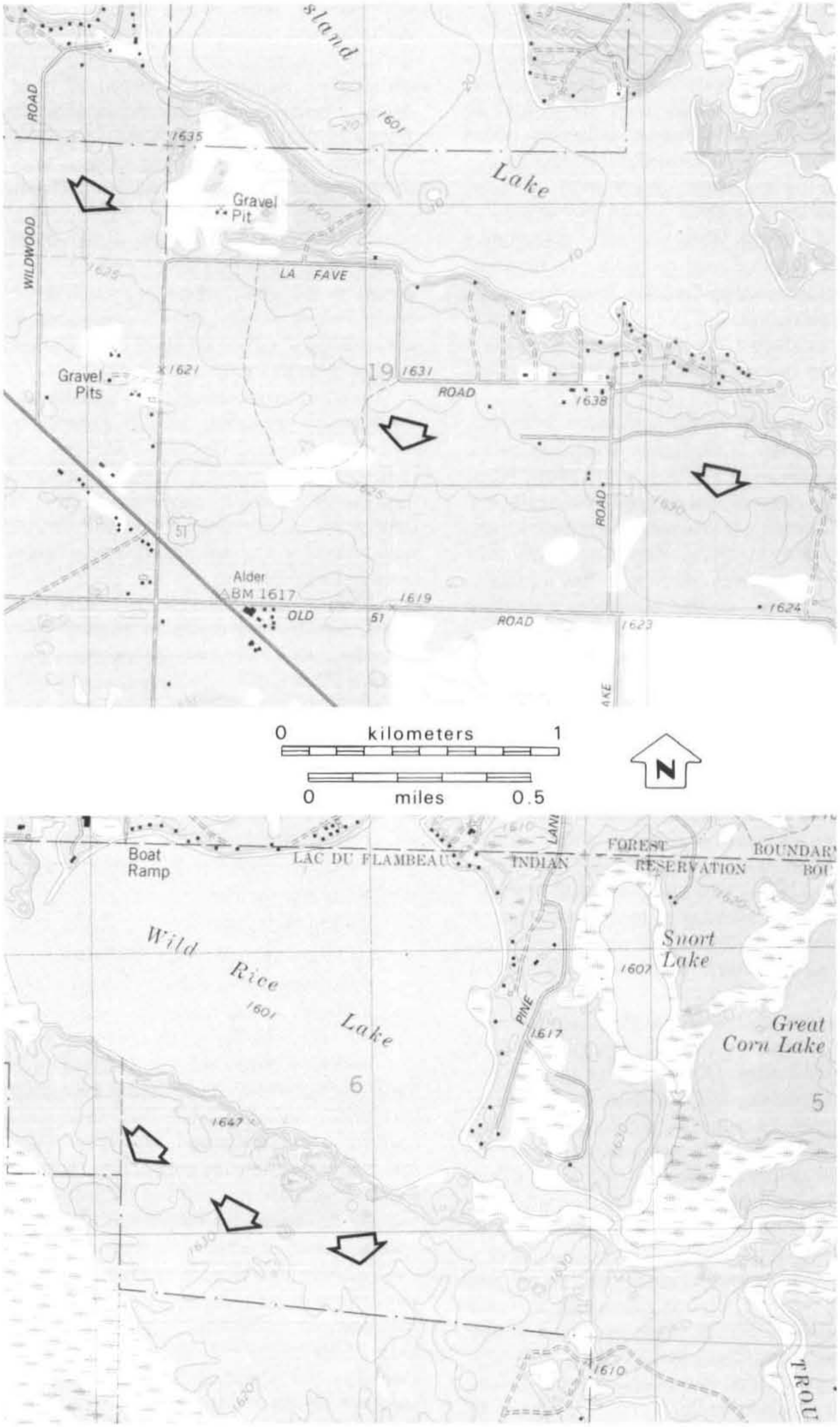

Figure 22. *Two parts of the Manitowish Lake 7.5-minute topographic quadrangle showing an area of proglacial fluvial sediment deposited in front of the Winegar ice margin and areas where local sediment sources resulted in higher elevations and steeper gradients south of ice-block depressions (T. 41 and 42 N., R. 6 E.).*

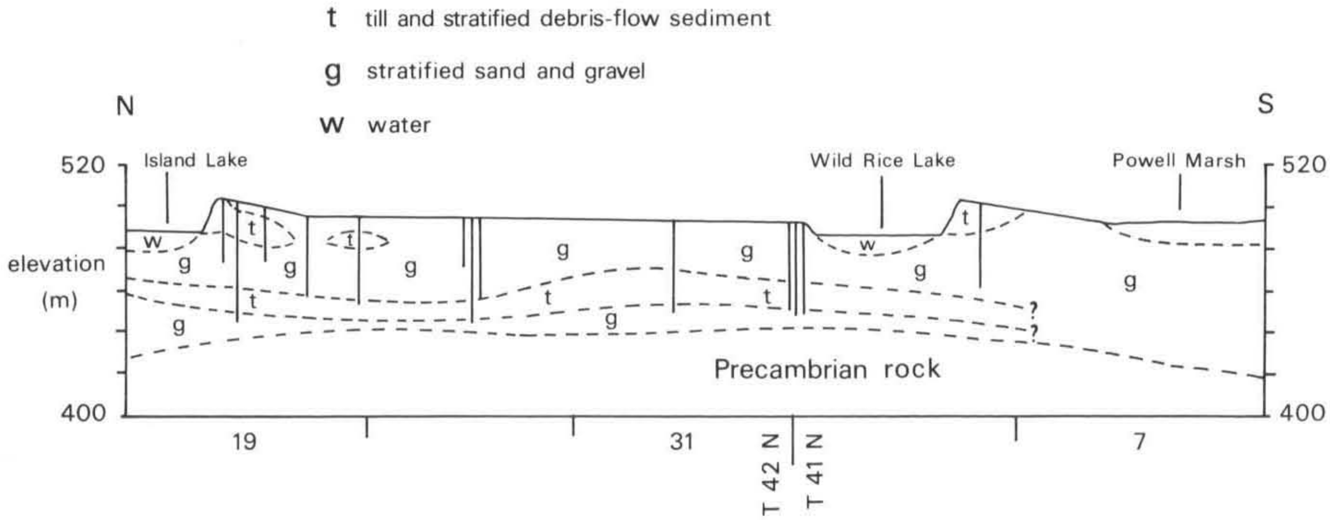

Figure 23. Diagram showing topography and sediment distribution in the areas of two local sources that contributed sediment to streams in front of the Winegar ice margin.

