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COUNTY ATLAS SERIES
ATLAS C-35, PART A
Meeker County
Plate 4—Quaternary Stratigraphy

QUATERNARY STRATIGRAPHY

By

Gary N. Meyer

2015

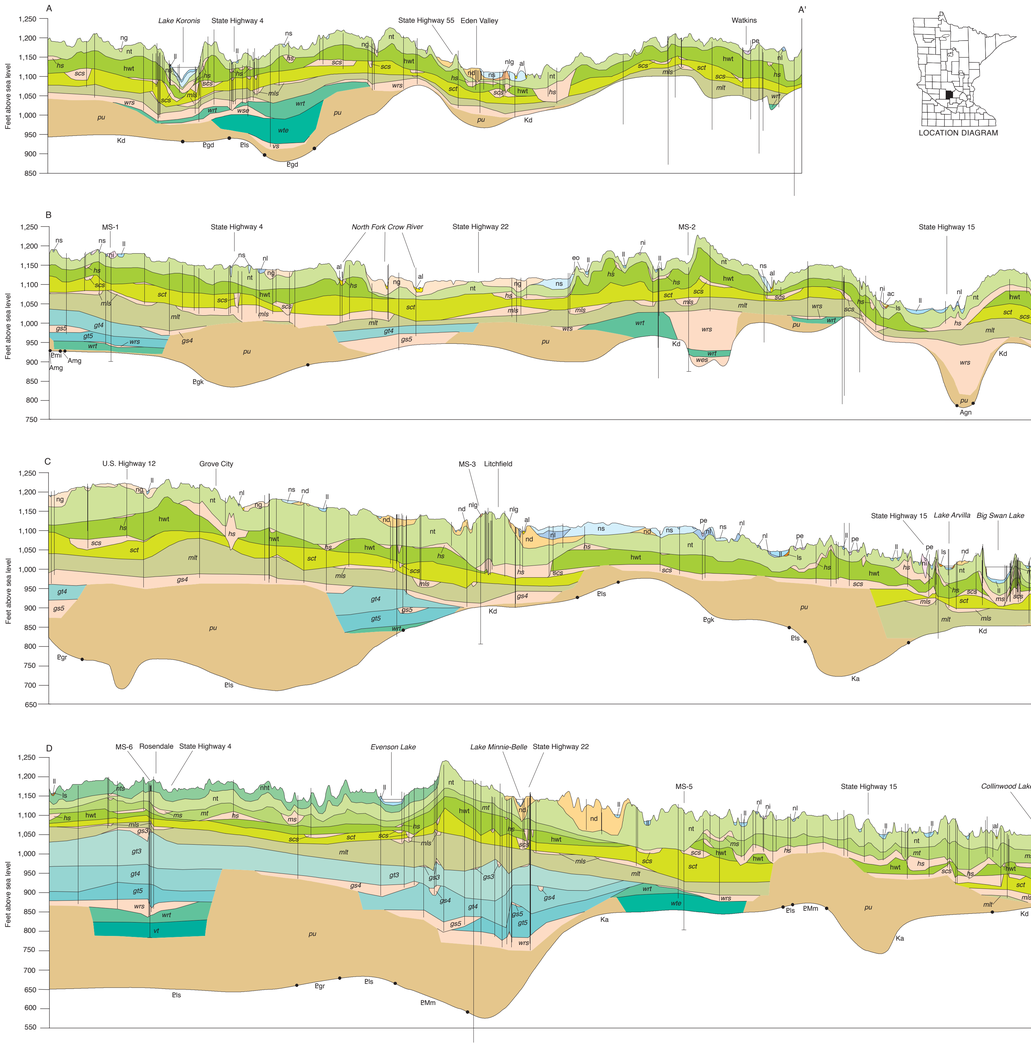

Figure 1. Location of the 50 cross sections, constructed at regular 0.6-mile (1-kilometer) intervals, used to create a three-dimensional model of the Quaternary deposits of Meeker County. The locations of cross sections A–A' through E–E' are shown here, and are also shown on Plate 3, *Surficial Geology.* Squares depict the locations of the six Minnesota Geological Survey rotary-sonic core sites and circles depict locations of water well sites with a log recorded in the County Well Index (only shown where within 0.3 mile [0.5 kilometer] of the cross section).

