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QUATERNARY STRATIGRAPHY

By

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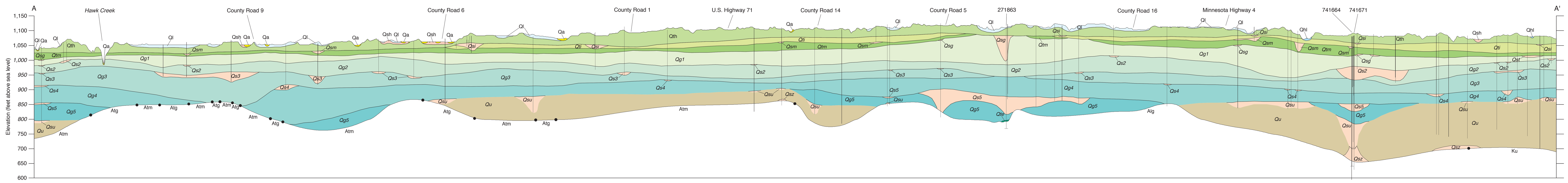
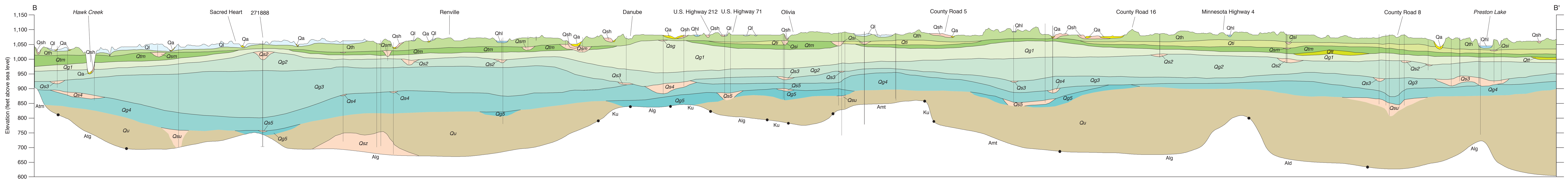
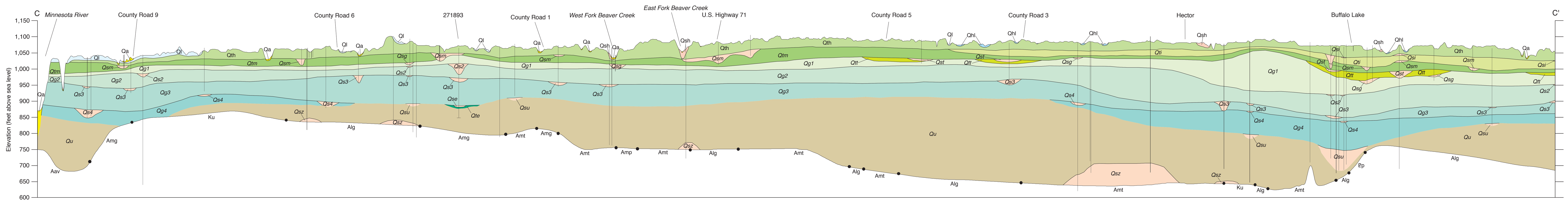
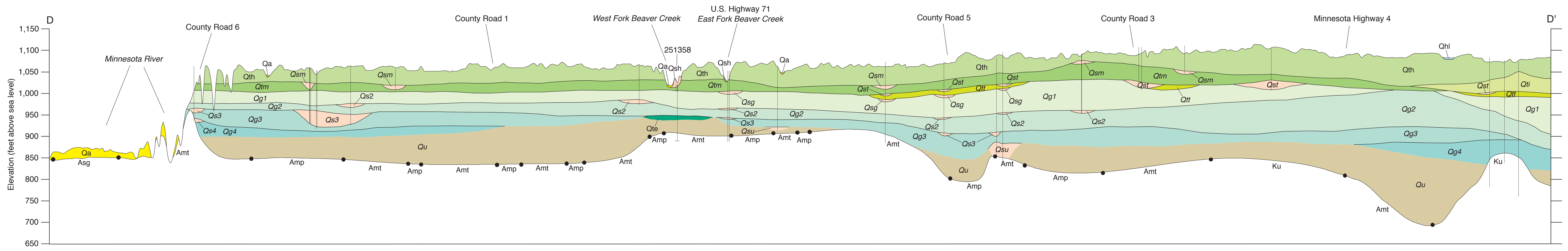
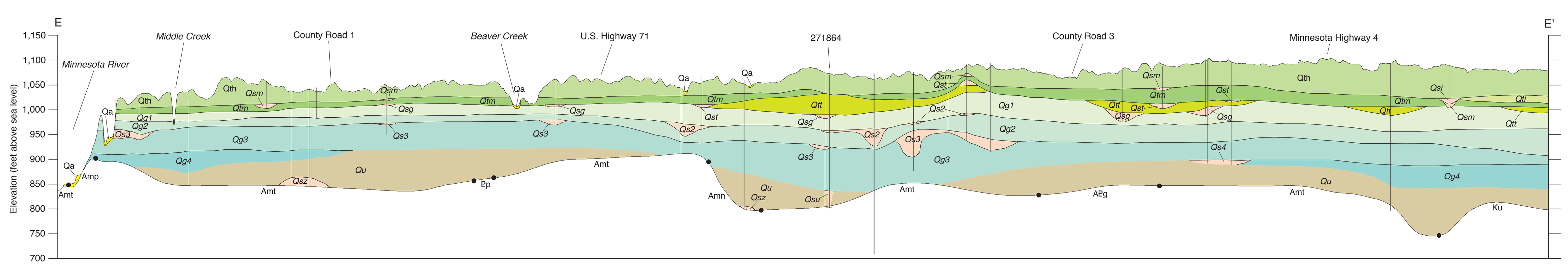
2013