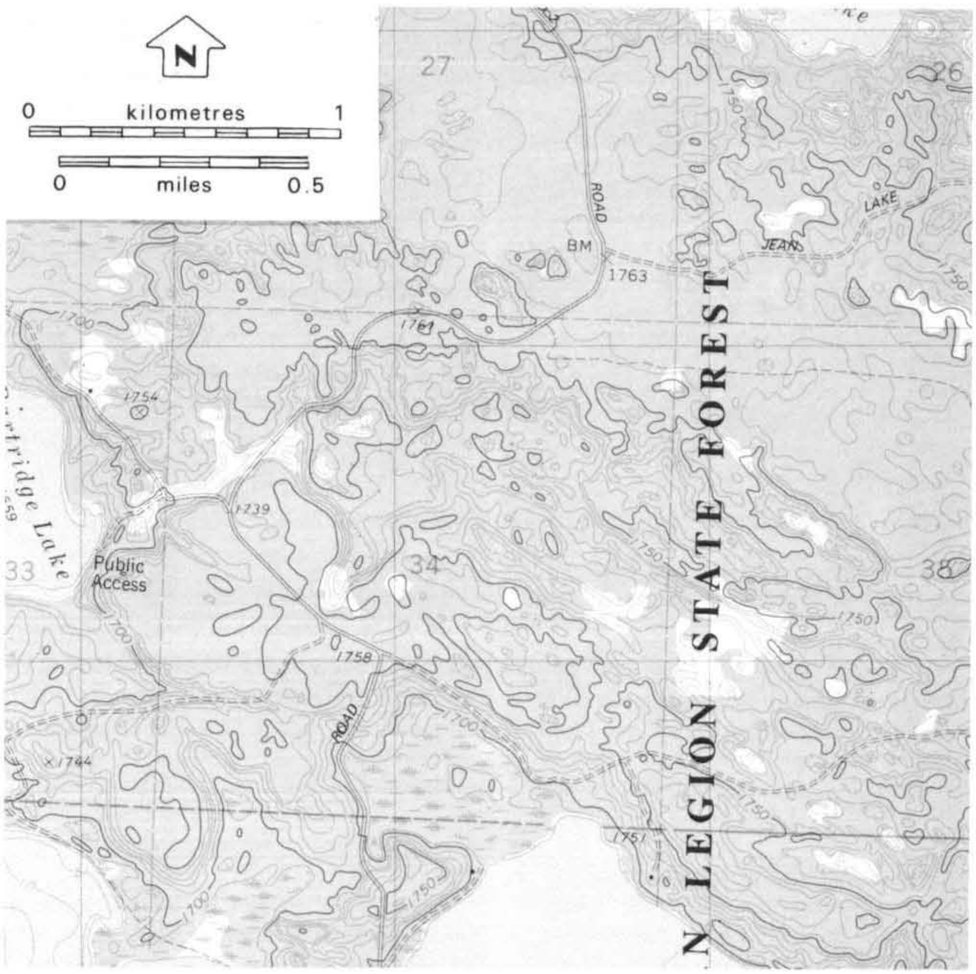

Figure 24. Part of the Star lake 7.5-minute topographic quadrangle showing an area consisting primarily of collapsed braided-stream sediment (T. 42 N., R. 8 E.).

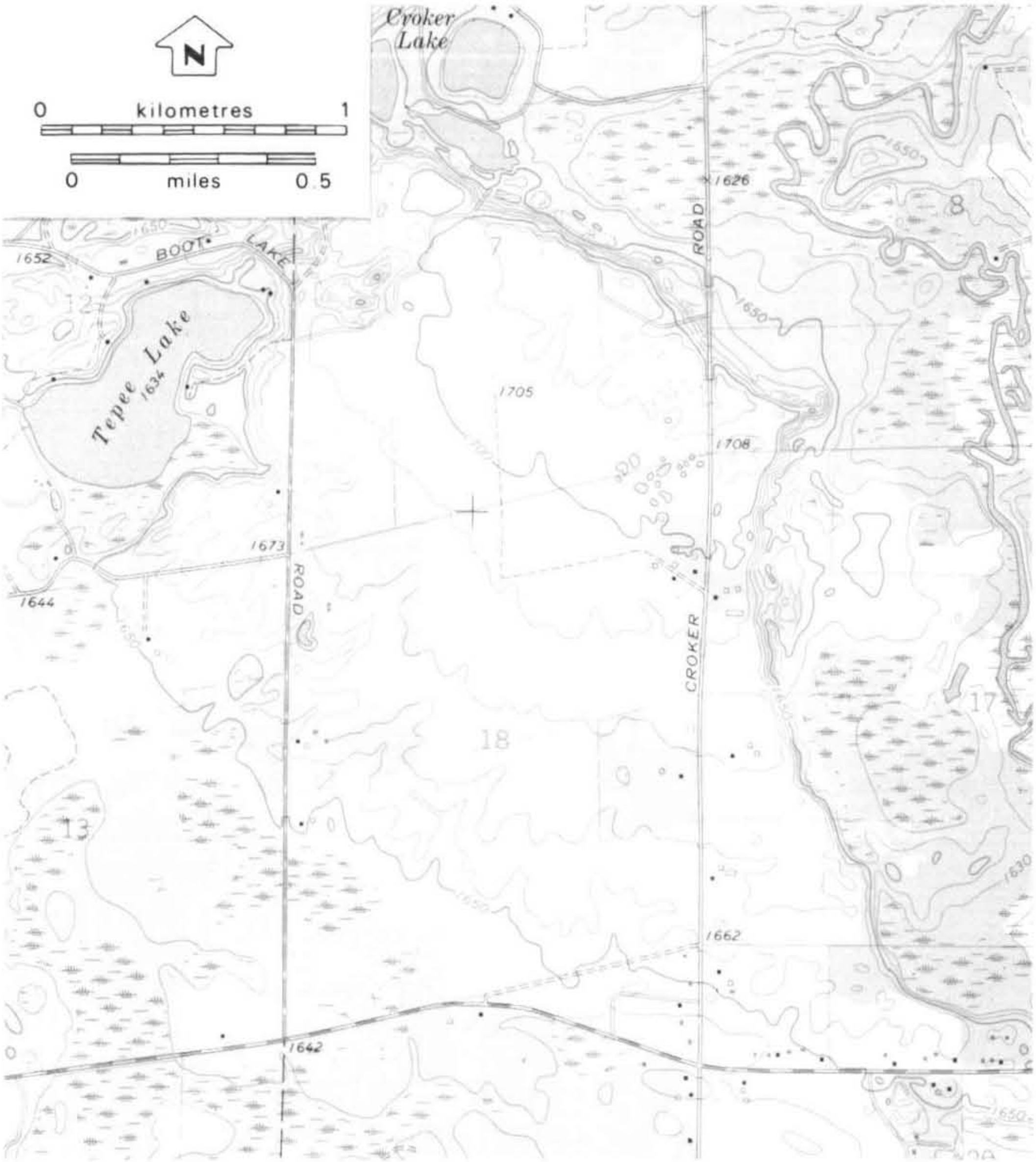

Figure 25. Part of the Eagle River West 7.5-minute topographic quadrangle showing a large ice-marginal fan deposited by meltwater streams flowing from the Langlade Lobe (T. 40 N., R. 10 E.).

ridge are poorly understood because there are few exposures. The surface sediment is gravelly and is probably supraglacial debris-flow sediment of the Crab Lake Member. The ridge probably formed as a result of minor thrusting of ice-marginal sediment by the ice and the accumulation of supraglacial debris at the foot of the ice slope.