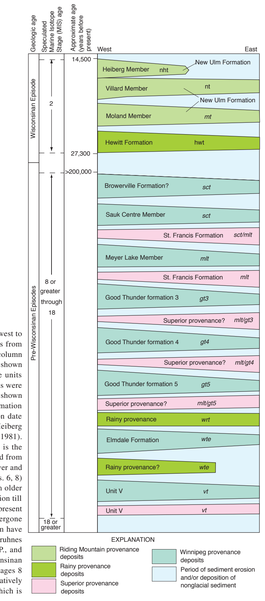

Figure 2. Diagram showing relative age, locations (across the county from west to east), provenance (on Plate 3 see Fig. 3 and Table 1), and related unit labels from the cross sections for glacial deposits of Meeker County (Table 1). The age column and deposit drawings are not to scale. The presence of some of the deposits shown is speculated from their occurrence to the south. Ice that deposited these units was probably part of the Superior lobe, which was the most extensive of the presumably crossed Meeker County. Marine Isotope Stage (MIS) correlations were estimated using figures in Jennings and others (2006). The approximate age shown for the end of deposition for till of the Heiberg Member of the New Ulm Formation is the calendar year conversion (Stuiver and others, 2014) of a radiocarbon date (12,400 ± 60 B.P.) from the base of peat active pond sediment above the Heiberg Member from a site in Sibley County to the south (Ashworth and others, 1981). The approximate age for the onset of deposition of the Hewitt Formation is the calendar year conversion of a radiocarbon date (22,960 ± 90 B.P.) from wood from correlative sediment in a core drilled in Blue Earth County to the south (Meyer and others, 2012). Wood found in Hewitt Formation till in Meeker County (Figs. 6, 8) that yielded much older radiocarbon dates is presumed to be reworked from older deposits. Two calcite samples from marl deposits above Browerville Formation till in Todd County had an uranium series minimum age of 200,000 years before present (Knaeble and Meyer, 2007). All core samples from the area that have undergone detrital remanent magnetization analysis at the Institute of Rock Magnetism have yielded normal polarity, indicating they were apparently deposited after the Brunhes normal–Matuyama reversed polarity boundary, dated at 780,000 years B.P., and thus no older than MIS 18. These inferred dates place the cored pre-Wisconsinan Episode units in the Middle Pleistocene Epoch, between Marine Isotope Stages 8 and 18. However, the oldest deposits may have been laid down during the relatively brief Jaramillo normal polarity event dated at over 1 million years ago, which is correlated with MIS stages 28-30 (Lisiecki and Raymo, 2005).

INTRODUCTION

The Quaternary Stratigraphy plate describes the unconsolidated sediment expected to be encountered between the land surface and bedrock in Meeker County. The stratigraphy is portrayed here using cross sections A–A' through E–E' that are representative of 50 cross sections (Fig. 1) used to construct a three-dimensional model of the Quaternary deposits of Meeker County. The major sand bodies from this model are depicted on Plate 5, *Sand Distribution Model*; the full model and all the cross sections used to develop it can be accessed through the digital files of the Minnesota Geological Survey. The geologic units shown on the cross sections were defined using core from six rotary-sonic drill holes, outcrops, auger logs and samples, drill cuttings collected by water-well drillers and the Minnesota Geological Survey (Southwick and others, 1990), and water-well and bridge-boring logs (Plate 1, *Data-Base Map*). Some units match those on Plate 3, *Surficial Geology,* a number of new units appear only on the cross sections, and others for simplification purposes are a combination of multiple units from Plate 3. Vertical exaggeration is 50x for all cross sections.

