UNIVERSITY OF MINNESOTA

MINNESOTA GEOLOGICAL SURVEY
Harvey Thorleifson, Director

Prepared and Published with the Support of
THE CROW WING COUNTY BOARD OF COMMISSIONERS AND
THE MINNESOTA DEPARTMENT OF NATURAL RESOURCES, DIVISION OF WATERS

COUNTY ATLAS SERIES
ATLAS C-16, PART A
Plate 3—Surficial Geology

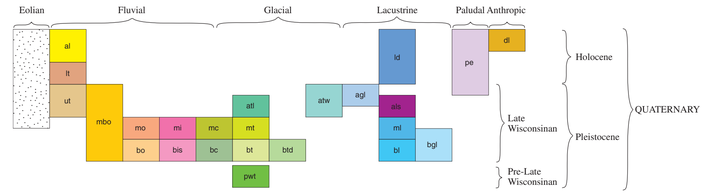
SURFICIAL GEOLOGY

By

Alan R. Knaeble, Gary N. Meyer, and Howard C. Hobbs

2004

CORRELATION OF MAP UNITS



INTRODUCTION

The surficial geologic map shows the materials expected to be encountered at the land surface beneath the topsoil in Crow Wing County. The surface materials can be simplified into three types: till (unsorted sediment [diamicton] deposited by glacial ice), sand and gravel, and lacustrine sand (Fig. 1). Unit contact lines, descriptions, and map symbols were determined from observation and sampling of outcrops, gravel pits, and construction exposures; description and sampling of 220 auger borings averaging approximately 20 feet (6 meters) deep; analysis of core from 3 Minnesota Department of Natural Resources rotary-sonic drill holes (two in Crow Wing County and one in Aitkin County); bridge boring logs; water-well driller's logs; analysis of cutting samples; correlation with soil map units (Arneman and others, 1965; Brug and Gorton, 1994; Richardson, 1997); and aerial photograph interpretation.

DESCRIPTION OF MAP UNITS

HOLOCENE AND LATE PLEISTOCENE

dl **Disturbed land**—Land disturbed by iron-ore mining; primarily waste rock and the formerly overlying unconsolidated sediment, including sand, gravel, till, and peat.

pe **Peat and other organic sediments**—Partially decomposed plant matter deposited in marshes and swamps. Includes fine-grained organic matter deposited in ponded water, marl (calcareous clay) at depth in places (Schwartz, 1959), narrow deposits of alluvium along streams, narrow beach deposits, and small bodies of open water. The unit is typically found in depressions; some deposits have been drained. Most depressions are interpreted to have formed from melting buried glacial ice along former glacial stream channels and as irregularities on flat, poorly drained lake plains.

al **Floodplain alluvium**—Mississippi River alluvium is generally less than 6 feet (2 meters) of silt loam to loamy sand including scattered wood and shell fragments overlying sand, gravelly sand, or gravel. Some depressions have been filled with thick silty to clayey sediment. In places covered by thick fill in developed areas near Brainerd. Alluvium in smaller streams is finer-grained and typically capped by and interbedded with thin, organic-rich layers. Contacts with other map units are commonly scarps.

ld **Lacustrine sediments**—Sand to loamy fine-grained sand; organic-rich layers occur in places and may include marl at depth (Schwartz, 1959). Gravelly zones occur in some beach ridges. Mostly deposited when lakes were at higher levels. In places includes silt and clay deposits at depth where mapped along the Nokasippi River (secs. 8, 9, 16, and 17, T. 43 N., R. 31 W.). Many deposits along the edges of lakes and bogs are too narrow to be mapped at this scale.

lt **Lower terrace sediments**—Sand and gravel that includes fine-grained sand, silt, and organic slackwater sediments in places; consists of river-channel fluvial deposits that now form terraces above the modern floodplain. South of the confluence of the Crow Wing and Mississippi Rivers (sec. 23, T. 44 N., R. 32 W.) the deposits are interpreted to be composed predominantly of Crow Wing River sediment. Here the rock fragment content includes about 10 to 15 percent carbonate rock where unleached, and only a trace amount—less than one percent—of northeastern-source red volcanic rock and sandstone. North of the confluence of the Crow Wing and Mississippi Rivers the deposits are composed of predominantly Mississippi River sediment and contain trace amounts of carbonate and about 5 to 10 percent red volcanic rock and sandstone fragments (Knaeble, 2001).

