UNIVERSITY OF MINNESOTA
MINNESOTA GEOLOGICAL SURVEY
Harvey Thorleifson, Director

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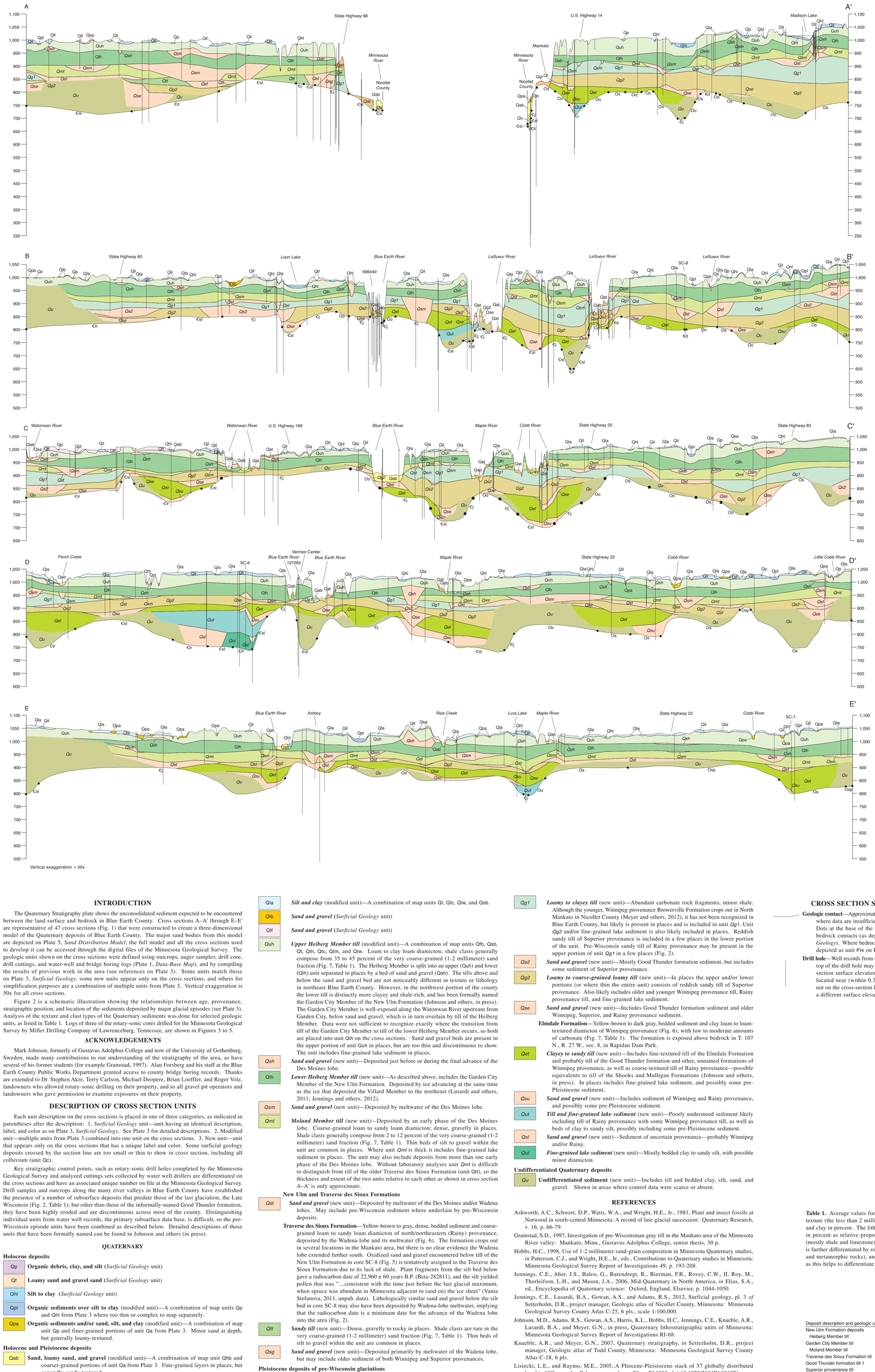
COUNTY ATLAS SERIES
ATLAS C-26, PART A
Blue Earth County
Plate 4—Quaternary Stratigraphy

LOCATION DIAGRAM




## INTRODUCTION

The Quaternary Stratigraphy plate shows the unconsolidated sediment expected to be encountered between the land surface and bedrock in Blue Earth County. Cross sections A–A' through E–E' are representative of 47 cross sections (Fig. 1) that were constructed to create a three-dimensional model of the Quaternary deposits of Blue Earth 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 outcrops, auger samples, drill core, drill cuttings, and water-well and bridge boring logs (Plate 1, *Data-Base Map*), and by compiling the results of previous work in the area (see references on Plate 3). Some units match those on Plate 3, *Surficial Geology,* some 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 (see Plate 3). Analysis of the texture and clast types of the Quaternary sediments was done for selected geologic units, as listed in Table 1. Logs of three of the rotary-sonic cores drilled for the Minnesota Geological Survey by Miller Drilling Company of Lawrenceburg, Tennessee, are shown in Figures 3 to 5.