Figure 2 is a schematic illustration showing the relationships between age, provenance, stratigraphic position, and location of the sediments deposited by major glacial episodes (on Plate 3, see Fig. 3, Table 1, and the text for supplementary information). Analysis of the texture and clast types of the Quaternary sediments was done for selected geologic units, as listed in Table 1. Logs of the six rotary-sonic cores drilled by Mark J. Traut Wells for the Minnesota Geological Survey for this study are shown in Figures 3 to 8.

DESCRIPTION OF CROSS SECTION UNITS

Each unit description on the cross sections is placed in one of three categories, as indicated in parentheses after the description: 1. *Surficial Geology* unit—unit having an identical description, label, and color as on Plate 3, *Surficial Geology*; see Plate 3 for detailed descriptions; 2. New unit—unit that appears only on the cross sections that has a unique label and color (the new sand and gravel units have the same color to emphasize their status as potential aquifers); or 3. Modified unit—multiple units from Plate 3 combined into one unit on the cross sections. Some surficial geology deposits along the cross section line are too narrow to be shown.

Drill samples have established the presence of a number of subsurface deposits in Meeker County that predate those of the last glaciation, the Wisconsinan Episode (Fig. 2, Table 1), but they have been eroded and are likely more discontinuous than portrayed in the cross sections. Distinguishing individual stratigraphic units from water-well records, the primary subsurface data base, is difficult, so the pre-Wisconsinan Episode units have been combined as described below. Detailed descriptions of those units that have been formally named can be found in Johnson and others (in press). Unit designations which begin with the letter "w" correlate with pre-Wisconsinan Episode deposits of the W sequence of Meyer and Knaeble (1996), and unit designations which begin with the letter "v" correlate with their older V sequence. The letter "p" at the beginning of the designations of the lowermost units stands for Pleistocene, undifferentiated.

By convention, the name designations of buried sand and gravel bodies depicted in this report are associated with their underlying till. The name does not necessarily mean that individual sand bodies have the same provenance as the underlying till; in fact, many were derived from mixed source regions as described below.

QUATERNARY

Hudson Episode

al **Alluvium** (*Surficial Geology* unit)

ac **Clayey alluvium** (*Surficial Geology* unit)

ll **Lake silt and clay** (*Surficial Geology* unit)

ls **Lake sand** (*Surficial Geology* unit)

pe **Peat and muck** (*Surficial Geology* unit)

eo **Eolian sand** (*Surficial Geology* unit)

Wisconsinan Episode

New Ulm Formation—Light olive-brown to dark gray, bedded sediment and clay loam to sandy loam-textured diamicton of northwestern (Riding Mountain) provenance, deposited by ice and meltwater of the Des Moines lobe. This formation is at or near the surface across most of Meeker County.

Heiberg Member

Heiberg Member till (modified unit)—A combination of map units nht and nha from Plate 3. Loam to clay loam diamicton; shale clasts generally compose from 35 to 45 percent of the very coarse-grained (1-2 millimeter) sand fraction (Table 1). The unit commonly includes generally thin beds of silt and clay; sand and gravel lenses are present in places.

Heiberg and Villard Members

Outwash (*Surficial Geology* unit)

Lake clay and silt (*Surficial Geology* unit)

Lake sand and silt (*Surficial Geology* unit)

Lake sand and gravel (*Surficial Geology* unit)

Deltaic sediment (*Surficial Geology* unit)

Ice-contact stratified deposit (*Surficial Geology* unit)

Sand and gravel (new unit)—Deposited just before or during the final advance of the Des Moines lobe into Meeker County.

Villard Member

Villard Member till (modified unit)—A combination of map units nvt, nva, and nvs from Plate 3. Loam to sandy loam diamicton; shale clasts generally compose from 5 to 30 percent of the very coarse-grained (1-2 millimeter) sand fraction (Table 1). The unit includes fine-grained lake sediment in places, and sand and gravel lenses are common in some areas.