Late Wisconsinan Deposits

ut **Upper terrace sediments**—Sand and gravel deposits including fine-grained sand and silt; primarily meltwater river-channel fluvial sediment of the glacial Crow Wing River. Where unleached, deposits contain about 10 to 15 percent carbonate rock fragments and trace amounts—less than one percent—of northeastern-source red volcanic rock and sandstone fragments. The Mississippi River also contributed a minor amount of sediment to the unit from sec. 13, T. 44 N., R. 32 W. southward (Knaeble, 2001). The unit is interpreted to have formed as Des Moines-lobe meltwater drained east through the Pillager gap (a mile-wide gap in the St. Croix moraine about 4 miles [6 kilometers] upstream from the confluence of the Crow Wing and Mississippi Rivers), eroding a wide valley (Goldstein, 1985; Mooers, 1988). As the water volume decreased, sediment refilled the scoured valley to the upper terrace level.

PLEISTOCENE

Aitkin assemblage—Glacial and lacustrine sediment of northwestern provenance (Table 1) deposited by ice and meltwater of the St. Louis sublobe, the most recent glacial advance into the area (Fig. 2). Very little sand and gravel outwash is found in these units, most likely because the ice advanced into Glacial Lake Aitkin I (lake boundaries are approximately the same as Glacial Lake Aitkin II—see Nelson Lake wave-washed till deposits [unit atw]) and incorporated the underlying silt and clay lake sediment; thus, when the ice melted, clay loam till and lacustrine sand, silt, and clay (including Glacial Lake Aitkin II sediment) were deposited. The till is yellow-brown (10YR5/4) to brown (7.5YR5/4) where oxidized and gray (10YR4/1 to 5/1) where unoxidized. Carbonate leaching depth varies but is usually less than 6 feet (2 meters). Sand grains (1 to 2 millimeters) and pebbles are commonly composed of 5 to 10 percent carbonate, rare to trace amounts of gray, northwest-source shale, and approximately 2 percent Superior provenance, red volcanic and sedimentary rock fragments.

agl ***Glacial Lake Aitkin II deposits***—Very fine- to medium-grained sand; laminated beds of silt and clay in places where the former lake was deepest. Gravel is found in areas where the former lake was shallow, and also within beach ridges. Radiocarbon dates indicate that lake sediments were deposited approximately 11,635 ± 350 years before present (Farnham and others, 1964).

als ***Lake sand and silt***—Interbedded very fine- to medium-grained sand to silt with lenses of silty clay to gravelly sand. Deposited in ponded water at or near the maximum ice margin (found only in secs. 2 and 12, T. 46 N., R. 28 W.)

atw ***Nelson Lake wave-washed till deposits***—Generally clayey-textured, unsorted sediment with scattered pebbles and rare cobbles and boulders that is commonly mantled by thin, sandy sediment. The surface was smoothed by wave action. Generally more clayey with depth, but in many places the unit is mostly clay due to extensive incorporation of underlying proglacial lake sediment by the advancing St. Louis sublobe. Brown in color (7.5YR5/4) between Indian Jack (sec. 34, T. 136 N., R. 26 W.) and Rabbit Lakes (sec. 19, T. 47 N., R. 28 W.), where the till is mixed with underlying Mille Lacs deposits. The outer margin of the unit roughly delineates the maximum extent of Glacial Lake Aitkin II.

atl ***Nelson Lake till deposits***—Generally clayey-textured, unsorted sediment with scattered pebbles and rare cobbles and boulders. Generally more clayey with depth, but in many places the unit is mostly clay due to extensive incorporation of proglacial lake sediment by the advancing St. Louis sublobe. Brown in color (7.5YR5/4) where mixed with underlying Mille Lacs deposits toward the outer ice margin; Mille Lacs deposits are at or near the surface in places.