The Muskellunge moraine and other moraine segments in southwest Vilas County (plate 1, unit **Wtm**) differ in both morphology and sediment composition from the Winegar moraine. These ridges (fig. 27) trend west-northwest and east-southeast and are much broader than the ice-marginal ridge at the southern extent of the Winegar moraine. Near the Muskellunge Fire Tower (secs. 34, and 35, T. 41 N., R. 7 E.) the Muskellunge moraine consists of a ridge up to 0.5 km wide. Few exposures are present, and they are small, but all show this moraine contains little till. The sediment is sand and gravelly sand that appears to be transitional from supraglacial, debris-flow sediment to stream sediment.

History

The glacial phases in Vilas County have not been absolutely dated; therefore, the late Wisconsin history of the area can only be discussed in terms of the relative ages of sediment and phases and by correlation with distant, dated sites. This section presents a discussion of the history of the last part of the Wisconsin Glaciation in Vilas County, the period between about 25,000 and

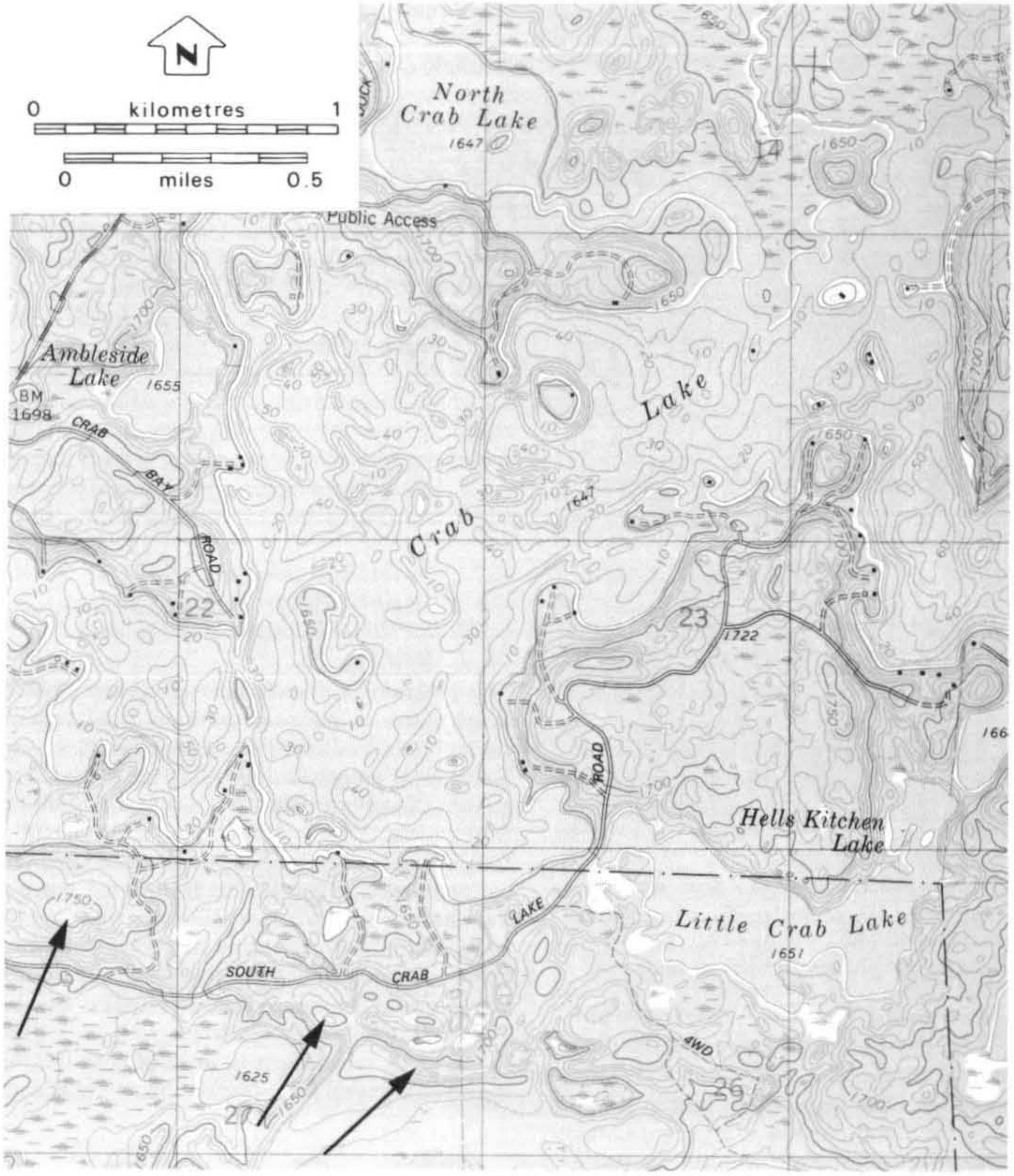

Figure 26. Part of the Presque Isle 7.5-minute topographic quadrangle showing hummocky topography behind the narrow, discontinuous ridge of the Winegar moraine (T. 43 N., R. 6 E.). Arrows point to segments of the discontinuous ridge.

10,000 years ago. The regional chronology of glacial phases in northern Wisconsin during the last part of the Wisconsin Glaciation is discussed by Attig (1984c; and Attig and others, in preparation).

The term "phase" is used to describe the period of time during which the glacial margin advanced to or paused during wastage, at an ice-margin position, and the time of wastage from that position. In most cases it is not known if a phase represents a pause of an ice margin that is wasting back or a considerable advance of the margin.

Former ice-margin positions are defined by the distribution of moraines, ice-contact slopes of stream-deposited fans or plains, and the extent of the till of a lithostratigraphic unit. Inferred ice-margin positions in Vilas County are shown in figure 28. In the following sections four phases are discussed starting with the oldest.