Villard and Moland Members

Sand and gravel (new unit)—Deposited by meltwater of the Des Moines lobe.

Moland Member

Moland Member till (new unit)—Deposited by an early phase of the Des Moines lobe. Loam to sandy loam diamicton; dense; gravelly in places. Shale clasts generally compose from 2 to 12 percent of the very coarse-grained (1-2 millimeter) sand fraction (Table 1). Thin beds of silt to gravel within the unit are common in places. Where unit *mt* is thick it may include fine-grained lake sediment. Without laboratory analyses, unit *mt* is difficult to distinguish from till of the older Hewitt Formation (unit hwt), so the thickness and extent of the two units relative to each other as shown in the cross sections is only approximate.

New Ulm and Hewitt Formations

Sand and gravel (new unit)—Deposited by meltwater of the Des Moines and/or Wadena lobes; clasts of Superior provenance are common in places.

Hewitt Formation—Yellow-brown to gray, bedded sediment and loam to sandy loam diamicton of north/northeastern (Rainy) provenance, deposited by the Wadena lobe and its meltwater. Correlative with the Traverse des Sioux Formation of south-central Minnesota (Knaeble, 2013a).

Sandy till (*Surficial Geology* unit)—Dense, gravelly to rocky in places. Shale clasts are very rare or absent in the very coarse-grained (1-2 millimeter) sand fraction (Table 1). Thin beds of silt to gravel within the unit are common in places. The unit includes fine-grained lake sediment in places. A few well logs in eastern Meeker County describe reddish colored sediment at the base of the Hewitt Formation till that may be equivalent to the Henderson Formation (Lusardi and others, 2012) and/or the Cromwell Formation deposited during the Emerald phase (Knaeble, 2013b).

Hewitt and Lake Henry Formations

Sand and gravel (new unit)—Deposited primarily by meltwater of the Wadena lobe, but includes older sediment of Winnipeg and possibly Superior provenance.

Pre-Wisconsinan Episodes

Lake Henry Formation—Yellow-brown to gray, bedded sediment and dense, generally silt-rich, loam-textured diamicton of north/northwestern (Winnipeg) provenance (Table 1). Common in the subsurface of central Minnesota (Meyer and Knaeble, 1996). The two members correlate with the upper two till units of the Good Thunder formation in south-central Minnesota (Lusardi and others, 2012; Knaeble, 2013a).

Sauk Centre Member till (new unit)—Ranges to silt loam texture, with abundant carbonate clasts and only rare shale clasts (Table 1). Includes Superior provenance till of the St. Francis Formation at the base in limited areas (Fig. 2). May include till of the Browerville Formation, or other younger deposits (Lusardi and others, 2012).

Sand and gravel (new unit)—Mostly Lake Henry Formation sediment but includes some sediment of the St. Francis Formation.

Meyer Lake Member till (new unit)—Similar to but slightly coarser-grained than till of the Sauk Centre Member, ranging to sandy-loam-textured in places, with common to abundant carbonate clasts and only rare shale clasts (Table 1). Includes Superior provenance till of the St. Francis Formation in the upper and/or lower portions in limited areas. Likely includes younger or older deposits of Winnipeg provenance, and possibly Superior provenance sediment older than that of the St. Francis Formation (Fig. 2).

Lake Henry Formation and Good Thunder formation

Sand and gravel (new unit)—Mostly Winnipeg provenance sediment, but includes some sediment of Superior provenance.

Good Thunder formation—Light olive-brown to dark gray, bedded sediment and dense, loam to silt loam-textured diamicton of Winnipeg provenance. Three tills are tentatively identified as part of the informally named Good Thunder formation in Meeker County, corresponding to the three lower tills of the Good Thunder formation mapped in Renville County to the south (Knaeble, 2013a). The tills in Meeker County generally have high carbonate content and very small amounts of gray shale (Table 1). One or more of the tills may correlate with till of the Eagle Bend Formation of central Minnesota.