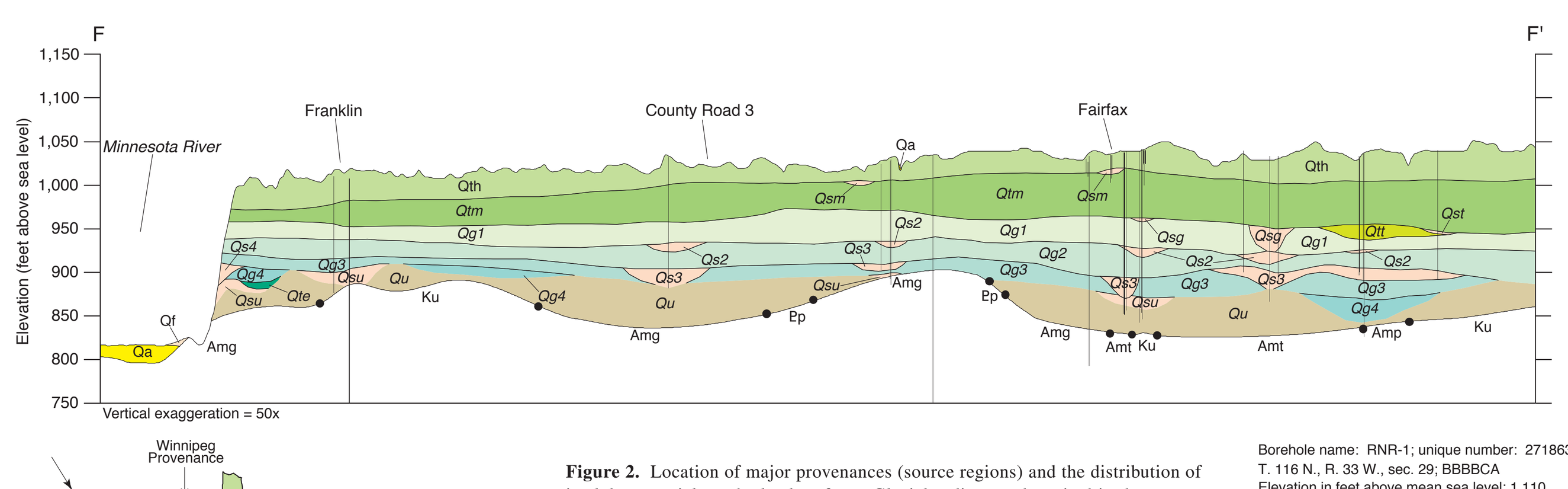












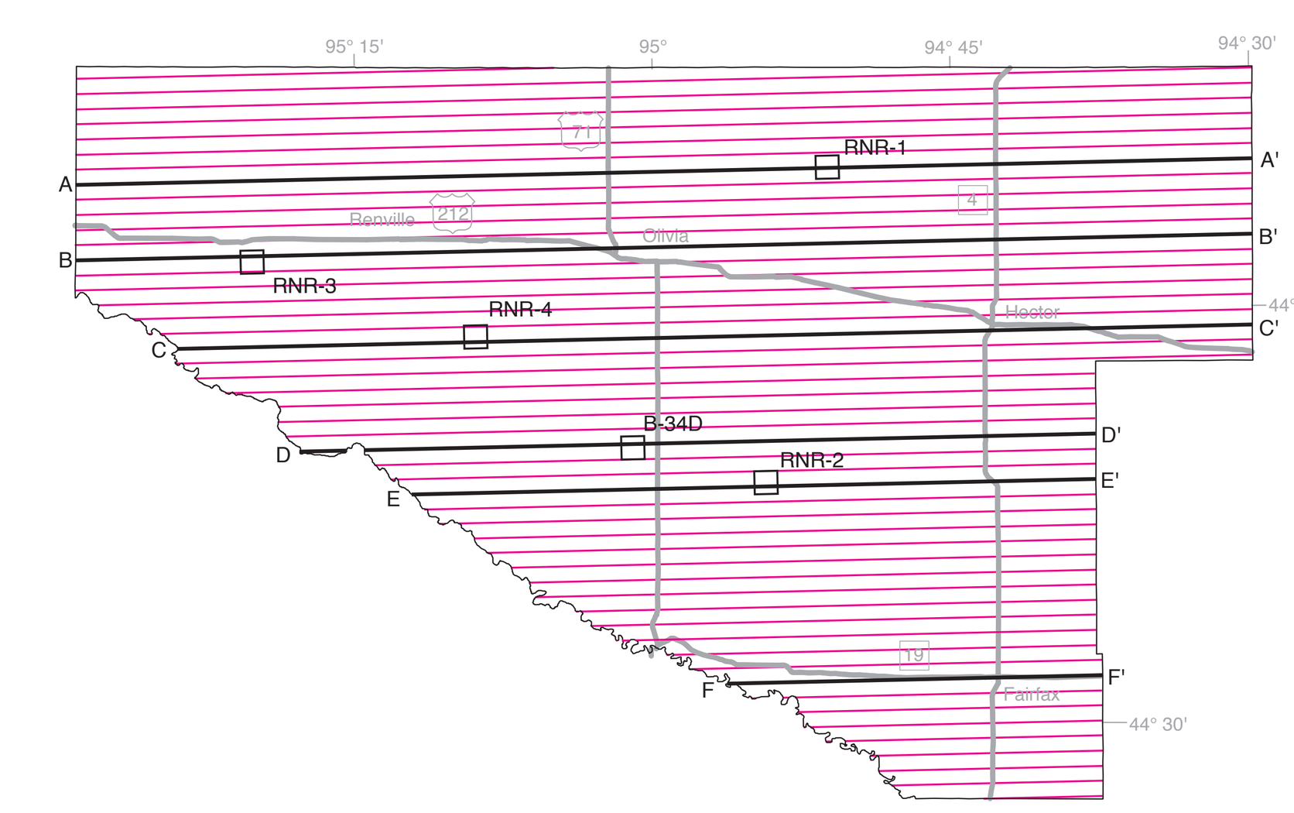


Figure 1. Location of 50 cross sections, constructed at regular 0.6-mile (1-kilometer) intervals, used to create a three-dimensional model of the Quaternary deposits of Renville County. The locations of cross sections A–A' through F–F' are shown here, and are also shown on Plate 3, *Surficial Geology*. Black squares depict the locations of four Minnesota Geological Survey (RNR 1-4) and one Renville County landfill (B-34D) rotary-sonic core sites.

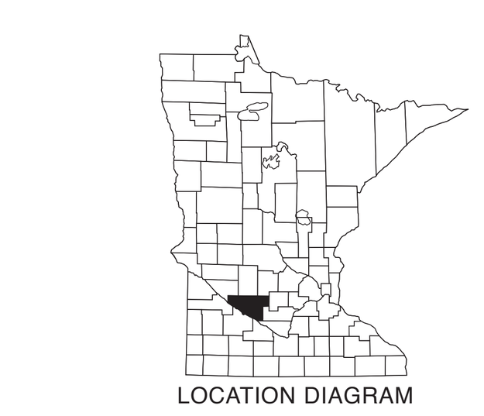
CROSS SECTION SYMBOLS

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

Scientific drill hole—Includes cored rotary-sonic drill holes and cuttings-sampled rotary drill holes with their associated unique numbers. See introduction for details.

Drill hole—Includes water-well drillers' sites. The top of the drill-hole symbol may not coincide with the cross section surface elevation line because the point is located near (commonly within 0.3 mile [0.5 kilometer]) but not on the cross section line and therefore may have a slightly 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*.