Mille Lacs deposits of the Cromwell Formation—Glacial, fluvial, and lacustrine sediment of northeastern (Superior) provenance (Table 1), deposited by the Superior lobe and its meltwater during the Automba phase (a readvance of Superior lobe ice after its retreat back into east-central Minnesota from its maximum advance at the St. Croix moraine during the previous St. Croix phase; Wright, 1972; Johnson and Mooers, 1998). The till is generally reddish brown (5YR5/4) where oxidized and gray (5YR4/1) where unoxidized. Some leaching of carbonate in the till is common but the depth of leaching varies; not as deeply leached as Brainerd assemblage till; sand and gravel deposits of both assemblages are deeply leached. Unoxidized and unleached deposits seldom contain more than 2 percent carbonate grains. Superior provenance, red volcanic and sedimentary rock fragments commonly compose 10 to 20 percent of the 1 to 2 millimeter sand fraction, and dark igneous and metamorphic rock fragments generally compose greater than 20 percent. The Mille Lacs deposits contain similar sand and pebble provenance indicator minerals to other Cromwell Formation deposits, but the till commonly contains more silt and clay because the glacier that deposited it advanced through a proglacial lake and incorporated the underlying lake sediments.

ml ***Lake sand and silt***—Interbedded very fine- to medium-grained sand to silt with lenses of silty clay to gravelly sand, including flow till (mudflow sediment). Generally, finer-grained sediment occurs toward the middle and deeper parts of the deposits. Coarse-grained sand and gravel may be present along unit boundaries. Where the unit occurs on flat-topped hills (commonly with rims at the margins—see ice-walled lake-plain rim symbol), the sediment was deposited in ice-walled depressions created during the early stages of glacial stagnation. Where the unit is mapped in lower-lying areas, the lakes in which the unit was deposited formed at the ice margin or in later stages of stagnant-ice melt-out.

mo ***Outwash***—Sand, gravelly sand, and gravel; cobbly in places. Deposited by meltwater from the receding ice margin. Includes deltaic sediment in the vicinity of Bay Lake. The highly irregular surface expression of the unit is due to local sediment collapse caused by ice-block melt-out.

mbo ***Mixed outwash***—Sand, gravelly sand, and gravel; cobbly in places, especially near former ice margins. May include ponded fine-grained sediment along former ice margins. Includes loamy, poorly sorted intervals in places. The surface of the deposits has collapsed in places from ice-block melt-out. Mantled in places by 3 feet (1 meter) or more of sandy loam- to loamy sand-textured unsorted sediments. The mantle in places may be mudflow deposits that issued from the former ice margin, but it likely is mostly the result of mixing windblown silt with the underlying sand and gravel through cryoturbation, bioturbation, and colluvial processes. In many places the unit consists largely of reworked sand and gravel of the Brainerd assemblage, or is thin over Brainerd assemblage deposits. Contacts with Brainerd assemblage outwash (unit bo) in places are gradational or approximately located. Deposited mostly by meltwater issuing from the ice margin, but also includes sand and gravel deposited by stagnant-ice meltwater flowing into the western end of Glacial Lakes Aitkin I and II. Includes deltaic sediment in proximity to Glacial Lakes Aitkin I and II or Glacial Lake Brainerd sediment.

mi ***Ice-contact stratified materials***—Sand, gravelly sand, and cobbly gravel; commonly includes interbeds of, and in places is capped by, sandy to clayey flow till and lacustrine silt. Deposits contain boulders in places. Some sediments were deposited by meltwater in fans at the ice margin; others were deposited beneath or surrounded by ice (eskers). Individual deposits may consist of reworked or thinly mantled Brainerd assemblage ice-contact deposits (unit bis).

mc ***Till, sand, and gravel complex***—Glacial, fluvial, and lacustrine sediment too intricately associated to distinguish at map scale; commonly formed by the melt-out of underlying stagnant ice, causing the collapse and mixing of overlying sediment. Includes areas of till capped by or thinly interbedded with sand and gravel, as well as areas of thin till over thick sand and gravel. Where mapped in proximity to the Nelson Lake till deposits (unit atl) there is a thin, discontinuous cap of Aitkin assemblage till, too irregular to show. Deposits may include incorporated Brainerd assemblage materials near the former ice margin and may also be thin or patchy over the Brainerd assemblage deposits in places. Contacts with other Mille Lacs deposits are gradational.