Flambeau Phase

The late Wisconsin ice margin of the Langlade and Wisconsin Valley Lobes probably wasted back from its terminal position in Langlade, Lincoln, and Taylor Counties sometime after 15,000 years ago (Clayton and Moran, 1982). The ice margin of the Wisconsin Valley Lobe eventually wasted back to southwestern Vilas County and stabilized for a period of time at the position

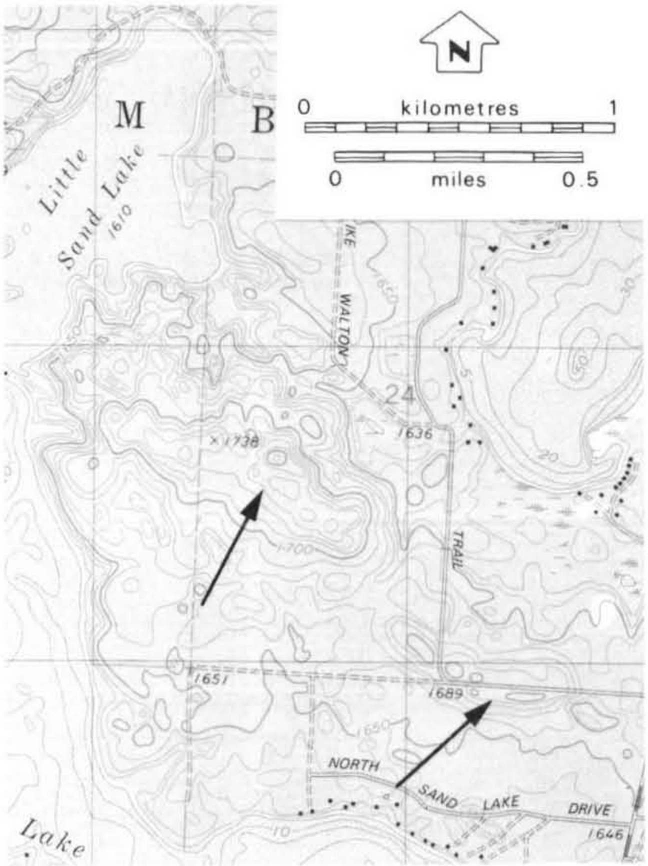

Figure 27. Part of the Manitowish Lake 7.5-minute topographic quadrangle showing several northwest-southeast trending segments of the Muskellunge moraine (T. 41 N., R. 5 E.). Arrows point to segments of the moraine.

marked on figure 28 as the Flambeau ice-margin position. The margin of the Langlade Lobe was south of Vilas County at this time. The Flambeau ice-margin position is marked by the ice-contact slope of two ice-marginal fans. It is also indicated in adjacent Oneida County by a stream-deposited plain with an ice-contact slope and a band of hummocky topography underlain primarily by sand and gravelly sand. The fans are shown on plate 1 as map unit **Wgf** in secs. 22, 27, 35 and 36, T. 40 N., R. 4 E. The areas of hummocky sand and gravel are shown as unit **Wgc.** The ice margin stood at this position long enough to build a stream-deposited surface that heads at about 500 m altitude (fig. 29). Many parts of this surface are collapsed (map units **Wgc,** and small parts of unit **Wgp**), indicating masses of ice stagnated and were buried by the stream sediment beyond the Flambeau ice margin.

The Flambeau Phase has been tentatively correlated with the Summit Lake Moraine in Langlade County (Attig, 1984; Attig and others, in preparation). Mickelson (in press) concluded that the Summit Lake Moraine was deposited by a readvance of the Langlade Lobe. During the Flambeau Phase and the later Bittersweet and Stormy Lake Phases in Vilas County, the Wisconsin Valley Lobe apparently continued to waste while the Langlade Lobe underwent a series of readvances that covered areas formerly occupied by the Wisconsin Valley Lobe.

Muskellunge-Bittersweet Phase

Following the pause at the Flambeau ice-margin position, the Wisconsin Valley Lobe margin next stabilized at the Muskellunge ice-margin position (fig. 30). This ice-margin position is marked by the Muskellunge moraine (Thwaites 1929), which consists of a band of high relief, hummocky gravelly sand with minor amounts of till (map unit **Wtm**, plate 1, secs. 33, 34 and 35, T. 41 N, R. 7 E.). Small ridges parallel to the ice front in this area may consist of ice-shoved stream sediment. The ice margin is traceable to the northwest where ice-marginal ridges occur in secs. 22 and 24, T. 41 N., R. 5 E. These ice-marginal ridges occur at the head of a stream-deposited surface that slopes to the southwest and heads at an altitude of about 520 m in sec. 5, T. 40 N., R. 5 E. and slightly lower, 510 m in sec. 34, T. 41 N., R. 5 E. (fig. 30). The Muskellunge moraine was named by Thwaites (1929) for the area near the Muskellunge fire tower, sec. 34, T. 40 N., R. 7 E.

At the time the Wisconsin Valley Lobe ice margin stood at the Muskellunge position, the Langlade Lobe ice margin stabilized at the Bittersweet position (fig. 30). The Bittersweet margin is defined by the ice-contact edge of a stream-deposited plain that reaches an altitude of about 520 m (sec. 24, T. 40 N., R. 7 E.) near its ice-contact face (map unit **Ngc,** plate 1). The stream-deposited surface associated with this former ice margin slopes to the southwest and merges with that heading at the Muskellunge ice-margin position. This indicates that the Bittersweet Phase of the Langlade Lobe and the Muskellunge Phase of the Wisconsin Valley Lobe may have been nearly contemporaneous.

The fluvial surfaces in front of both the Muskellunge and Bittersweet ice margins have collapsed in many

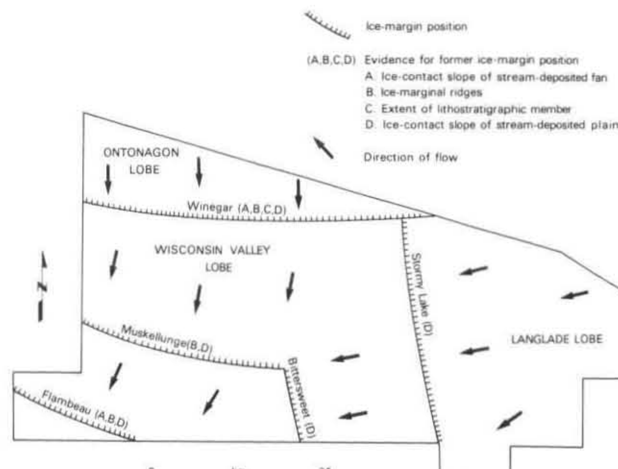

Figure 28. Map showing former ice-margin postions and ice-flow directions in Vilas County.