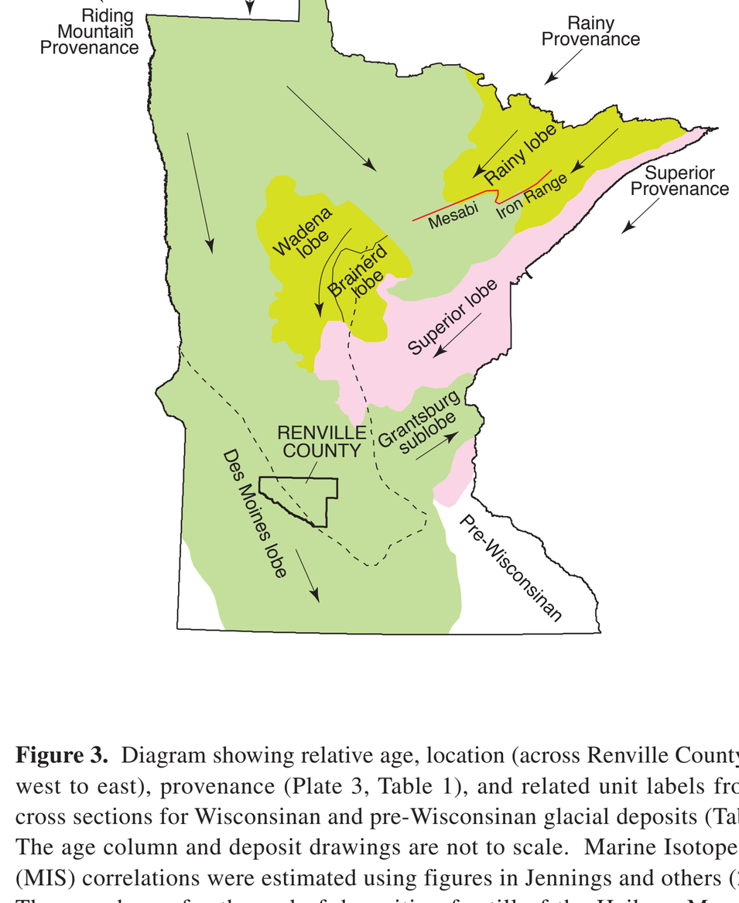


Figure 2. Location of major provenances (source regions) and the distribution of ice lobe materials at the land surface. Glacial sediments deposited in the county derive their distinct material content from bedrock and sediment found in the region of these provenances. During the last glaciation, the Late Wisconsinan, ice carrying debris of predominantly Rainy provenance (yellow-green) covered portions of northeast (Rainy lobe) and central (Wadena lobe) Minnesota and these deposits are discontinuously present in the subsurface as far south and east as the Minnesota River. The approximate maximum extent of the Wadena lobe is shown by the dashed line. After Wadena-lobe ice melted back, Renville County was completely covered by deposits of at least three advances of the Des Moines lobe. Plate 3, Figure 2 shows two of these deposits, the Heiberg and Villard Members.