## ACKNOWLEDGEMENTS

Mark Johnson, formerly of Gustavus Adolphus College and now of the University of Gothenburg, Sweden, made many contributions to our understanding of the stratigraphy of the area, as have several of his former students (for example Gramstad, 1997). Alan Forsberg and his staff at the Blue Earth County Public Works Department granted access to county bridge boring records. Thanks are extended to Dr. Stephen Akre, Terry Carlson, Michael Deopere, Brian Loeffler, and Roger Volz, landowners who allowed rotary-sonic drilling on their property, and to all gravel pit operators and landowners who gave permission to examine exposures on their property.

## 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. Modified unit—multiple units from Plate 3 combined into one unit on the cross sections. 3. New unit—unit that appears only on the cross sections that has a unique label and color. Some surficial geology deposits crossed by the section line are too small or thin to show in cross section, including all colluvium (unit Qc).

Key stratigraphic control points, such as rotary-sonic drill holes completed by the Minnesota Geological Survey and analyzed cuttings sets collected by water well drillers are differentiated on the cross sections and have an associated unique number on file at the Minnesota Geological Survey. Drill samples and outcrops along the many river valleys in Blue Earth County have established the presence of a number of subsurface deposits that predate those of the last glaciation, the Late Wisconsin (Fig. 2, Table 1), but other than those of the informally-named Good Thunder formation, they have been highly eroded and are discontinuous across most of the county. Distinguishing individual units from water well records, the primary subsurface data base, is difficult, so the pre-Wisconsin 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).

### QUATERNARY

**Holocene deposits**

**Qp** **Organic debris, clay, and silt** (*Surficial Geology* unit)

**Qf** **Loamy sand and gravel sand** (*Surficial Geology* unit)

**Qhl** **Silt to clay** (*Surficial Geology* unit)

**Qpl** **Organic sediments over silt to clay** (modified unit)—A combination of map units Qp and Qhl from Plate 3 where too thin or complex to map separately.

**Qpa** **Organic sediments and/or sand, silt, and clay** (modified unit)—A combination of map unit Qp and finer-grained portions of unit Qa from Plate 3. Minor sand at depth, but generally loamy-textured.

**Holocene and Pleistocene deposits**

**Qab** **Sand, loamy sand, and gravel** (modified unit)—A combination of map unit Qhb and coarser-grained portions of unit Qa from Plate 3. Fine-grained layers in places, but generally sandy-textured.

**Qat** **Sand and gravelly sand with silt and clay** (*Surficial Geology* unit)

**Pleistocene deposits of the Late Wisconsin glaciation**

**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 (Fig. 6).

**Qsa** ***Sand, gravelly sand, and cobbly gravel*** (modified unit)—A combination of map units Qs and Qsc.

**Qil** ***Diamicton with silt, clay, and sand*** (*Surficial Geology* unit)

**Qla** ***Silt and clay*** (modified unit)—A combination of map units Ql, Qlc, Qlw, and Qsb.

**Qlb** ***Sand and gravel*** (*Surficial Geology* unit)

**Qlf** ***Sand and gravel*** (*Surficial Geology* unit)

**Quh** ***Upper Heiberg Member till*** (modified unit)—A combination of map units Qfb, Qsb, Qt, Qth, Qtc, Qtm, and Qtw. Loam to clay loam diamicton; shale clasts generally compose from 35 to 45 percent of the very coarse-grained (1-2 millimeter) sand fraction (Fig. 7, Table 1). The Heiberg Member is split into an upper (Quh) and lower (Qlh) unit separated in places by a bed of sand and gravel (Qsh). The tills above and below the sand and gravel bed are not noticeably different in texture or lithology in northeast Blue Earth County. However, in the northwest portion of the county the lower till is distinctly more clayey and shale-rich, and has been formally named the Garden City Member of the New Ulm Formation (Johnson and others, in press). The Garden City Member is well-exposed along the Watonwan River upstream from Garden City, below sand and gravel, which is in turn overlain by till of the Heiberg Member. Data were not sufficient to recognize exactly where the transition from till of the Garden City Member to till of the lower Heiberg Member occurs, so both are placed into unit Qlh on the cross sections. Sand and gravel beds are present in the upper portion of unit Quh in places, but are too thin and discontinuous to show. The unit includes fine-grained lake sediment in places.