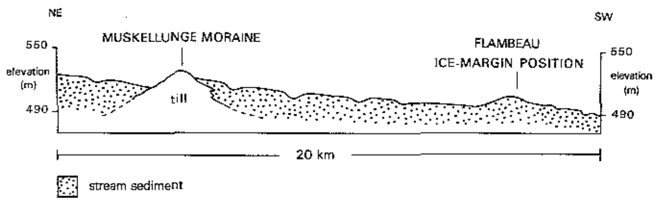

Figure 29. Diagram showing the fluvial surfaces in front of the Flambeau and Muskellunge ice-margin positions.

areas, indicating that stagnant ice was buried by sediment being carried from the glacier by braided streams.

The location of the margin of the Langlade Lobe during the Bittersweet Phase and the later Stormy Lake Phase indicates that the Langlade Lobe was advancing into an area previously occupied by the Wisconsin Valley Lobe. Each of these phases is believed to represent an advance of the Langlade Lobe. The Langlade Lobe was probably advancing over a landscape, that contained masses of ice left from the Wisconsin Valley Lobe. There is no evidence to indicate if the Wisconsin Valley Lobe readvanced during the Muskellunge Phase or simply stabilized during wastage.

Stormy Lake Phase

Following the Muskellunge-Bittersweet Phase, the ice margin of the Wisconsin Valley Lobe is not known to have stabilized again in Vilas County. Thwaites (1929) reported finding the Boulder moraine, of the Wisconsin Valley Lobe, in the Nichols Lake area. This area consists primarily of collapsed sand and gravelly sand, and no evidence is recognized of a pause or readvance of an ice margin in this area.

The Langlade Lobe margin retreated from the Bittersweet position and next stabilized at the Stormy Lake ice-margin position (figs. 28 and 30). This is defined by an extensive ice-contact slope that trends north-south through the central part of the county and reaches a maximum elevation of about 550 m (secs. 21, 28, 9 and 16, T. 42 N., R. 9 E.) near the interpreted ice-contact face. This stream-deposited surface, much of which collapsed, slopes to the west-southwest. Like some of the other surfaces already discussed, it was deposited over stagnant ice and subsequently collapsed in most areas (units **Ngc** and **Ngp** in central part of Vilas County, plate 1).

Attig (1984) and Attig and others (in preparation) have correlated the Stormy Lake Phase with the Laona moraine in Forest County. Thwaites (1943) correlated the Laona moraine with the Bowler moraines which he concluded resulted from a marked readvance of the Green Bay Lobe.

Winegar Phase

After active ice of both the Langlade and Wisconsin Valley Lobes was gone from Vilas County, extensive areas still contained stagnant ice blocks; some of which were buried under stream sediment, others of which were only partly buried. Prior to the melting of this stagnant ice, the Ontonagon Lobe advanced into northern Vilas County and formed the Winegar moraine during the Winegar Phase (figs. 28 and 30). This ice-margin position is defined by the southernmost extent of the till of the Crab Lake Member, the Winegar moraine, and the ice-contact slope of plains deposited by braided streams. The till deposited during the Winegar Phase contains more silt than the till deposited by the Wisconsin Valley and Langlade Lobes, indicating that the ice of the Ontonagon Lobe was advancing over and incorporating silt-rich lake sediment. This shows that the ice margin was north of the drainage divide prior to advancing during the Winegar Phase, and that lakes had formed between the ice and the south flank of the Superior basin.

Following the retreat from the Winegar ice margin, remnant ice of the Wisconsin Valley and Langlade Lobes underlying the Winegar moraine and underlying or partially buried in stream sediment in front of the Winegar moraine melted. This resulted in the formation of the many depressions in the stream sediment, many of which now contain lakes, and was responsible for formation of some of the hummocky topography in the Winegar moraine. The formation of hummocky topography in the Winegar moraine is discussed more completely by Attig (1984c). Where debris-laden ice blocks projected through the stream sediment, debris flows deposited coarse, poorly-sorted debris around the margins of collapse features.

HOLOCENE HISTORY

The landscape of Vilas County has undergone relatively little modification during the Holocene, the last 10,000 years. The glacial features produced between about 25,000 and 10,000 years ago, when glaciers advanced and then wasted, have been modified only

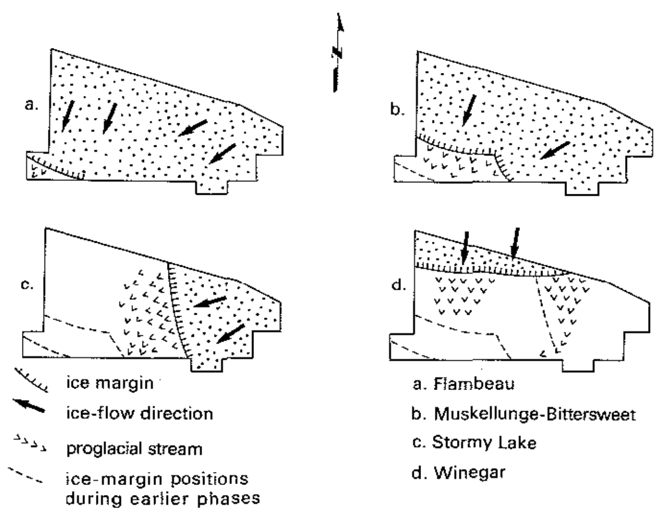

Figure 30. Ice-margin positions during deglaciation of Vilas County (sequence A through D).

slightly. The modification of materials near the surface by physical and chemical processes have led to soil development. Vegetation has covered the area influencing soil development and retarding erosion. Low, wet areas have accumulated organic and mineral material.

The permeable nature of much of the surface sediment in Vilas County facilitates rapid infiltration of rain and snow melt minimizing erosion and inhibiting the formation of a well-developed (integrated) drainage system. Ultimately erosion will reduce the relief of the landscape in the area destroying many glacial landforms, and headward erosion by streams will drain many of the lakes.

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APPENDIX

LOGS OF POWER AUGER HOLES

Explanation of the format and abbreviations used for the logs of auger holes.

auger hole #
location
¼,¼,¼ sec., Township, Range
depth in metres
short verbal description
sorting, compaction, color, rounding, (see below for abbreviations)

1	SE,SE,NW,19,42N,6E 0-30.5	uniform fine-to-medium sand	W,NC,LB,MWR

sorting:
- W well sorted
- MW moderately-well sorted
- P poorly sorted
- VP very-poorly sorted

compaction:
- C compact
- NC not compact
- VC very compact

color:
- VLB very-light brown
- LB light brown
- B brown
- RB reddish brown
- R red
- VDR very-dark reddish brown
- G gray

rounding:
- A angular
- PR poorly rounded
- MWR moderately well rounded
- VWR very-well rounded
- W well rounded