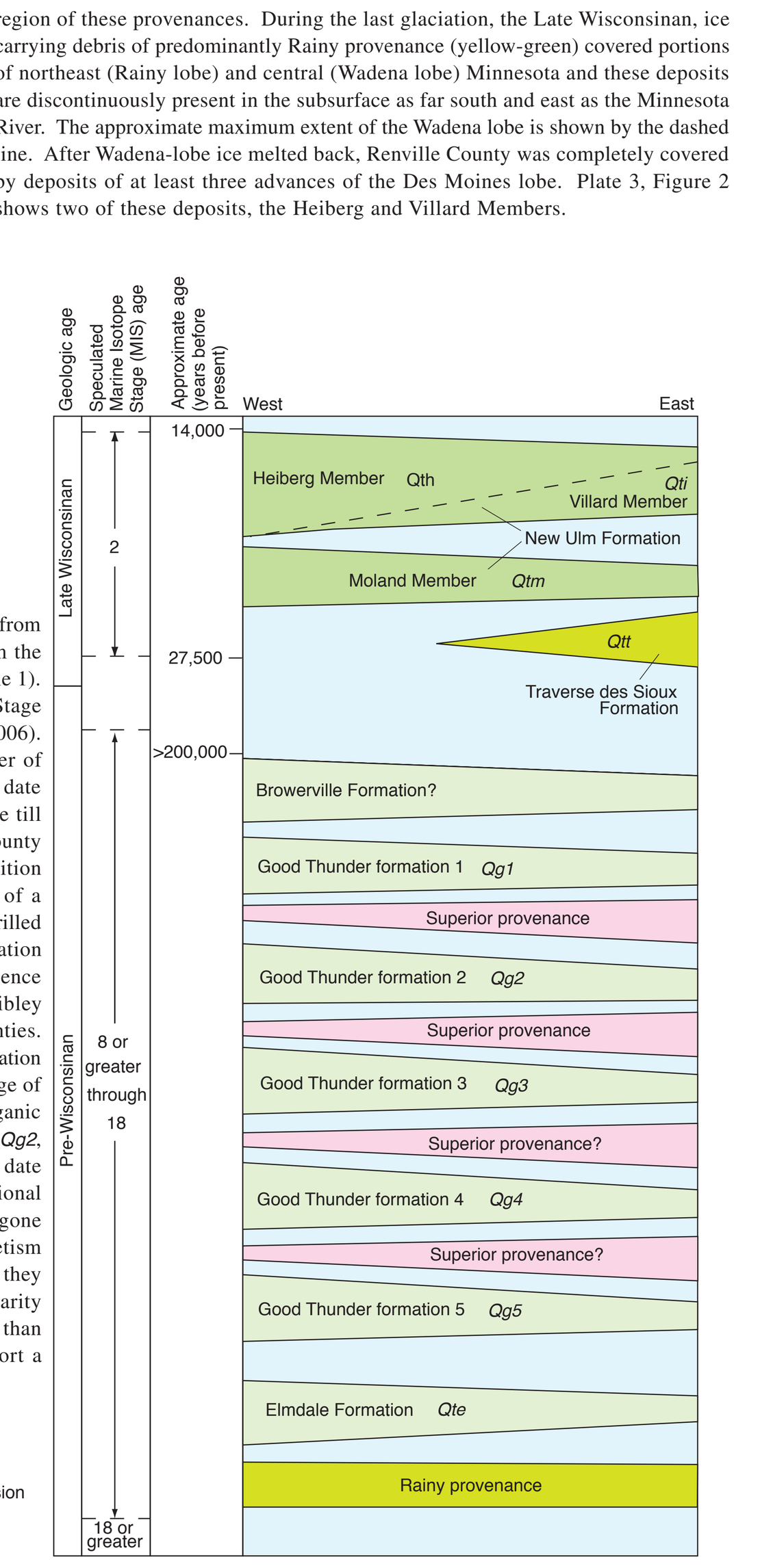


Figure 3. Diagram showing relative age, location (across Renville County from west to east), provenance (Plate 3, Table 1), and related unit labels from the cross sections for Wisconsinan and pre-Wisconsinan glacial deposits (Table 1). The age column and deposit drawings are not to scale. Marine Isotope 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 years before present) from wood at the contact between the till and overlying lake sediment from a site to the southeast in Blue Earth County (Jennings and others, 2012). 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 years before present) from wood in a core drilled in Blue Earth County (Meyer and others, 2012a). The Browerville Formation has not been recognized in the subsurface in Renville County and its presence is speculative based on its patchy occurrence to the east in adjacent Sibley (Lusardi and others, 2012) and Nicollet (Meyer and others, 2012b) Counties. Two calcite samples from interglacial marl deposits above Browerville Formation till in Todd County in central Minnesota had a uranium series minimum age of 200,000 years before present (Knaeble and Meyer, 2007). Wood from organic deposits in lake sediment between Good Thunder formation units *Qg1* and *Qg2*, in core from rotary-sonic drill hole RNR-3 (Fig. 6), produced an infinite date of greater than 48,500 radiocarbon years before present (Livermore National laboratory, no. 152996). All core samples from the area that have undergone detrital remanent magnetization analysis at the Institute for Rock Magnetism at the University of Minnesota have yielded normal polarity, indicating they were likely deposited after the Bruhnes normal-Matuyama reversed polarity boundary, dated at 780,000 years before present, and therefore no older than MIS 18 (Lisiecki and Raymo, 2005). The three analyses above support a Middle Pleistocene age for Good Thunder formation deposits.

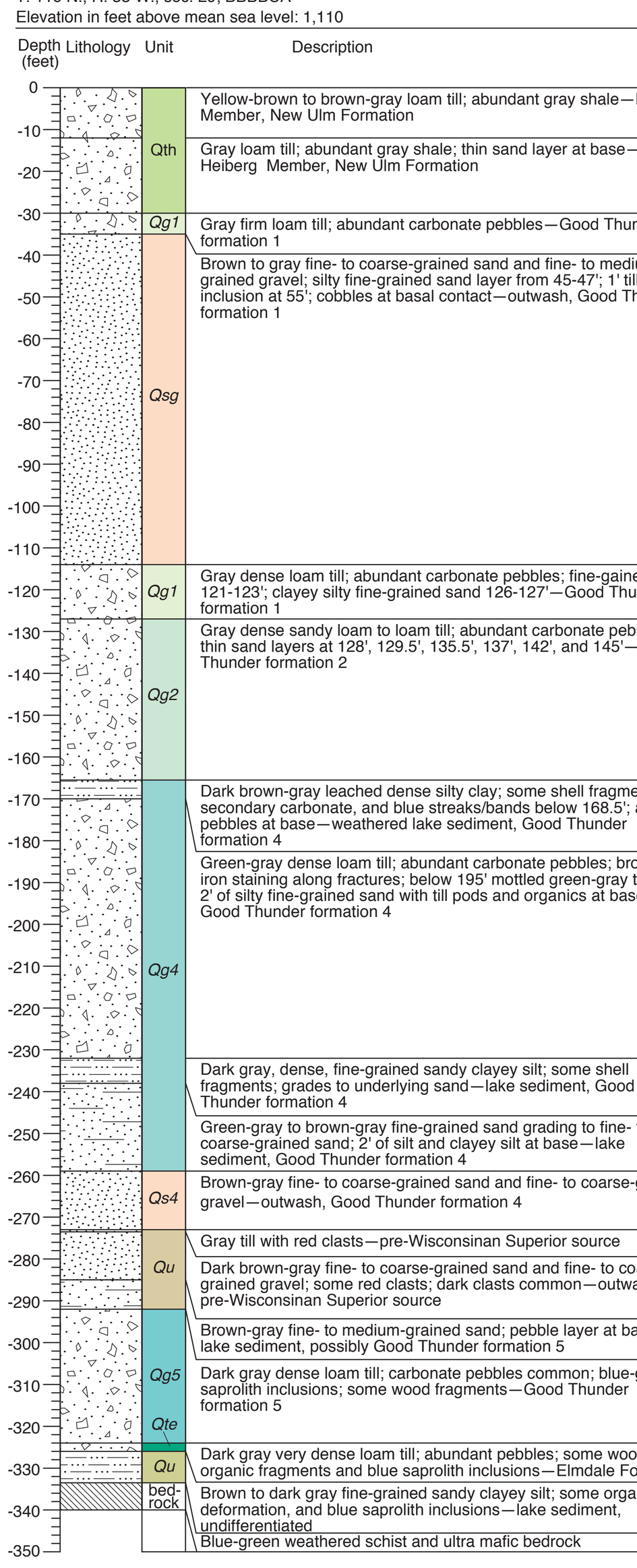


Figure 4. Descriptive log of rotary-sonic core RNR-1 drilled by Mark J. Traut Wells for this study. Drill site location is shown on Figure 1 and Plate 1, *Data-Base Map*. Unit symbols and colors are identical to those shown on cross sections. See Table 1 for matrix texture and composition averages of till units. Samples from all Pre-Wisconsinan units exhibited normal polarity remanent magnetism (Chandler, unpub. data).