mt ***Garrison till deposits***—Silt loam- to loam-textured, unsorted sediment with pebbles, cobbles, and boulders. Includes small bodies of bedded sediment at or near the surface in places. The matrix texture varies widely from clayey, due to extensive local incorporation of proglacial lake sediment, to sandy, due to mixing with the underlying Brainerd assemblage deposits, but in general the till of the Mille Lacs deposits is finer-grained than typical Cromwell Formation till.

Brainerd assemblage—Glacial, fluvial, and lacustrine sediment of northeast (Rainy) provenance (Table 1), deposited by the Rainy lobe and its meltwater (Schneider, 1961). Where mapped in the proximity of Mille Lacs deposits, Brainerd assemblage sediments commonly show reworking at the top and are mantled in places by generally less than 10 feet (3 meters) of the Mille Lacs deposits. Till deposits are yellow-brown (10YR5/4) to brown (7.5YR5/4) where oxidized and gray (10YR4/2 to 7.5YR4/2) where unoxidized, but range to a red-brown (5YR5/4 to 5YR5/5) color in the Crosby–Trommald–Riverton area, presumably due to glacial incorporation of local iron ore. Deposits are commonly deeply leached of carbonate materials and contain less than 5 percent carbonate where unleached. Superior provenance, red volcanic and sedimentary rock fragments commonly compose 5 to 10 percent of the 1 to 2 millimeter sand fraction.

bgl ***Glacial Lake Brainerd deposits***—Well-sorted, very fine- to medium-grained, noncalcareous sand. At depths greater than 10 feet (3 meters) sediment may contain interbedded silt and clay layers. May be interbedded with turbidite and deltaic sand and gravel deposited by meltwater streams of the retreating Rainy lobe and possibly the Superior lobe as they entered the lake from the north and east. Deposited on and around large buried ice blocks left by the Rainy lobe. These ice blocks melted following the drainage of Glacial Lake Brainerd (Mooers, 1988), leaving depressions in the landscape that are now lakes. Eolian sand commonly covers the

bl ***Lake sand and silt***—Interbedded very fine- to medium-grained sand to silt, with lenses of silty clay to gravelly sand, including till. Generally, finer-grained sediment occurs toward the middle and in the deeper portions of a deposit. Coarse-grained sand and gravel may be present along unit boundaries. Where the unit occurs on flat-topped hills (commonly with rims at the margins), the sediment was deposited in ice-walled depressions created during the early stages of glacial stagnation. Shallow lakes also formed in depressions scoured out by glacial ice in drumlinized areas.

bo ***Outwash***—Sand, gravelly sand, and gravel; cobbly in places, especially near ice margins. Includes loamy, poorly sorted intervals. Mantled in places by 3 feet (1 meter) or more of sandy loam- to loamy sand-textured unsorted sediments. The mantle is likely the result of the mixing of windblown silt with the underlying sand and gravel through cryoturbation, bioturbation, and colluvial processes, but in places the mantle may be mudflow deposits that issued from former ice margins. Collapsed bedding in places is due to sediment deposition on melting ice (Zumberge, 1952). Deposited by meltwater from the receding Rainy lobe. Includes deltaic sediment in proximity to Glacial Lake Brainerd sediments (unit bgl).

bis ***Ice-contact stratified materials***—Sand, gravelly sand, and cobbly gravel; commonly includes interbeds of sandy till and silt, and in places is capped by these sediments. Deposits may contain boulders and ice-collapse deformation features. Most materials were deposited by meltwater in coalescing fans at the ice margin, but some were deposited beneath or surrounded by ice resulting in the formation of eskers and kames.