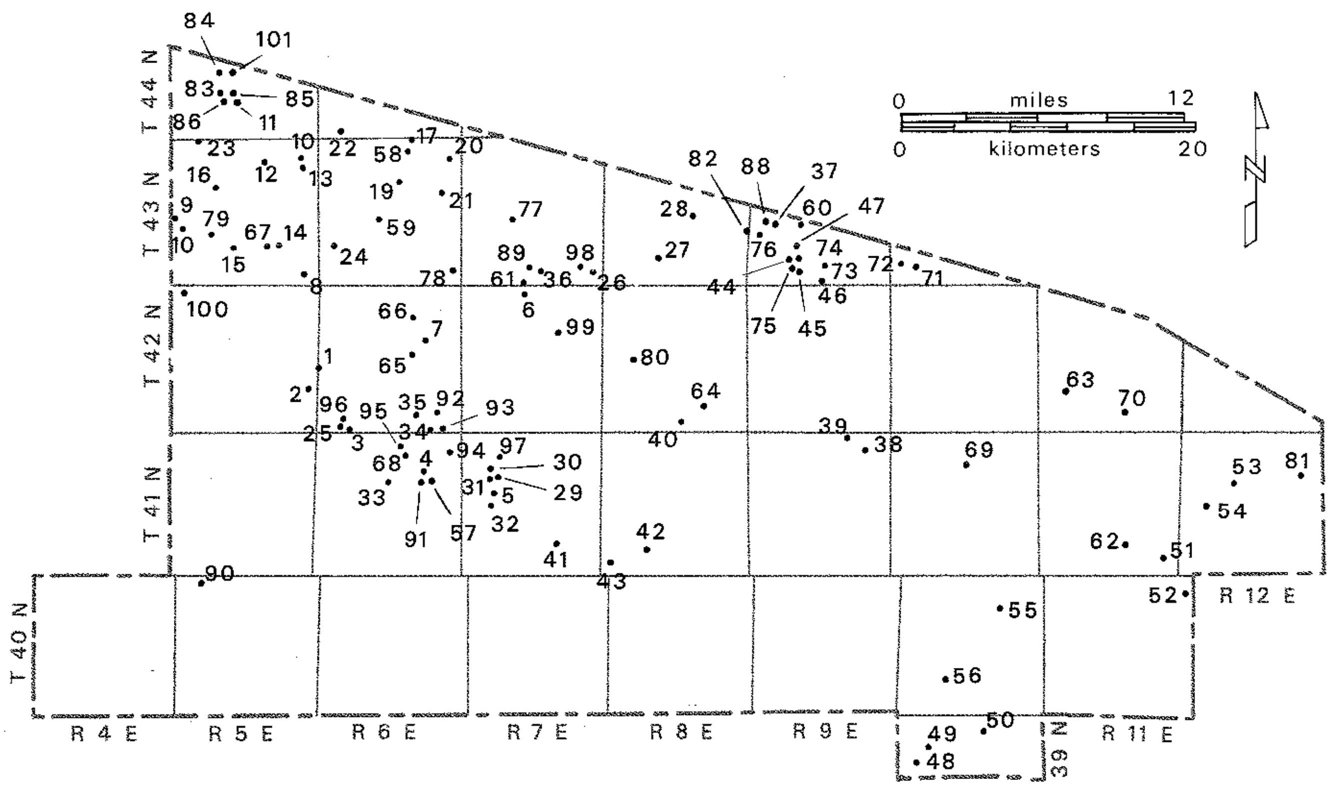

Figure A-1. Location of power auger holes

1	SE,SE,NW,19,42N,6E		
	0-30.5	uniform fine-to-medium sand	W,NC,LB,MWR
2	SE,NE,NE,25,42N,5E.		
	0-10.2	uniform fine-to-medium sand with lenses of silt	W,NC,LB,NWR
	10.2-14	variable gravelly loamy sand	VP,C,B-G,PR
3	NE,SE,SW,32,42N,6E		
	0-11	uniform medium-to-coarse sand	MW,NC,B,A
	11-15.5	variable gravelly loamy sand	P,C,RB,PR-A
4	SE,NW,SE,11,41N,6E		
	0-3	variable slightly gravelly loamy sand	P,NC-C,RB,A
5	SW,NE,SW,17,41N,7E		
	0-2.4	variable gravelly loamy sand	P,C,RB,A
6	SW,NW,NE,4,42N,7E		
	0-30	uniform fine and medium sand with lenses of coarse sand, becomes more gray with depth	MW,NC,B-G,MWR
7	SE,NW,NE,14,42N,6E		
	0-3.3	uniform medium and fine sand	W,NC,LB,MWR
	3.3-7	variable gravelly sand and loamy sand	P,C,RB,PR
	7-20.1	uniform medium sand with lenses of pebbles	W,NC,LB,MWR
8	SE,SW,NE,36,43N,5E		
	0-16	uniform medium and fine sand with lenses of gravel	MW,NC,LB,MWR
9	NE,SE,NW,19,43N,5E		
	0-2	variable gravelly sandy loam	P,C,RB,PR
10	SW,SW,NE,19,43N,5E		
	0-16.5	uniform medium to coarse sand with some gravel	MW,NC,LB,MWR
11	NW,SE,NE,28,44N,5E		
	0-6.1	variable gravelly sandy loam	P,NC,RB,PR
	6.1-10	uniform silty sand	WS,NC,RB,MWR
	10-13	variable gravelly sandy loam	P,NC-C,RB,PR
12	SW,SW,SW,2,43N,5E		
	0-6	variable slightly gravelly silty loam	MW,C,VDR,PR
	6-16.5	uniform sandy silt	MW,NC,RB,PR
13	SW,SE,SE,1,43N,5E		
	0-2.5	variable slightly gravelly silty loam	MW,C,VDR,PR
	2.5-4	uniform very fine sand	W,NC,RB,MWR
14	SW,NW,NE,26,43N,5E		
	0-4.1	variable gravelly loamy sand and sandy loam	VP,NC-C,RB,PR
	4.1-6.5	uniform silty fine sand	MW,NC,RB,PR
	6.5 15	variable gravelly loamy sand to sandy loam	VP,NC-C,RB,PR
	15-21.1	gravelly sand	P,NC,RB,A
15	SW,SE,NE,28,43N,5E		
	0-31	uniform medium and fine sand with lenses of gravel	W,NC,B,MWR
16	NW,SW,SW,9,43N,5E		
	0-3.5	gravelly sand	VP,NC-C,B,PR
17	NW,NW,NW,2,43N,6E.		
	0-7.4	variable gravelly sand and loamy sand	VP,NC-C,B,PR
18	NW,SE,SE,1,43N,5E		
	0-3.5	uniform medium sand with lenses of fine sand and silty sand	W,NS,B,MWR
	3.5-17	uniform silty fine sand	W,NC,RB,MWR
	17-21.2	variable gravelly loamy sand	P,C,RB,PR
19	NW,NW,SE,10,43N,6E		
	0-5	gravelly sand and loamy sand with lenses of uniform medium or coarse sand	VP,NC,RB,PR
20	SW,NW,SE,1,43N,6E		
	0-4.5	gravelly sand and loamy sand	VP,NC,RB,PR
21	NW,NE,NW,13,43N,6E		
	0.3.1	coarse sand with lenses of gravel	P,NC,G-B,PR
	3.1-5	uniform fine sand with lenses of clay	W,C,B,MWR
	5-8.5	variable gravelly sand and loamy sand	VP,C,RP,PR
22	SW,NE,SW,35,44N,6E		
	0-4.5	variable gravelly loamy sand	VP,C,RB,PR
23	SE,SE,SW,35,44N,5E		
	0-30	uniform medium and coarse sand with lenses of gravel	W,NC,LB,MWR
24	NE,SE,NE,30,43N,6E		
	0-4	variable gravelly sand and loamy sand	VP,NC-C,RB,PR
	4-13.1	very coarse sand with lenses of gravel	P,NC,LB-G,PR
25	SE,NW,SW,32,42N,6E		
	0-3.6	uniform medium and coarse sand	MW,NC,LB,PR