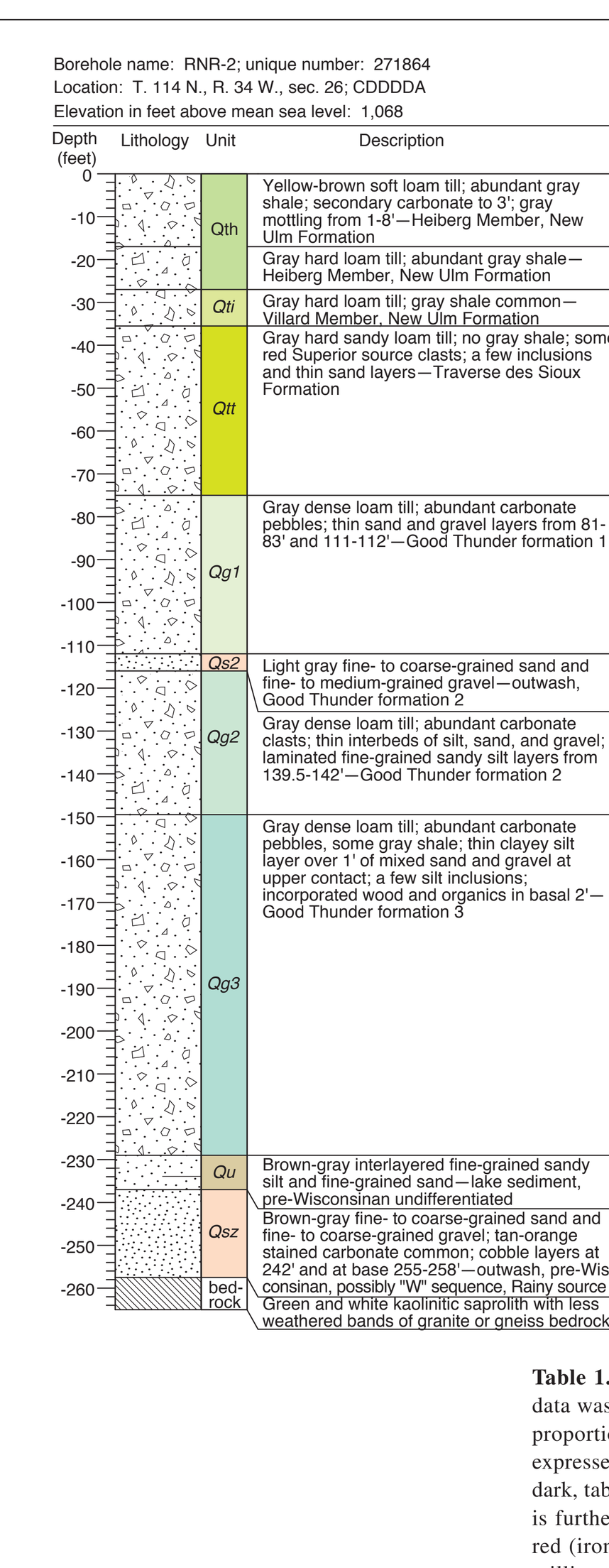


Figure 5. Descriptive log of rotary-sonic core RNR-2 drilled by Mark J. Traut Wells for this study. Drill site location is shown on Figure 1 and Plate 1. Unit symbols and colors are identical to those shown on cross sections. See Table 1 for matrix texture and composition averages of till units.

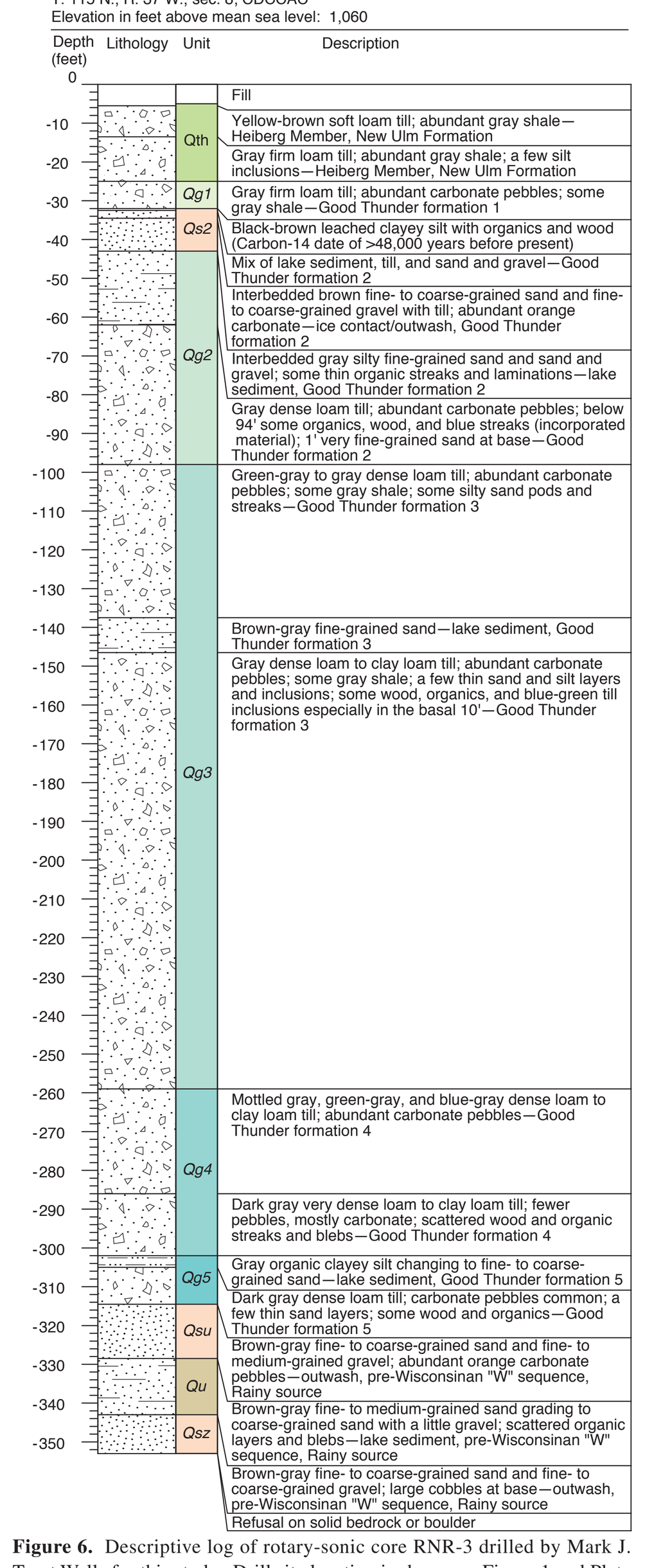


Figure 6. Descriptive log of rotary-sonic core RNR-3 drilled by Mark J. Traut Wells for this study. Drill site location is shown on Figure 1 and Plate 1. Unit symbols and colors are identical to those shown on cross sections. See Table 1 for matrix texture and composition averages of till units.

Table 1. Average values for the matrix texture and sand composition of tills recognized in Renville County (a small portion of this data was used in Plate 3, Fig. 3C). 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 crystalline rocks, Paleozoic carbonate rocks, and Cretaceous shale (includes dark, tabular Cretaceous limestone) using the classification system of Hobbs (1998). The Precambrian crystalline 1-2 millimeter fraction is further differentiated by crystalline rock type—light (granite and gneiss), dark (mafic-igneous and other metamorphic rocks), and red (iron-formation, rhyolite, agate, and sandstone). Clear quartz is a further differentiation of the Precambrian crystalline light 1-2 millimeter fraction. The total number of samples (299) for all Good Thunder formation tills includes 6 samples that were identified as Good Thunder formation but could not be differentiated as one of the five subdivided units.