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

**Qlh** ***Lower Heiberg Member till*** (new unit)—As described above, includes the Garden City Member of the New Ulm Formation. Deposited by ice advancing at the same time as the ice that deposited the Villard Member to the northeast (Lusardi and others, 2011; Jennings and others, 2012).

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

**Qmt** ***Moland Member till*** (new unit)—Deposited by an early phase of the Des Moines lobe. Coarse-grained 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 (Fig. 7, Table 1). Thin beds of silt to gravel within the unit are common in places. Where unit *Qmt* is thick it includes fine-grained lake sediment in places. The unit may also include deposits from more than one early phase of the Des Moines lobe. Without laboratory analyses unit *Qmt* is difficult to distinguish from till of the older Traverse des Sioux Formation (unit Qtt), so the thickness and extent of the two units relative to each other as shown in cross section A–A' is only approximate.

**New Ulm and Traverse des Sioux Formations**

**Qst** ***Sand and gravel*** (new unit)—Deposited by meltwater of the Des Moines and/or Wadena lobes. May include pre-Wisconsin sediment where underlain by pre-Wisconsin deposits.

**Traverse des Sioux Formation**—Yellow-brown to gray, dense, bedded sediment and coarse-grained loam to sandy loam diamicton of north/northeastern (Rainy) provenance, deposited by the Wadena lobe and its meltwater (Fig. 6). The formation crops out in several locations in the Mankato area, but there is no clear evidence the Wadena lobe extended further south. Oxidized sand and gravel encountered below till of the New Ulm Formation in core SC-8 (Fig. 5) is tentatively assigned to the Traverse des Sioux Formation due to its lack of shale. Plant fragments from the silt bed below gave a radiocarbon date of 22,960 ± 60 years B.P. (Beta-282811), and the silt yielded pollen that was "…consistent with the time just before the last glacial maximum, when spruce was abundant in Minnesota adjacent to (and on) the ice sheet" (Vania Stefanova, 2011, unpub. data). Lithologically similar sand and gravel below the silt bed in core SC-8 may also have been deposited by Wadena-lobe meltwater, implying that the radiocarbon date is a minimum date for the advance of the Wadena lobe into the area (Fig. 2).

**Qtf** ***Sandy till*** (new unit)—Dense, gravelly to rocky in places. Shale clasts are rare in the very coarse-grained (1-2 millimeter) sand fraction (Fig. 7, Table 1). Thin beds of silt to gravel within the unit are common in places.

**Qsg** ***Sand and gravel*** (new unit)—Deposited primarily by meltwater of the Wadena lobe, but may include older sediment of both Winnipeg and Superior provenances.

**Pleistocene deposits of pre-Wisconsin glaciations**

**Good Thunder formation**—Light olive-brown to dark gray, bedded sediment and dense, loam to clay loam-textured diamicton of Winnipeg provenance (Fig. 6). The till generally has high carbonate and small amounts of gray shale (Fig. 7, Table 1). There are at least two tills identified as part of the Good Thunder formation in Blue Earth County. They are well exposed along the Blue Earth River, separated in places by reddish sandy till of Superior provenance, organic-rich silt with logs, or sand and gravel. The lower till, unit *Qg2*, is more greenish in color, generally coarser in texture, and commonly has less carbonate than unit *Qg1*. These units likely correlate with the Lake Henry Formation of central Minnesota, whereas the red till correlates with till of the St. Francis Formation (Johnson and others, in press).

**Qg1** ***Loamy to clayey till*** (new unit)—Abundant carbonate rock fragments, minor shale. Although the younger, Winnipeg-provenance Browerville Formation crops out in North Mankato in Nicollet County (Meyer and others, 2012), it has not been recognized in Blue Earth County, but likely is present in places and is included in unit *Qg1*. Unit *Qg2* and/or fine-grained lake sediment is also likely included in places. Reddish sandy till of Superior provenance is included in a few places in the lower portion of the unit. Pre-Wisconsin sandy till of Rainy provenance may be present in the upper portion of unit *Qg1* in a few places (Fig. 2).