bc ***Till, sand, and gravel complex***—Includes areas of sandy till capped by or thinly interbedded with sand and gravel, and areas of thin, sandy till over thick sand and gravel. Till matrix texture ranges from loamy to very sandy. Contacts are gradational with other Brainerd assemblage units. Glacial, fluvial, and lacustrine sediments are too intricately associated to distinguish separately at map scale; commonly formed by processes at the fluctuating ice margin, and through the melt-out of underlying stagnant ice. Particularly evident as remnant retreatal moraines.

bt ***South Long Lake till deposits***—Chiefly sandy loam-textured, unsorted sediment that contains pebbles, cobbles, and boulders; sand and gravel lenses occur in places. Generally consists of greater than 10 feet (3 meters) of rocky supraglacial till over dense subglacial till. Patchy, fine-grained eolian sand mantles this unit on the uplands south of Brainerd and east of the Mississippi River (Hobbs, 2001a; Knaeble, 2001).

btd ***South Long Lake drumlinized till deposits***—Chiefly sandy loam-textured, unsorted sediment with pebbles, cobbles, and boulders; sand and gravel lenses are uncommon at depths greater than 10 feet (3 meters). Generally consists of less than 10 feet (3 meters) of very sandy supraglacial till over dense, subglacial till. Commonly molded into elongate hills (drumlins) by overriding glacial ice. Commonly overlain by a few feet (1 meter) of fluvial, eolian, or lacustrine sand near outwash and lake deposits. Patchy, fine-grained eolian sand mantles this unit on the uplands south of Brainerd and east of the Mississippi River (Hobbs, 2001a; Knaeble, 2001).

Pre-Late Wisconsinan Deposits

pwt **Till**—Dense, sandy loam- to loam-textured, unsorted sediment that contains pebbles, cobbles, and boulders. Carbonate pebbles are present. May be an incorporated thrust slab of older Winnipeg-source till that was excavated by Rainy-lobe ice, or this material may be an isolated remnant of old till exposed following the last glaciation. Occurs only in secs. 19 and 30, T. 43 N., R. 31 W.

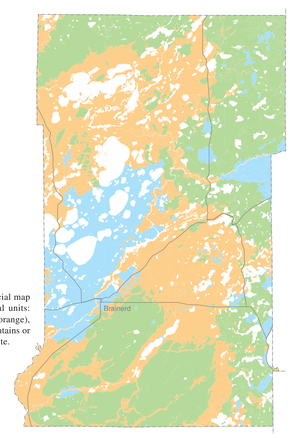


Figure 1. The map units from the 1:100,000 surficial map have been combined into three simplified material units: unsorted sediment or till (green), sand and gravel (orange), and lacustrine fine-grained sand, which in places contains or overlays silt and clay (blue). Water bodies are white.

MAP SYMBOLS

Geologic contact—Approximately located.

Eolian sand—Pattern indicates windblown sand as thick as 10 feet (3 meters) on top of other mapped sediments. In a few places west and south of Brainerd eolian sand dunes are up to 30 feet (9 meters) thick. Sand is irregular in thickness and patchy in distribution on the uplands south of Brainerd and east of the Mississippi River (Hobbs, 2001a; Knaeble, 2001). Eolian sand is common in Glacial Lake Brainerd deposits (unit bgl) and less common in Glacial Lake Aitkin II deposits (unit agl), but it is difficult to distinguish eolian from lacustrine deposits, as both are composed of well-sorted, very fine- to medium-grained sand; thus, the mapped extent is highly speculative where overlying glacial lake sand.

Beach ridge—Sand, gravelly sand, and sand and gravel deposited at the former margins of Glacial Lake Aitkin and Mille Lacs Lake.

Stream-cut scarp—Marks a former fluvial channel. Where paired, scarps bound stream-scoured areas. Till deposits downslope of scarps are fluvially scoured and may be mantled by sand and gravel too thin and patchy to map separately. Boundaries of terrace units and alluvium are commonly at scarps and are not shown by a scarp symbol on the map. Ticks point downslope.

General flow direction of a meltwater stream that deposited surficial sand and gravel—Arrowheads point in the direction that glacial meltwater last flowed within a unit. Flow direction indicators may point in opposite directions in adjacent units (see sec. 23, T. 47 N., R. 29 W.).