Loamy till (new unit)—Only recognized in core hole MS-6 (Fig. 8) in Meeker County, so the areal extent of the unit is uncertain, and it is only mapped in the southwest portion of the county. The unit likely includes older or younger Winnipeg provenance till or fine-grained lake sediment in places. Reddish clayey sediment reported in well logs implies unnamed reddish till of Superior provenance is present in a few places in the lower portion of the unit (Fig. 2). The unit termed Good Thunder formation till 3 in Sibley (Lusardi and others, 2012) and Renville Counties (Knaeble, 2013a) to the south is somewhat more clayey-textured, and in Renville County has many more shale clasts.

Sand and gravel (new unit)—Mostly Winnipeg provenance sediment, but includes or consists of sediment of Rainy or Superior provenance in places.

Loamy till (new unit)—Only recognized in core holes MS-1 and MS-6 (Figs. 3 and 8) in Meeker County, so the areal extent of the unit is uncertain, and it is only mapped in the western portion of the county. The unit likely includes older or younger Winnipeg provenance till or fine-grained lake sediment in places. Reddish clayey sediment reported in well logs implies unnamed reddish till of Superior provenance is present in a few places in the lower portion of the unit (Fig. 2). Where unit *gt4* is thin it may be composed entirely of Superior provenance till. The unit termed Good Thunder formation till 4 in Sibley (Lusardi and others, 2012) and Renville Counties (Knaeble, 2013a) to the south is somewhat more clayey-textured.

Sand and gravel (new unit)—Mostly Winnipeg provenance sediment, with minor sediment of Superior provenance.

Loamy till (new unit)—Only recognized in core holes MS-1 and MS-6 (Figs. 3 and 8) in Meeker County, so the areal extent of the unit is uncertain, and it is only mapped in the western portion of the county. The unit likely includes older or younger Winnipeg provenance till, fine-grained lake sediment, or Rainy provenance till. The till in MS-1 included in unit *gt5* has much less carbonate than does typical Good Thunder formation till (Table 1), and could instead be correlative to till of the Superior provenance. Well logs imply unnamed reddish till of Superior provenance is present in a few places in the lower portion of unit *gt5* (Fig. 2). Where the unit is thin it may be composed entirely of Superior provenance till. The unit termed Good Thunder formation till 5 in Renville County to the south (Knaeble, 2013a) is somewhat coarser-textured.

Good Thunder formation and Rainy provenance sediment

Sand and gravel (new unit)—Includes Winnipeg, Rainy, and minor Superior provenance sediment.

Rainy provenance sediment—Yellow-brown to gray, bedded sediment and loam to sandy loam diamicton of north/northeastern (Rainy) provenance.

Sandy till (new unit)—Dense, gravelly to rocky in places. Shale clasts are very rare or absent in the very coarse-grained (1-2 millimeter) sand fraction (Table 1). This beds of silt to gravel within the unit are common in places. The unit includes fine-grained lake sediment in places. The till likely correlates, at least in part, with till of the Shooks Formation of north-central Minnesota. Includes older and/or younger Winnipeg provenance till in places.

Rainy provenance sediment and Elmdale Formation

Sand and gravel (new unit)—Primarily of Rainy provenance, but includes sediment of Winnipeg and possibly Superior provenance.

Elmdale Formation—Yellow-brown to dark gray, bedded sediment and clay loam to loam-textured diamicton of Winnipeg provenance, with low to moderate amounts of carbonate (Table 1).

Loamy till (new unit)—Only recognized in core hole MS-5 (Fig. 7), but assumed to underlie the entire county, at least in erosional remnants, because the formation is present in counties "down-ice" to the south (Meyer and others, 2012; Knaeble, 2013a). Elmdale Formation till in core MS-5 is mixed with Superior provenance till, presumably eroded from the underlying "unit v" till (Meyer and Knaeble, 1996). Unit *wte* in some areas likely includes other till of Winnipeg or Rainy provenance (Fig. 2), or fine-grained lake sediment.