**Qs2** ***Sand and gravel*** (new unit)—Mostly Good Thunder formation sediment, but includes some sediment of Superior provenance.

**Qg2** ***Loamy to coarse-grained loamy till*** (new unit)—In places the upper and/or lower portions (or where thin the entire unit) consists of reddish sandy till of Superior provenance. Also likely includes older and younger Winnipeg provenance till, Rainy provenance till, and fine-grained lake sediment.

**Qse** ***Sand and gravel*** (new unit)—Includes Good Thunder formation sediment and older Winnipeg, Superior, and Rainy provenance sediment.

**Elmdale Formation**—Yellow-brown to dark gray, bedded sediment and clay loam to loam-textured diamicton of Winnipeg provenance (Fig. 6), with low to moderate amounts of carbonate (Fig. 7, Table 1). The formation is exposed above bedrock in T. 107 N., R. 27 W., sec. 8, in Rapidan Dam Park.

**Qet** ***Clayey to sandy till*** (new unit)—Includes fine-textured till of the Elmdale Formation and probably till of the Good Thunder formation and other, unnamed formations of Winnipeg provenance, as well as coarse-textured till of Rainy provenance—possible equivalents to till of the Shooks and Mulligan Formations (Johnson and others, in press). In places includes fine-grained lake sediment, and possibly some pre-Pleistocene sediment.

**Qsu** ***Sand and gravel*** (new unit)—Includes sediment of Winnipeg and Rainy provenance, and possibly some pre-Pleistocene sediment.

**Qut** ***Till and fine-grained lake sediment*** (new unit)—Poorly understood sediment likely including till of Rainy provenance with some Winnipeg provenance till, as well as beds of clay to sandy silt, possibly including some pre-Pleistocene sediment.

**Qsl** ***Sand and gravel*** (new unit)—Sediment of uncertain provenance—probably Winnipeg and/or Rainy.

**Qul** ***Fine-grained lake sediment*** (new unit)—Mostly bedded clay to sandy silt, with possible minor diamicton.

**Undifferentiated Quaternary deposits**

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

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# QUATERNARY STRATIGRAPHY

By

Gary N. Meyer, Alan R. Knaeble, Barbara A. Lusardi,
Carrie E. Jennings, and Angela S. Gowan

2012

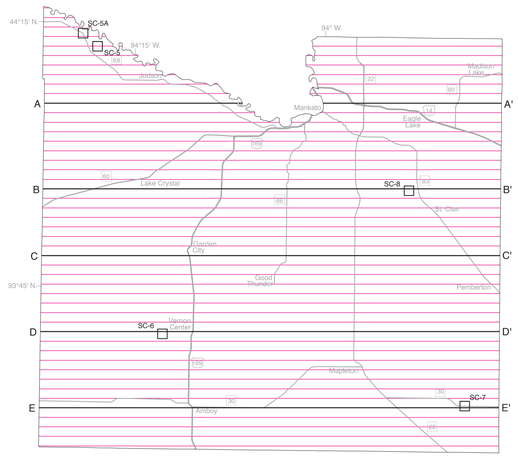


**Figure 1.** Location of the 47 cross sections, constructed at regular 0.6 mile (1 kilometer) intervals, used to create a three-dimensional model of the Quaternary deposits of Blue Earth County. The locations of cross sections A–A' through E–E' are shown here, and are also shown on Plate 3, *Surficial Geology*. Black squares depict the locations of the five Minnesota Geological Survey rotary-sonic core sites.