Kame—Conical hill composed predominantly of sand and gravel (secs. 15 and 22, T. 135 N., R. 29 W.; sec. 12, T. 134 N., R. 28 W.; sec. 26, T. 138 N., R. 26 W.). Interpreted to be a deposit within the confines of supporting ice. When the ice melted, the sand and gravel remained above the surrounding topography. Collapsed bedding is common.

Drumlin—A streamlined hill or ridge composed typically of glacial till; feature formed at the base of moving Rainy-lobe ice. Drumlins are partially masked in places by supraglacial sediment or eolian sand, and can also be partially buried by glaciofluvial sand and gravel. Drumlins on the highlands in northern Crow Wing County are generally not as distinct as those south and east of Brainerd, due to a thicker cover of supraglacial material. Arrow shows inferred direction of ice movement; the length of the arrow is approximately equivalent to drumlin width.

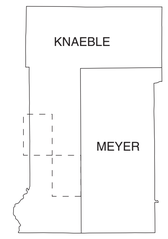
Fan deposit—Sand and gravel, interpreted to be an alluvial fan at an ice margin (sec. 23, T. 138 N., R. 27 W.).

Esker—Sinuous narrow ridge of predominantly sand and gravel; interpreted as having been deposited in an ice-tunnel or ice-walled channel by a glacial meltwater stream. The fluvial sediment may be covered by 10 feet (3 meters) or more of till. Arrowheads point in the direction of transport.

Ice-walled lake-plain rim—Line marks the rim of an elevated plateau of lake sediment interpreted to be the deposits of a former lake once walled by glacial ice.

Inferred ice margin—Approximate location of the maximum or recessional ice margins of the Rainy and Superior lobes (modified from Johnson and Mooers, 1998) and approximate maximum ice margin of the St. Louis sublobe (Fig. 2). Superior-lobe and St. Louis-sublobe ice entered the map area from the east, Rainy-lobe ice entered from the northeast. Lines are thin where the margin is speculative.

Broad irregular trough—Interpreted to be a buried subglacial drainage channel (tunnel valley) or a preexisting drainage valley that was subsequently filled by sediment. Ticks point downslope.



INDEX TO MAPPING

The index above shows the portions of Crow Wing County mapped by Knaeble and Meyer. The two dashed 7.5-minute quadrangles (Gull Lake and Brainerd) were originally mapped by Hobbs (2001a, b) with subsequent modifications by Knaeble.

ACKNOWLEDGMENTS

Dr. Allan Schneider granted interviews and supplied samples, field descriptions, and test data from work he did in the area a half century ago. This information was a significant aid in the map compilation and is greatly appreciated. He also provided us with field books that Dr. Leonard Weiss compiled while a University of Minnesota graduate student. Wayne Green, a former instructor at Brainerd Technical College, helped locate outcrops and assisted us in the field. Thanks are extended to Anderson Brothers, Hengel Incorporated, Wannebo Excavating Incorporated, and all other gravel pit operators and land owners who gave us permission to examine exposures on their property.

REFERENCES

Arneman, H.F., Hanson, L.D., Hermanson, H.P., and Hilde, D., 1965, Soil survey of Crow Wing County, Minnesota: U.S. Soil Conservation Service Series 1957, no. 21, 40 p., scale 1:20,000.

Brug, W.H., Jr., and Gorton, J.F., 1994, Soil survey of Morrison County, Minnesota: U.S. Soil Conservation Service, 191 p., scale 1:20,000.

Farnham, R.S., McAndrews, J.H., and Wright, H.E., Jr., 1964, A Late-Wisconsin buried soil near Aitkin, Minnesota, and its paleobotanical setting: American Journal of Science, v. 262, p. 393-412.

Goldstein, B.S., 1985, Stratigraphy, sedimentology, and Late-Quaternary history of the Wadena drumlin region, central Minnesota: Minneapolis, University of Minnesota, Ph.D. dissertation, p. 171-187.

Hobbs, H.C., 2001a, Surficial geology of the Brainerd quadrangle, Crow Wing County, Minnesota: Minnesota Geological Survey Miscellaneous Map M-112, scale 1: 24,000.