Elmdale Formation and Unit V

Sand and gravel (new unit)—Mostly sediment of Winnipeg provenance, but includes sediment of Superior and Rainy provenance in places.

Unit V—Yellow-brown to gray, bedded sediment and silt loam to loam-textured diamicton of Winnipeg provenance, with moderate to abundant amounts of carbonate; and reddish-brown, bedded sediment and sandy loam-textured diamicton of Superior provenance (Table 1; Meyer and Knaeble, 1996).

Loamy to silty till (new unit)—Only recognized in core hole MS-6 (Fig. 8), but assumed to be preserved in the deeper buried valleys cut into bedrock, especially in the southwest portion of Meeker County. Tentatively correlated with the "unnamed till" (unit *vt*) of Lusardi (2014). Includes reddish-brown sandy till of Superior provenance in limited areas.

Sand and gravel (new unit)—Includes sediment of Winnipeg and Superior provenance.

Undifferentiated Quaternary deposits

Undifferentiated sediment (new unit)—Includes till and bedded clay, silt, sand, and gravel. Shown in areas where control data were scarce or absent.

CROSS SECTION SYMBOLS

Geologic contact—Approximate. No-line boundaries occur where data were insufficient to reliably extend units.

Scientific core hole—Rotary-sonic cores drilled for this project (Figs. 3 to 8).

Drill hole—Well records from the County Well Index. The top of the drill hole may not coincide with the cross section surface elevation line because the point is located near (within 0.3 mile [0.5 kilometer]) but not on the cross section line and therefore may have a different surface elevation.

Bedrock contact—Point representing the contact between bedrock units at the bedrock surface. Map unit labels match those on Plate 2, *Bedrock Geology.*

ACKNOWLEDGEMENTS

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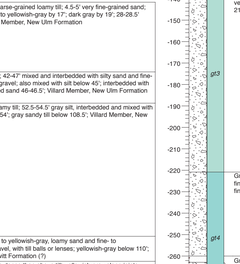

Figure 6. Descriptive log of rotary-sonic core MS-4, drilled by Mark J. Traut Wells for this study. The drill site location is shown on Figure 1. Bedrock was described by Julia R. Steenberg and John H. Mossler. Drill hole MS-4 is not shown on cross section C–C' because it is too far from the line.

Figure 7. Descriptive log of rotary-sonic core MS-5, drilled by Mark J. Traut Wells for this study. The drill site location is shown on Figure 1. Bedrock was described by Julia R. Steenberg and John H. Mossler.

Figure 8. Descriptive log of rotary-sonic core MS-6, drilled by Mark J. Traut Wells for this study. The drill site location is shown on Figure 1. Pollen analysis by Vania Stefanova of the Limnological Research Center of the University of Minnesota indicated a transition from a spruce forest at 323 feet (98 meters) to prairie at 314 feet (96 meters), and back to spruce forest at 310 feet (94 meters; see full report in digital files).

Table 1. Average values for the matrix texture and sand composition of tills recognized in Meeker County. Matrix texture (the less than 2-millimeter grain size fraction of the sample) is expressed as relative proportions of sand, silt, and clay in percent. The lithologic composition of the very coarse-grained sand fraction (1-2 millimeters) is expressed in percent as relative proportions of Precambrian rocks, Paleozoic rocks (mostly shale and limestone) using the classification system of Hobbs (1998). Cretaceous shale as a percent of the total 1-2 millimeter fraction is also given. The Precambrian 1-2 millimeter fraction is further differentiated by rock type—light (granite and gneiss), monomineralic (clear) quartz, dark (mafic-rich igneous and metamorphic rocks), and red (rhyolite, sandstone); T = trace amount.