	3.6-6	gravelly sandy loam	P,C,RB,PR
	6-23.5	coarse sand with lenses of fine sand and gravel	MW,NC,LB,PR
26	NW,SW,NE,36,43N,7E		
	0-3	coarse sand with lenses of gravel	P,NC,B,PR
27	NE,SW,SW,28,43N,8E		
	0-2.4	variable gravelly loamy sand	VP,NC-C,RB,PR
	2.4-8.5	sandy gravel	P,NC,LB,PR
28	NW,NE,NE,22,43N,8E		
	0-8.2	variable gravelly sandy loam	VP,NC,RB,PR
	8.2-9.3	uniform medium and fine sand with lenses of gravel	W,NC,LB,PR
	9.3-15	gravelly sandy loam	VP,NC,RB,PR
29	SE,NE,SW,8,41N,7E		
	0-4.1	uniform medium sand	W,NC,LB,PR
	4.1-6.5	variable gravelly sand to loamy sand	VP,NC-C,RB,PR
30	SE,NE,SW,8,41N,7E		
	0-7.5	uniform medium sand	W,NC,LB,MWR
31	SE,SE,SW,8,41N,7E		
	0-3.4	uniform slightly gravelly sandy loam	P,C,RB,PR
32	NE,NE,NW,20,41N,7E		
	0-3.3	variable gravelly sand	MW,NC,LB,A
33	NE,NW,NW,15,41N,6E		
	0-1.1	uniform medium sand	W,NC,LB,PR
	1.1-4	uniform gravelly sand	P,C,RB,PR
34	SE,SE,SE,35,42N,6E		
	0-1.5	variable gravelly sand	P,NC,RB,MWR
35	SE,SW,NW,35,42N,6E		
	0-3	variable gravelly sand	P,C,RB,PR
36	NE,SE,NW,34,43N,7E		
	0-6.5	very gravelly sand	P,NC,LB,PR
	6.5-11	uniform coarse sand with lenses of gravel	MW,NC,LB,MWR
37	NE,SW,NW,20,43N,9E		
	0-4	variable gravelly sandy loam	P,NC-C,RB,PR
38	NW,NE,SE,2,41N,9E		
	0-2.5	variable slightly gravelly sand and loamy sand	P,C,B,PR
39	SW,NW,NW,2,41N,9E		
	0-6	uniform medium sand with lenses of gravel	MW,NC,LB,MWR
	6-11.5	variable gravelly loamy sand	P,NC-C,B,PR
40	SE,NE,SW,34,42N,8E		
	0-21	uniform fine and medium sand with lenses of gravel	MW,NC,LB,PR
41	NE,SE,SE,27,41N,7E		
	0-14.5	sand and gravelly sand	MW,NC,LB,MWR
42	NW,NW,NE,32,41N,8E		
	0-31	sand and gravelly sand	MW,NC,LB,MWR
43	NW,NW,SW,31,41N,8E		
	0-33	uniform fine sand with lenses of gravel	MW,NC,LB,MWR
44	NE,SE,SE,29,43N,9E		
	0-10	uniform medium sand with lenses of gravel	MW,NC,LB,MWR
45	SE,SW,NW,33,43N,9E		
	0-6	uniform medium and coarse sand with lenses of gravel	MW,NC,LB,MWR
46	NW,NW,SW,34,43N,9E		
	0-5.5	medium and fine sand with some silt lenses	MW,NC,LB,MWR
47	NW,SW,NW,28,43N,9E		
	0-3.4	variable gravelly sandy loam	P,C,RB,PR
48	NW,SW,SE,18,39N,10E		
	0-8.5	uniform medium and fine sand with thin lenses of gravel	MW,NC,LB,MWR
49	NW,NW,NW,17,39N,10E		
	0-3	variable gravelly sand	P,NC,B,PR
50	SE,SE,NW,10,39N,10E		
	0-3	gravelly sandy loam	VP,NC-C,B,PR
51	SW,SE,NW,36,41N,11E		
	0-4	gravelly sand	VP,NC-C,B,PR
52	NW,SE,SE,1,40N,11E		
	0-6.5	variable gravelly sandy loam	VP,NC,B,PR
53	SW,NE,NW,16,41N,12E		
	0-3	variable slightly gravelly sand	P,NC-C,B,PR
54	SE,NW,NW,20,41N,11E		
	0-4.5	gravelly sand	P,C,B,PR
55	NW,SW,SW,11,40N,10E		
	0-17.5	uniform medium sand	W,NC,G,MWR
56	SE,SW,SE,29,40N,10E		
	0-15	uniform silty fine sand	W,NC,G,MWR
57	SE,NW,SE,11,41N,6E		
	0-2.5	variable gravelly sand	VP,NC,B-RB,PR
58	NW,NW,NW,2,43N,6E		
	0-3.1	uniform slightly gravelly sandy loam	VP,C,RB,PR
	3.1-4.2	variable gravelly loamy sand and sandy loam	VP,NC-C,RB-B,PR
	4.2-6	uniform coarse sand with lenses of gravel	P,NC,G,PR