———2001b, Surficial geology of the Gull Lake quadrangle, Cass and Crow Wing Counties, Minnesota: Minnesota Geological Survey Miscellaneous Map M-113, scale 1:24,000.

Johnson, M.D., and Mooers, H.D., 1998, Ice-margin positions of the Superior lobe during Late Wisconsinan deglaciation, *in* Patterson, C.J., and Wright, H.E., Jr., eds., Contributions to Quaternary studies in Minnesota: Minnesota Geological Survey Report of Investigations 49, p. 7-14.

Knaeble, A.R., 2001, Surficial geology of the Baxter quadrangle, Crow Wing, Morrison, and Cass Counties, Minnesota: Minnesota Geological Survey Miscellaneous Map M-111, scale 1:24,000.

Mooers, H.D., 1988, Quaternary history and ice dynamics of the St. Croix phase of Late Wisconsin glaciation, central Minnesota: Minneapolis, University of Minnesota, Ph.D. dissertation, p. 168-176.

Richardson, T.N., 1997, Soil survey of Cass County, Minnesota: U.S. Soil Conservation Service, 300 p., scale 1: 24,000.

Schneider, A.F., 1961, Pleistocene geology of the Randall region, central Minnesota: Minnesota Geological Survey Bulletin 40, 151 p.

Schwartz, G.M., 1959, Investigation of the commercial possibilities of marl in Minnesota: Office of the Commissioner of Iron Range Resources and Rehabilitation, p. 133-146.

Wright, H.E., Jr., 1972, Quaternary history of Minnesota, *in* Sims, P.K., and Morey, G.B., eds., Geology of Minnesota: A centennial volume: Minnesota Geological Survey, p. 515-547.

Zumberge, J.H., 1952, The lakes of Minnesota, their origin and classification: Minnesota Geological Survey Bulletin 35, p. 18-20.

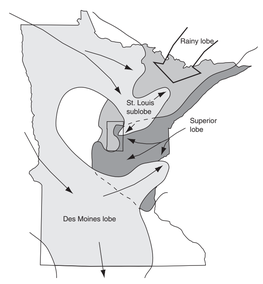


Figure 2. During the last glaciation, the Late Wisconsinan, Crow Wing County was completely covered by ice of the Rainy lobe, which moved into the county from the northeast. Following the retreat of the Rainy lobe, the Superior lobe moved into the county from the east (the line of maximum extent of the Superior lobe is dashed where buried by later advances). Lastly, ice originating northwest of Crow Wing County formed the St. Louis sublobe, which also flowed into the county from the east.

Table 1. Physical characteristics of glacial deposits in Crow Wing County.

	NORTHWEST		NORTHEAST
PROVENANCE	WINNIPEG	RAINY	SUPERIOR
	LobeSt. Louis	Rainy	Superior
TILL TEXTURE	Loamy to clayey	Sandy	Silty to loamy
TILL COLOR			
Oxidized	Yellow-brown to brown	Brown	Red-brown
Unoxidized	Gray to dark gray	Gray to brown-gray	Gray to red-gray
PEBBLE TYPE			
Carbonate	Uncommon	Absent to rare	Absent to rare
Gray-green rock	Uncommon to common	Uncommon to common	Common to abundant
Red felsite	Absent to uncommon	Uncommon	Common
Gray shale	Absent to rare	Absent	Absent

Digital base modified from the Minnesota Department of Transportation BaseMap data; digital base annotation by the Minnesota Geological Survey.

Elevation contours were derived from the U.S. Geological Survey 30-meter Digital Elevation Model (DEM) by the Minnesota Geological Survey.

Universal Transverse Mercator Projection, grid zone 15
1983 North American Datum

LOCATION DIAGRAM

SCALE 1:100 000

1 0 1 2 3 4 5 MILES
1 0 1 2 3 4 5 6 7 8 KILOMETERS

CONTOUR INTERVAL 15 METERS

GIS compilation by R.S. Lively and Joyce Meints
Edited by Lori Robinson

GEOLOGIC ATLAS OF CROW WING COUNTY, MINNESOTA