	MATRIX TEXTURE					CLAST TYPE						
			Percentage of the less than 2-millimeter fraction			Percentage of total grains counted of the 1-2 millimeter fraction			Percentage of total Precambrian grains counted			
Deposit description and geologic units shown on cross sections	Total number of samples (percentage of total sand, gravel)	Gravel (percentage of total)	Sand	Silt	Clay	Total number of samples	Precambrian	Paleozoic	Cretaceous	Cretaceous shale	Light	Monomineralic quartz	Dark	Red
New Ulm Formation														
Heiberg Member till (unit nht)	43	4	33	42	25	30	37	25	38	37	73	14	12	1
Villard Member till (unit nt)	260	6	50	34	16	206	58	26	16	15	72	14	12	2
Loamy-textured portion (unit nvt on Plate 3)	103	5	46	37	17	85	49	27	24	23	74	13	12	1
Sandy-textured portion (unit nva on Plate 3)	157	6	52	33	15	121	64	26	10	9	70	15	13	2
Moland Member till (unit *mt*)	5	11	52	36	12	5	65	28	7	5	73	13	13	1
Hewitt Formation till (unit hwt)	40	8	53	34	13	40	80	19	1	T	60	15	18	7
Lake Henry Formation														
Sauk Centre Member till (unit *sct*)	49	7	39	44	17	49	51	48	1	1	76	11	13	T
Meyer Lake Member till (unit *mit*)	65	7	41	42	17	65	57	42	1	1	74	12	13	1
St. Francis Formation till (included in unit *mit*)	3	5	61	28	11	2 leached	94 1	5 100	1 0	0 0	36 0	27 46	19 27	18 18
Good Thunder formation														
Till 3 (unit *gt3*)	23	6	37	43	20	21	48	50	2	1	76	12	12	T
Till 4 (unit *gt4*)	25	3	34	45	21	19	52	47	1	1	70	15	14	1
Till 5 (unit *gt5*)	11	4	32	47	21	10	71	28	1	T	67	20	12	1
Till 5 from MS-1 (included in unit *gt5*)	15	2	30	50	20	4	87	12	1	T	66	25	13	T
Till 5 from MS-6 (included in unit *gt5*)	6	6	35	44	21	6	55	44	1	T	69	18	12	1
Rainy provenance till (unit *wrt*)	11	7	60	32	8	11	77	21	1	T	57	24	15	4
Till from MS-1 and MS-6 (included in unit *wrt*)	5	5	52	35	13	5	87	13	T	T	56	24	15	4
Till from MS-6 (included in unit *wrt*)	6	8	68	29	3	6	68	30	2	T	54	23	17	6
Elmdale Formation till (unit *wte*)	14	4	43	38	19	11	80	17	3	T	47	26	18	9
Winnipeg provenance "v" till (unit *vt*)	7	6	31	49	20	6	63	36	1	T	62	17	19	2
Superior provenance "v" till (included in unit *vt*)	1	4	62	31	7	1	92	8	0	0	31	35	17	17

Figure 3. Descriptive log of rotary-sonic core MS-1, drilled by Mark J. Traut Wells for this study. The drill site location is shown on Figure 1. Bedrock was described by Julia R. Steenberg and John H. Mossler.

Figure 4. Descriptive log of rotary-sonic core MS-2, drilled by Mark J. Traut Wells for this study. The drill site location is shown on Figure 1. Bedrock was described by Julia R. Steenberg and John H. Mossler.

Figure 5. Descriptive log of rotary-sonic core MS-3, drilled by Mark J. Traut Wells for this study. The drill site location is shown on Figure 1. Bedrock was described by Julia R. Steenberg and John H. Mossler.

Every reasonable effort has been made to ensure the accuracy of the factual data on which this map interpretation is based; however, the Minnesota Geological Survey does not warrant or guarantee that there are no errors. Users may wish to verify critical information; sources include both the references listed here and information on file at the offices of the Minnesota Geological Survey in St. Paul. In addition, effort has been made to ensure that the interpretation conforms to sound geologic and cartographic principles. No claim is made that the interpretation shown is rigorously correct, however, and it should not be used to guide engineering-scale decisions without site-specific verification.

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