59	NE,SW,NE,21,43N,6E		
	0-17.5	uniform medium sand	W,NC,B,MWR
	17.5-22	variable gravelly sand to loamy sand	VP,NC,RB,PR
60	NE,SW,NW,20,43N,9E		
	0-13.5	variable slightly gravelly sand	VP,NC,RB,PR
	13.5-18	uniform medium sand	W,NC,B,MWR
61	NW,SE,SE,33,43N,7E		
	0-10	uniform medium sand	W,NC,B,MWR
	10-13	variable gravelly sand to loamy sand	VP,NC-C,RB,PR
62	NW,SE,SE,27,41N,11E		
	0-11	uniform medium to coarse sand with some gravel	P,NC,B,PR
63	SW,NE,NW,29,42N,11E		
	0-1.5	gravelly sand	VP,NC-C,B,PR
	1.5-6.4	uniform medium to coarse sand with some gravel	MW,NC,B,PR
64	NE,SW,SW,26,42N,8E		
	0-13.5	uniform medium sand with lenses of gravel	MW,NC,B,MWR
65	NE,SW,SE,14,42N,6E		
	0-17.5	uniform medium sand	MW,NC,LB,MWR
66	NE,SW,NW,11,42N,6E		
	0-4.6	variable gravelly sand and loamy sand	P,NC,RB,PR
67	NW,SE,NW,26,43N,5E		
	0-8	variable gravelly sand and loamy sand	P,NC-C,RB,PR
68	NW,SE,SE,3,41N,6E		
	0-4	variable gravelly sand	VP,NC,B-RB,A
	4-13	uniform slightly gravelly loamy sand	P,C,RB,A
69	SW,SW,NW,10,41N,10E		
	0-14.5	uniform gravelly sand to sandy loam	P,C,B,A
70	NW,NW,NE,34,42N,11E		
	0-2	variable gravelly sand	VP,NC,B,A
	2-6.5	uniform gravelly sandy loam	P,C,B,A
71	NW,NW,NW,32,43N,10E		
	0-21	uniform fine and medium sand with lenses of gravel	MW,NC,LB,A
72	NW,NE,NW,31,43N,10E		
	0-5	uniform gravelly sand	P,NC,LB,PR
73	NE,NE,NW,34,43N,9E		
	0-2.5	variable gravelly sand	VP,NC-C,RB,PR
	2.5-28	gravelly sand with lenses of gravel	P,NC,LB,MWR
74	SW,NW,SW,28,43N,9E		
	0-2	variable gravelly loamy sand	VP,NC,RB-B,PR
	2-6	uniform slightly gravelly sandy loam	VP,C,RB,PR
	6-14	uniform medium and coarse sand	MW,NC,B,MWR
75	SE,SE,SE,29,43N,9E		
	0-2.5	variable gravelly sand	VP,NC-C,RB,PR
	2.5-14	uniform medium and coarse sand	MW,NC,B,MWR
76	NW,SE,SW,19,43N,9E		
	0-7.5	uniform gravelly sandy loam	VP,C,RB,PR
	7.5-14.5	uniform coarse sand	MW,NC,G,A
77	NE,SW,NW,21,43N,7E		
	0-3.5	variable gravelly sand to loamy sand	VP,NC-C,B,PR
78	NW,SW,NE,36,43N,6E		
	0-13.5	uniform medium to coarse sand with lenses of gravel	MW,NC,LB,MWR-A
79	NE,SE,SE,20,43N,5E		
	0-3.5	variable gravelly loamy sand to sandy loam	VP,NC,RB,PR
80	SE,SE,SW,17,42N,8E		
	0.9.5	uniform coarse sand	W,NC,B,A
81	NW,SW,SW,12,41N,12E		
	0-3.5	variable gravelly sand to sandy loam	P,NC-C,B,PR
82	NW,NW,SW,19,43N,9E		
	0-6	uniform medium to coarse sand	MW,NC,LB,MWR
83	SE,SE,SW,21,44N,5E		
	0-4.5	gravelly sand	P,NC-C,RB,PR
84	SE,NW,NW,21,44N,5E		
	0-7.5	gravelly sand and loamy sand	W,NC,LB,MWR
	7.5-14	medium and coarse sand	P,NC,LB,MWR
85	NW,SE,NE,28,44N,5E		
	0-1	uniform slightly gravelly loam to clay loam	MW,C,VDR,PR
	1-14.5	variable gravelly sand to loamy sand	VP,NC,RB,PR
86	SE,SE,NE,28,44N,5E		
	0-1.4	uniform coarse sand with lenses of gravel	MW,NC,G,MWR
	1.4-12	variable gravelly sand to loamy sand	VP,NC,RB,PR
87	NW,SE,SE,33,44N,5E		
	0-11	variable gravelly sand to loamy sand with lenses of silt	VP,NC,RB,PR
88	NW,NW,NE,19,43N,9E		
	0-2.5	variable gravelly sand to loamy sand	VP,NC,RB,PR
	2.5-5	uniform sandy loam	VP,C,RB,PR
	5-24.5	uniform medium sand	W,NC,LB,MWR
89	NE,SW,NW,34,43N,7E		
	0-19.5	coarse sand with thin lenses of fine sand	MW,NC,LB,A
	19.5-22	variable gravelly loamy sand to sand	VP,C,RB,PR
90	SE,NE,SW,5,40N,5E		
	0-10	uniform medium sand	W,NC,LB,MWR
91	SE,NW,SE,11,41N,6E		
	0-1.5	variable gravelly sand to loamy sand	VP,NC-C,RB,PR
	1.5-6	uniform loamy sand to sandy loam	VP,C,RB,PR
	6-12	gravelly sand with lenses of fine to medium sand	P,NC,LB,MWR
92	NW,NW,NW,36,42N,6E		
	0-1.5	variable gravelly sand to loamy sand	VP,C,RB,PR
	1.5-7.2	uniform slightly gravelly loamy sand to sandy loam	VP,C,RB,PR
93	SE,SE,SW,36,42N,6E		
	0-7	variable gravelly sand to loamy sand	VP,C,RB,PR
94	NW,SW,SE,1,41N,6E		
	0-9.5	variable gravelly sand to loamy sand	VP,C-NC,RB,PR
95	SE,NW,SE,3,41N,6E		
	0-5	variable gravelly sand to loamy sand	VP,NC,RB,PR
	5-8.5	uniform sand to loamy sand	VP,C,RB,PR
96	NW,NE,SW,32,42N,6E		
	0-5.5	uniform medium to fine sand with lenses of gravel	MW,NC,LB,MWR
	5.5-8	gravelly sand to loamy sand	VP,C-NC,RB,PR
97	SE,NW,NE,8,41N,7E		
	0-31	uniform medium sand with lenses of silty fine sand	W,NC,LB-B,MWR
98	SE,NW,NW,36,43N,7E		
	0-6.5	uniform medium sand with lenses of gravel	W,NC,LB,PR-MWR
99	SW,SE,SW,11,42N,7E		
	0-22.5	uniform medium sand becomes finer with depth	W,NC,LB,MWR
100	SE,SE,NE,6,42N,5E		
	0-18.5	uniform medium sand	W,NC,LB-B,MWR
101	SE,NW,NE,21,44N,5E		
	0-15	variable gravelly sand to sandy loam	VP,C-NC,RB,PR