	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 crystalline grains counted			
Deposit description and geologic units	Total number of samples	Gravel (percentage of total sample weight)	Sand	Silt	Clay	Total number of samples	Precambrian crystalline	Paleozoic carbonate	Cretaceous shale	Light	Dark	Red	Clear quartz
Deposits of the Des Moines lobe													
New Ulm Formation													
Heiberg Member till (units Qtl, Qtm, Qtw, and Qtz on Plate 3; unit Qth on cross sections)	170	4	34	41	25	152	34	24	42	90	9	1	18
Villard Member till (unit *Qti* on cross sections)	20	5	41	37	22	20	51	28	21	92	8	0	13
Moland Member (unit *Qtm* on cross sections)	24	7	48	37	15	24	56	35	9	90	10	0	8
Deposits of the Wadena lobe													
Traverse des Sioux Formation till (unit *Qtt* on cross sections)	8	7	52	30	18	8	74	25	1	85	12	3	24
Pre-Wisconsinan deposits													
Good Thunder formation	299	6	36	41	23	299	47	47	6	90	10	0	18
Good Thunder till 1 (unit *Qg1* on cross sections)	81	7	38	41	21	81	48	47	5	90	10	0	14
Good Thunder till 2 (unit *Qg2* on cross sections)	70	7	39	40	21	70	47	50	3	91	9	0	13
Good Thunder till 3 (unit *Qg3* on cross sections)	95	5	34	40	26	95	42	48	10	90	10	0	23
Good Thunder till 4 (unit Qg4 on cross sections)	39	5	32	43	25	39	49	49	2	88	12	0	20
Good Thunder till 5 (unit *Qg5* on cross sections)	8	3	38	38	24	8	70	28	2	89	11	0	27
Elmdale Formation till (unit *Qte* on cross sections)	6	3	31	38	31	6	79	15	6	92	8	0	46

INTRODUCTION

The Quaternary stratigraphy plate shows the unconsolidated materials expected to be encountered between the land and bedrock surfaces in Renville County. Cross sections A–A' through F–F' are representative of 50 cross sections (Fig. 1) that were constructed to create a three-dimensional model of the Quaternary deposits of Renville 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 Quaternary geologic units shown on the cross sections were defined from interpretation of new data collected for this study and from existing data from previous investigations. These include (in order of importance): rotary-sonic drill core from 4 drill holes completed by the Minnesota Geological Survey; outcrops along the bluffs of Minnesota River valley and the river's tributaries; rotary-sonic core completed for the Minnesota Pollution Control Agency from the Renville County landfill; 4 drill holes with split spoon samples from near the town of Hector completed by the Minnesota Waste Management Board; outcrops along Hawk and Beaver Creeks (Patterson and others, 1999); drill cutting descriptions from the Minnesota Geological Survey cuttings library; rotary-sonic drill core in adjacent Sibley (Lusardi and others, 2012) and McLeod (Lusardi, 2009) Counties; wire-line core and logs from 3 exploration holes completed by IDEA Drilling Company; water-well drillers' logs; 31 shallow auger borings completed by the Minnesota Geological Survey for Plate 3, *Surficial Geology*; Minnesota Department of Transportation bridge boring logs (Minnesota Department of Transportation, 2011); and from previous project work completed by Anderson (2003), Jennings (2010), and Berg (unpub. data).

Where the above data are scarce along the cross section lines, units composed of till and fine-grained lake sediments are generally portrayed (modeled) as continuous, with relatively uniform thicknesses and minimal elevation change, and the less common, thinner sand and gravel units are portrayed as discontinuous. The basis for this portrayal is the fact that abundant fine-grained sediment was present in the source ice and stream dissection and sedimentation appear to have been the dominant processes active during deposition. Where there are more data, all units tend to be discontinuous and variable in thickness and elevation over relatively short distances—which reflects more accurately the actual complexity of glacial deposits, especially as older, deeper, more eroded and dissected units are examined. These factors should be kept in mind when viewing the cross sections.

Cross section locations are shown on Figure 1 and on Plate 3, *Surficial Geology.* Some units match those on Plate 3, some new units appear only on the cross sections because they are present only in the subsurface or because the area of exposure on the surficial map is too small to be mapped (river bluff exposures), and others are a combination of multiple units from Plate 3. Peat and organic deposits (Qp) and colluvium (Qc) are too thin to show in cross section. Unit modifications were made in order to produce subsurface models of sand and till layer interfaces that could be processed to create the sand distribution models in Plate 5. A few key stratigraphic control points (rotary-sonic drill holes and drill holes with cutting sets) are shown on the cross sections with an associated unique number. Some rotary-sonic drill core from Sibley (Lusardi and others, 2012) and McLeod (Lusardi, 2009) Counties, as well as water-well drillers' cuttings samples collected from sites outside the county, were used for interpretation because they were near the county border and provided significant detail. These drill sites are not shown on the cross sections, but their unique well numbers are included in the digital data file. Drill holes, represented by the vertical lines, may start above or below the land surface elevation because the data are projected onto the cross section from a distance of up to 0.3 mile (0.5 kilometer) from the line of section. Bedrock units taken from Plate 2, *Bedrock Geology*, are shown at the base of the Quaternary deposits between associated black dots (unit contact lines).

Figure 2 is a map showing the general up-ice location of major provenances (source regions) and the extent of the surficial ice lobes. A schematic illustration showing the relationships between age, provenance, stratigraphic position, and location of the sediments deposited in Renville County by major glacial episodes is shown in Figure 3. Logs of three of the five rotary-sonic cores recovered for the Minnesota Geological Survey by Traut Well Drilling Company are shown in Figures 4 to 6. Analyses of the texture and clast composition of the Quaternary sediments were completed for selected geologic units, and are listed in Table 1.

DESCRIPTION OF CROSS SECTION UNITS

Each unit on the cross sections is designated by a letter code, which is described below and placed in one of three categories that designates the origin of the code, as indicated in parentheses after the description: 1. *Surficial Geology* unit—units having an identical description, label, and color as on Plate 3, *Surficial Geology*; see Plate 3 for the detailed descriptions; 2. New unit—unit that appears only on the cross section and has a unique label and color; and 3. Modified unit—multiple units from Plate 3 that are combined into one unit on the cross sections (for example units Qs and Qsc are combined into unit Qsh). Contact lines that intersect the land surface on cross sections do not match all contact lines shown on the surficial map because some units shown on Plate 3 are too small or thin to be shown on the cross sections.

HOLOCENE

Qa — **Sand and pebbly sand with silt and clay—alluvium** (modified unit)—Map units Qa and Qrk from Plate 3. May be thin over bedrock or include bedrock in some areas where associated with unit Qrk.