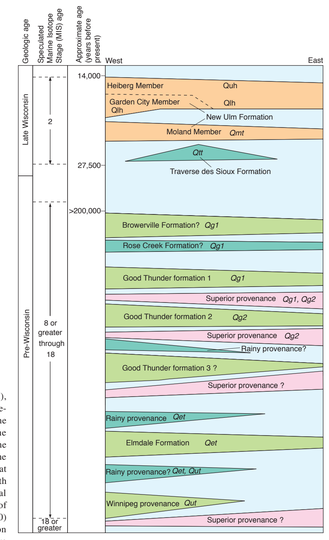


**Figure 2.** Diagram showing relative age, location (across Blue Earth County from west to east), provenance (Plate 3, Table 1), and related unit labels from the cross sections for Wisconsin and pre-Wisconsin glacial deposits (Table 1). The age column and deposit drawings are not to scale. Marine Isotope Stage (MIS) correlations were estimated using figures in Jennings and others (2006). The age shown for the end of deposition for till of the Heiberg Member of the New Ulm Formation is the calendar year conversion of a radiocarbon date (12,260 ± 90) from wood at the contact between the till and overlying lake sediment (see Plate 3). To the north at a site in Sibley County, the base of peat above pond sediment above the Heiberg Member yielded a radiocarbon date of 12,400 ± 60 (Ashworth and others, 1981). Similar radiocarbon ages have been determined for wood in similar depositional settings in the Twin Cities area (Meyer, 1998). The approximate age for the onset of deposition of the Traverse Des Sioux Formation is the calendar year conversion of a radiocarbon date (22,960 ± 90) from wood in core SC-8 (Fig. 5). Two calcite samples from marl deposits above Browerville Formation till in Todd County in central Minnesota 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 remnant magnetization analysis at the Institute for Rock Magnetism at the University of Minnesota have yielded normal polarity, indicating they were likely deposited after the Brunhes normal–Matuyama reversed polarity boundary, dated at 780,000 years B.P., and thus no older than MIS 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).

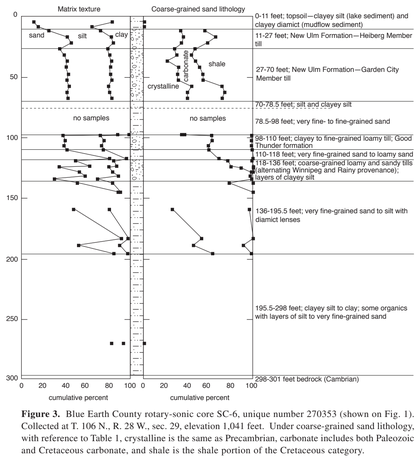


**Figure 3.** Blue Earth County rotary-sonic core SC-6, unique number 270353 (shown on Fig. 1). Collected at T. 106 N., R. 28 W., sec. 29, elevation 1,041 feet. Under coarse-grained sand lithology, with reference to Table 1, crystalline is the same as Precambrian, carbonate includes both Paleozoic and Cretaceous carbonate, and shale is the shale portion of the Cretaceous category.

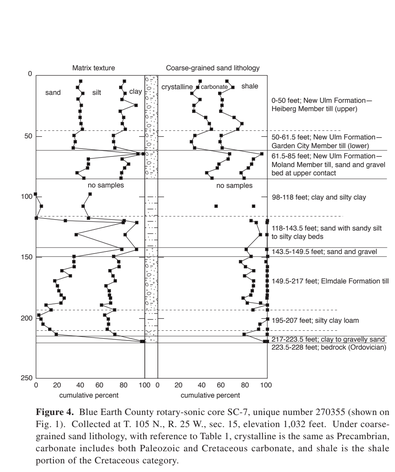


**Figure 4.** Blue Earth County rotary-sonic core SC-7, unique number 270355 (shown on Fig. 1). Collected at T. 105 N., R. 25 W., sec. 15, elevation 1,032 feet. Under coarse-grained sand lithology, with reference to Table 1, crystalline is the same as Precambrian, carbonate includes both Paleozoic and Cretaceous carbonate, and shale is the shale portion of the Cretaceous category.

## CROSS SECTION SYMBOLS

**Geologic contact**—Approximate. No-line boundaries occur where data are insufficient to reliably extend units. Dots at the base of the Quaternary section denote bedrock contacts (as depicted on Plate 2, *Bedrock Geology*). Where bedrock occurs at the surface, it is depicted as unit Prk on Plate 3, *Surficial Geology*.

**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.

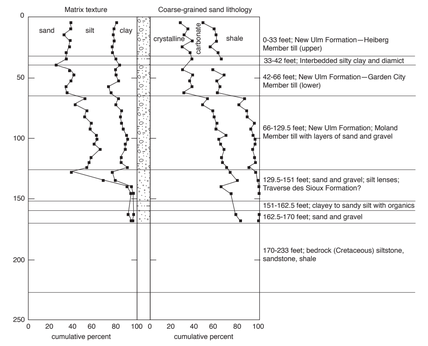


**Figure 5.** Blue Earth County rotary-sonic core SC-8, unique number 270356 (shown on Fig. 1). Collected at T. 107 N., R. 25 W., sec. 7, elevation 1,011 feet. Under coarse-grained sand lithology, with reference to Table 1, crystalline is the same as Precambrian, carbonate includes both Paleozoic and Cretaceous carbonate, and shale is the shale portion of the Cretaceous category.