Qf — **Loamy sand and sand—alluvial fan sediment** (*Surficial Geology* unit)—Small, thin areas may not be shown on the cross sections.

Qhl — **Silt and clay—modern lake sediment** (*Surficial Geology* unit)—Small, thin areas may not be shown on the cross sections.

PLEISTOCENE

Late Wisconsinan glacial deposits

New Ulm Formation (Des Moines-lobe deposits)—See Figure 2 and Plate 3, Figure 3B.

Heiberg Member—The youngest glacial material at the surface in Renville County (Fig. 3; Plate 3, Fig. 3B).

Qsh — **Sand, gravelly sand, and cobbly gravel—glacial stream sediment** (modified unit)—Map units Qs and Qsc from Plate 3. Includes both uncollapsed and collapsed sediment deposited by glacial meltwater; associated with the deglaciation of the ice that deposited the Heiberg Member.

Ql — **Silt and clay—glacial lake sediment** (*Surficial Geology* unit)—Deposits of glacial Lake Benson and other unnamed proglacial lakes associated with the Des Moines lobe. May include well-sorted sand in places.

Qth — **Loam till deposits with patchy areas of thin glacial lake sediment** (modified unit)—Map units Qtl, Qtm, Qtw, and Qtz from Plate 3. Primarily loamy till, which contains abundant clasts of gray siliceous shale, typically composing 30 to 60 percent of the very coarse-grained sand fraction (Table 1). May include Villard Member till within the unit and at the surface, in and north of the shear zone where Villard Member materials were incorporated into Heiberg Member ice as it advanced over the area. May also include thin lake sediment (similar to unit Ql), debris flows, locally sorted and redeposited material, and inclusions of sand and gravel, particularly near the land surface.

Villard Member—See Figure 3 and Plate 3, Figure 3B.

Qsi — **Sand, gravelly sand, and cobbly gravel—glacial stream sediment** (new unit)—Sediment deposited by glacial meltwater chiefly associated with the Villard Member of the New Ulm Formation (Johnson and others, in press), but may include proglacial meltwater deposits of the overlying Heiberg Member.

Qti — **Loam till deposits** (new unit)—Till deposits found in the subsurface along and north of the shear zone, generally beneath Heiberg Member deposits (Plate 3, Fig. 2), but in places beneath thin lake sediment, debris flows, and locally sorted and redeposited materials. At the surface in a few isolated areas, too small to be shown on the surficial map (Plate 3). Till of this unit commonly contains clasts of gray siliceous shale, typically composing 15 to 30 percent of the very coarse-grained sand fraction (Table 1). May include pods, lenses, and thin layers of outwash sand and gravel, and sand, as well as lacustrine sand, silt, and clay.

Moland Member—Discontinuous deposits attributed to an early phase of the Des Moines lobe (Johnson and others, in press). Exposed in places along the river bluffs but otherwise found only in the subsurface in this area (Fig. 3).

Qsm — **Sand, gravelly sand, and cobbly gravel—glacial stream sediment** (new unit)—Sediment deposited by glacial meltwater. May include proglacial meltwater deposits of the overlying Villard and Heiberg Members.

Qtm — **Sandy loam till deposits** (new unit)—Till tends to be denser and contains more matrix sand and fewer clasts of gray siliceous shale than the overlying Villard and Heiberg Member deposits of the Des Moines lobe. Typically, shale content ranges from 3 to 15 percent of the very coarse-grained sand fraction (Table 1). Without laboratory analyses this unit 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 the cross sections is only approximate. May include pods, lenses, and thin layers of outwash sand and gravel, and sand, as well as lacustrine sand, silt, and clay.

Traverse des Sioux Formation (Wadena-lobe deposits)—Evidence from recent studies (Lusardi and others, 2012; Meyer and others, 2012a, b) completed along the Minnesota River valley between Henderson and New Ulm suggests that the Traverse des Sioux Formation (Johnson and others, in press) is correlative with the Hewitt Formation (Johnson and others, in press), which was deposited by the north–northeastern (Rainy) provenance Wadena lobe and its meltwater in central Minnesota (Figs. 2, 3).

Qst — ***Sand, gravelly sand, and cobbly gravel—glacial stream sediment*** (new unit)—Sediment deposited by glacial meltwater. Existence is based on one core interval in rotary-sonic drill core from RNR-4 and water-well log interpretations; not seen in outcrop. May include proglacial meltwater deposits of the overlying Moland Member (New Ulm Formation).

Qtt — ***Sandy loam till deposits*** (new unit)—Gray, dense, sandy loam till was recognized in rotary-sonic drill core from RNR-2, where 40 feet (12 meters) of till was encountered (Fig. 5). This site is the only confirmed occurrence of this unit in Renville County and provides, along with evidence of its presence in adjacent Sibley (Lusardi and others, 2012) and Nicollet (Meyer and others, 2012b) Counties, the basis for showing its patchy subsurface distribution on the cross sections in eastern Renville County. Traverse des Sioux Formation till is similar in texture, color, and density to the overlying Moland Member till, but can be distinguished from the Moland Member in the core by its scarcity (trace amounts) of gray shale (Table 1). Yet in the cross sections where differentiation is more difficult, the thickness and extent of the two units relative to each other is only approximate. Includes pods, lenses, and thin layers of outwash sand and gravel and sand.

Pre-Wisconsinan glacial deposits

Good Thunder formation—Light olive-brown to dark gray bedded sediment and dense, loam to clay loam till of Winnipeg provenance (Figs. 2, 3; Plate 3, Table 1) was recognized and informally named the Good Thunder formation by Johnson (unpub. data). Recent studies in Sibley (Lusardi and others, 2012), Nicollet (Meyer and others, 2012b), and Blue Earth (Meyer and others, 2012a) Counties suggest multiple units comprise the formation. The till typically contains abundant carbonate and some gray shale (Table 1). Rotary-sonic drill core and exposures along the Minnesota River valley have identified at least five similar yet distinct tills as part of the informally named Good Thunder formation in Renville County (Fig. 3). These units vary in thickness and are typically widespread throughout the county (with the exception of unit *Qg5*, which may be patchy and less extensive), although each is missing in places and all five were encountered at only one drill site (RNR-3; Fig. 6). In places, these tills are separated by at least two, and possibly three separate, scattered, thin, red, Superior provenance deposits and/or organic-rich clayey silt with wood, which are all included within the Good Thunder formation units on the cross sections. These intervening deposits are leached of carbonate in places, which along with the fact that the upper portion of Good Thunder formation units is locally oxidized to yellow-brown or oxidized/reduced to green or green-blue, suggests that a significant period of exposure and weathering took place between these ice advances. Some of these units probably correlate to the Lake Henry and Eagle Bend Formations of central Minnesota (Johnson and others, in press), whereas some of the intervening red tills may correlate with the St. Francis Formation (Johnson and others, in press) of central Minnesota and the Hawk Creek Formation (Matsch, 1971, 1972; Johnson and others, in press) of southwest Minnesota. Although all five Good Thunder formation units are similar in texture and grain content, subtle distinctions can be made, as shown in Table 1 and noted in the unit descriptions. All units contain pods, lenses, and thin layers of outwash sand and gravel, and sand.