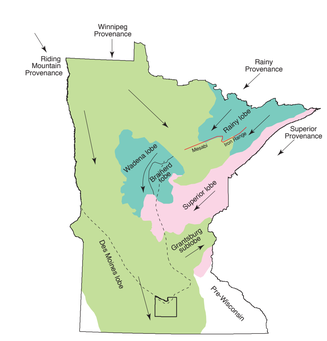


**Figure 6.** Location of major provenances (source regions). Glacial sediments deposited in the county derive their distinct material content from bedrock and sediment found in the region of these provenances. During the last glaciation, the Late Wisconsin, ice carrying debris of predominantly Rainy provenance—the Wadena lobe—reached at least as far as Mankato. The approximate maximum extent of the Wadena lobe is shown by the dashed line. When the Wadena lobe waned, Blue Earth County was completely covered by at least three advances of the Des Moines lobe.

**Table 1.** Average values for the matrix texture and sand composition of tills recognized in Blue Earth 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 (mostly carbonate) rocks, and Cretaceous rocks (mostly shale and limestone) using the classification system of Hobbs (1998). 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). Gray shale as a percent of the total Cretaceous is also given, as this helps to differentiate units of the New Ulm Formation from older deposits.

| | | 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 unit | Total number of samples | Gravel (percentage of total sample weight) | Sand | Silt | Clay | Total number of samples | Precambrian | Paleozoic | Cretaceous | Light | Clear quartz | Dark | Red | Gray shale/total Cretaceous (percent) |
| New Ulm Formation deposits | | | | | | | | | | | | | | |
| Heiberg Member till | 220 | 5 | 36 | 42 | 22 | 220 | 38 | 26 | 36 | 76 | 15 | 9 | 0 | 96 |
| Garden City Member till | 54 | 7 | 35 | 40 | 25 | 54 | 27 | 21 | 52 | 70 | 18 | 11 | 1 | 93 |
| Moland Member till | 38 | 9 | 56 | 31 | 13 | 38 | 62 | 30 | 8 | 70 | 20 | 9 | 1 | 86 |
| Traverse des Sioux Formation till | 5 | 6 | 50 | 35 | 15 | 5 | 70 | 28 | 2 | 66 | 20 | 11 | 3 | 48 |
| Good Thunder formation till 1 | 69 | 5 | 34 | 42 | 24 | 69 | 52 | 43 | 5 | 66 | 22 | 11 | 1 | 51 |
| Superior provenance till leached | 14 | 6 | 61 | 27 | 12 | 9<br>5 | 77<br>100 | 22<br>0 | 1<br>0 | 50<br>42 | 32<br>29 | 12<br>17 | 6<br>12 | |
| Good Thunder formation till 2 | 49 | 3 | 39 | 40 | 21 | 49 | 66 | 32 | 2 | 65 | 23 | 11 | 1 | 30 |
| Rainy provenance till | 10 | 5 | 56 | 29 | 15 | 10 | 76 | 23 | 1 | 50 | 36 | 11 | 3 | |
| Elmdale Formation till | 22 | 1 | 31 | 42 | 27 | 22 | 81 | 15 | 4 | 51 | 36 | 11 | 2 | 7 |
| Pre-Elmdale Rainy provenance till leached | 19 | 6 | 56 | 31 | 13 | 14<br>5 | 87<br>99 | 13<br>1 | 0<br>0 | 56<br>52 | 33<br>43 | 10<br>4 | 1<br>1 | |
| Pre-Elmdale Winnipeg provenance till leached | 6 | 5 | 46 | 33 | 21 | 4<br>2 | 79<br>99 | 20<br>1 | 1<br>0 | 61<br>56 | 27<br>32 | 11<br>11 | 1<br>1 | |

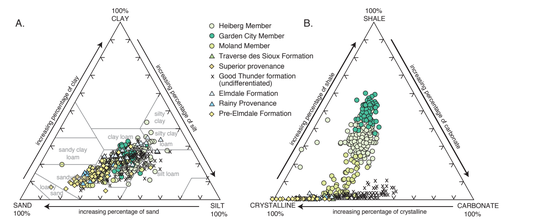


**Figure 7.** Ternary diagrams showing (A) matrix texture (less than 2 millimeter size fraction) and (B) composition of the very coarse-grained (1-2 millimeters) sand fraction in samples from Blue Earth County; with reference to Table 1, crystalline is the same as Precambrian, carbonate includes both Paleozoic and Cretaceous carbonate, and shale is the shale portion of the Cretaceous category.



Edited by Lori Robinson



# GEOLOGIC ATLAS OF BLUE EARTH COUNTY, MINNESOTA