Qsg — ***Sand and gravel*** (new unit)—Chiefly composed of outwash sediment derived from unit *Qg1* but may also include materials from overlying units *Qtt*, *Qtm*, *Qti*, and *Qth*.

Qg1 — ***Loam till*** (new unit)—Contains slightly more gray shale and other Cretaceous rock fragments than Good Thunder formation units *Qg2*, *Qg4*, and *Qg5* (Table 1). In a few places in the lower portion of the unit, it may include reddish sandy loam till of Superior provenance. Unit *Qg2* and/or fine-grained lake sediment is also likely included in places. Sediments in the upper portion may be green to greenish-blue in a few places due to post-deposition oxidation caused by a significant period of surface exposure, which was followed by reduction as the next ice advance created saturated conditions.

Qs2 — ***Sand and gravel*** (new unit)—Commonly composed of outwash sediment from unit *Qg2*, but may include some materials derived from overlying units *Qg1*, *Qtt*, and *Qtm* and Superior provenance deposits.

Qg2 — ***Loam till*** (new unit)—Contains trace amounts of gray shale and other Cretaceous rock fragments, similar to unit *Qg4* (Table 1). May include reddish sandy loam till of Superior provenance, as well as material derived from units *Qg1* and *Qg3*, and fine-grained lake sediment. In places an organic soil horizon (locally leached) has developed, commonly in lake sediment, forming the upper contact of this unit. Wood from rotary-sonic drill core RNR-3 (Fig. 6) in one of these horizons produced an infinite date of more than 48,500 radiocarbon years before present (Livermore National laboratory, no. 152996). Green to greenish-blue (oxidized/reduced) sediment is also present in places beneath the upper contact of this unit.

Qs3 — ***Sand and gravel*** (new unit)—Commonly composed of outwash sediment derived from unit *Qg3*; may include some materials derived from overlying units *Qg2* and *Qg1*, and Superior provenance deposits.

Qg3 — ***Loam till*** (new unit)—Contains approximately 10 percent gray shale and other Cretaceous rock fragments (Table 1), which makes this unit easy to confuse with Des Moines-lobe till deposits in outcrops along the Minnesota River valley bluffs. May include reddish sandy loam till of Superior provenance, as well as material from units *Qg2* and *Qg4*, and fine-grained lake sediment. In places an organic soil horizon has developed, commonly in lake sediment, forming the upper contact of this unit. Green to greenish-blue (oxidized/reduced) sediment is also present in a few places beneath the upper contact of this unit.

Qs4 — ***Sand and gravel*** (new unit)—Commonly composed of outwash sediment from unit *Qg4*; may include some materials derived from overlying units *Qg2* and *Qg3*, and Superior provenance deposits.

Qg4 — ***Loam till*** (new unit)—Contains trace amounts of gray shale and other Cretaceous rock fragments, similar to unit *Qg2* (Table 1). May include reddish sandy loam till of Superior provenance, as well as material from units *Qg3* and *Qg5*, older undifferentiated units, and fine-grained lake sediment. In places an organic soil horizon (sometimes leached) has developed, commonly in lake sediment, forming the upper contact of this unit. Green to greenish-blue (oxidized/reduced) sediment is also present in places at and beneath the upper contact of this unit—more so than in other Good Thunder formation units.

Qs5 — ***Sand and gravel*** (new unit)—Commonly composed of outwash sediment from unit *Qg5*; may include some materials from overlying units *Qg4* and *Qg3*, Superior provenance deposits, and older undifferentiated units.

Qg5 — ***Loam till*** (new unit)—Contains trace amounts of gray shale and other Cretaceous rock fragments (Table 1). Its moderate carbonate content distinguishes it from other Good Thunder formation units. May include reddish sandy loam till of Superior provenance, as well as material from unit *Qg4*, older undifferentiated units, and fine-grained lake sediment. In places an organic soil horizon has developed, commonly in lake sediment, forming the upper contact of this unit. Some wood fragments are present.

Elmdale Formation—Yellow-brown to dark gray bedded sediment and dense loam to clay loam till of Winnipeg provenance (Figs. 2, 3; Plate 3, Table 1) associated with the "W" sequence units of central and north-central Minnesota (Meyer, 1997). The till contains small to moderate amounts of carbonate and some gray shale and other Cretaceous clasts (Table 1). Commonly thin and patchy and where present appears to be the basal glacial unit above bedrock. May contain significant amounts of incorporated saprolite (weathered bedrock) and bedrock.

Qse — ***Sand and gravel*** (new unit)—Commonly composed of outwash sediment from unit *Qte*; may include materials from overlying units *Qg3*, *Qg4*, and *Qg5*, Superior provenance deposits, older glacial deposits, and reworked bedrock.

Qte — ***Loam till*** (new unit)—Recognized in 3 rotary-sonic drill holes (RNR-1, RNR-4, and B-34D; Figs. 1, 4) and one outcrop along the Minnesota River bluff. May include materials from the overlying units *Qg3*, *Qg4*, and *Qg5*, Superior provenance deposits, older glacial deposits, and possibly some pre-Pleistocene sediment.

Undifferentiated deposits

Qsu — **Sand and gravel** (new unit)—May be composed of outwash sediment from units *Qg2*, *Qg3*, *Qg4*, *Qg5*, and *Qte*, Superior provenance deposits, and older glacial deposits, but is probably composed primarily of materials from the unit directly above it and/or older materials. May include till in places.

Qu — **Sediment** (new unit)—Includes till, sand, gravel, and fine-grained lake sediments. Shown in areas where control data were scarce or absent. Till of this unit may contain Good Thunder and Elmdale formation deposits, other Rainy provenance "W" sequence deposits (Meyer, 1997), and older deposits. Although some water wells extend below this boundary, the data are too few to make meaningful correlations.

Qsz — **Basal sand and gravel** (new unit)—Includes primarily sand and gravel, but may include till and other fine-grained lake sediments. Shown in areas where control data were scarce or absent. Although some water wells extend below this boundary, the data are too few to make meaningful correlations.

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