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MINNESOTA GEOLOGICAL SURVEY
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QUATERNARY STRATIGRAPHY

By
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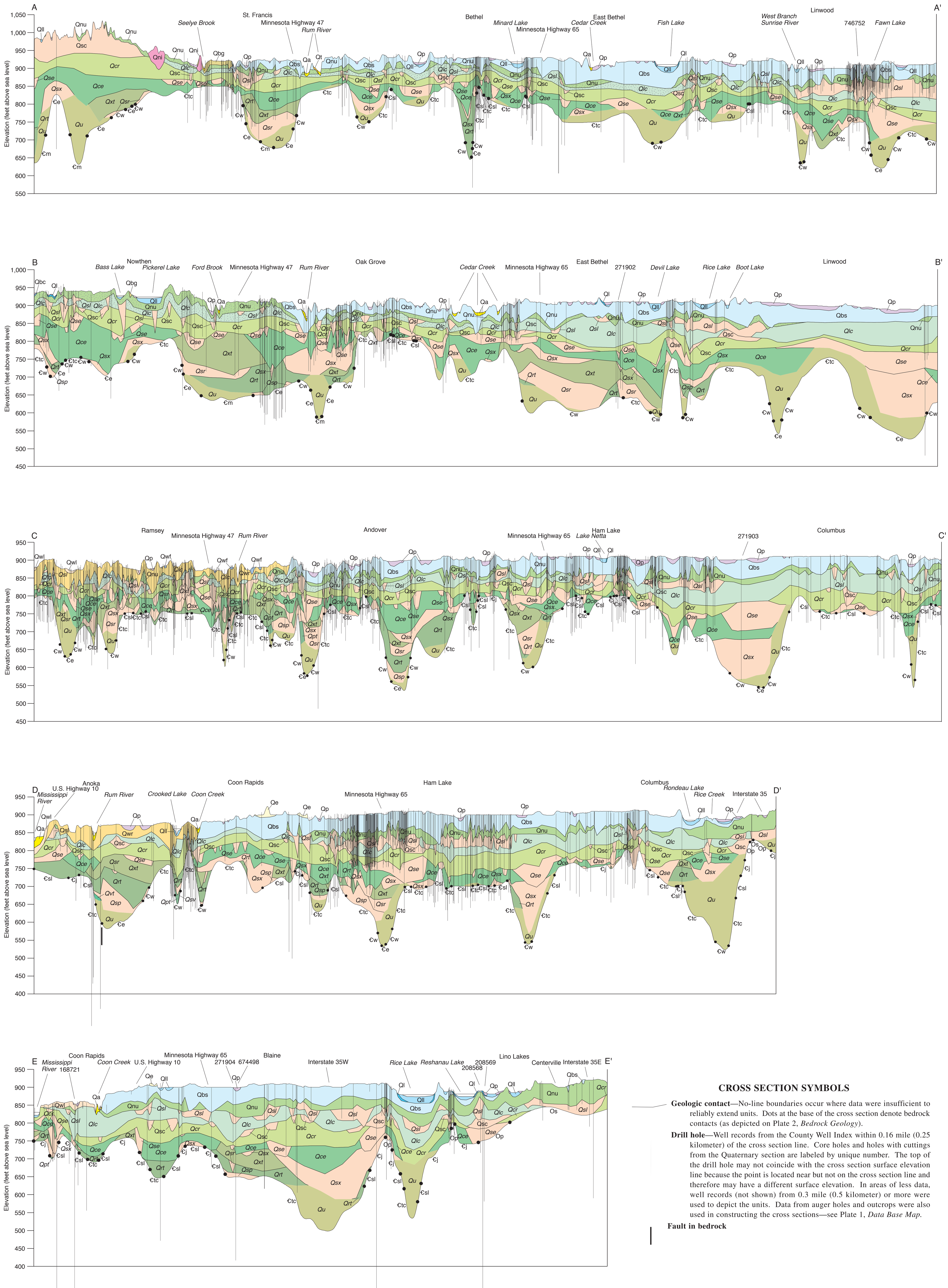
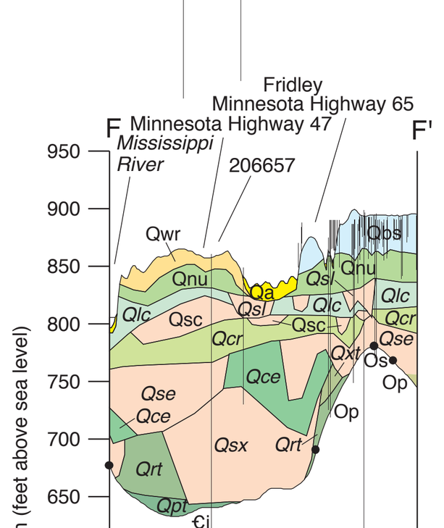
2013

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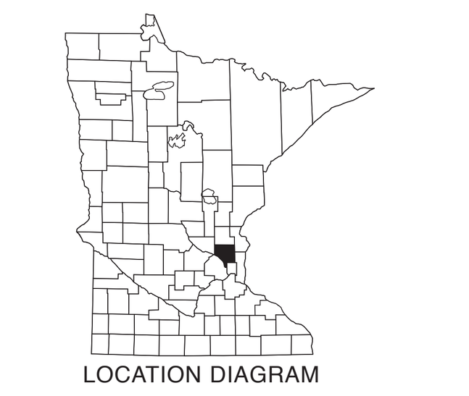
LOCATION DIAGRAM

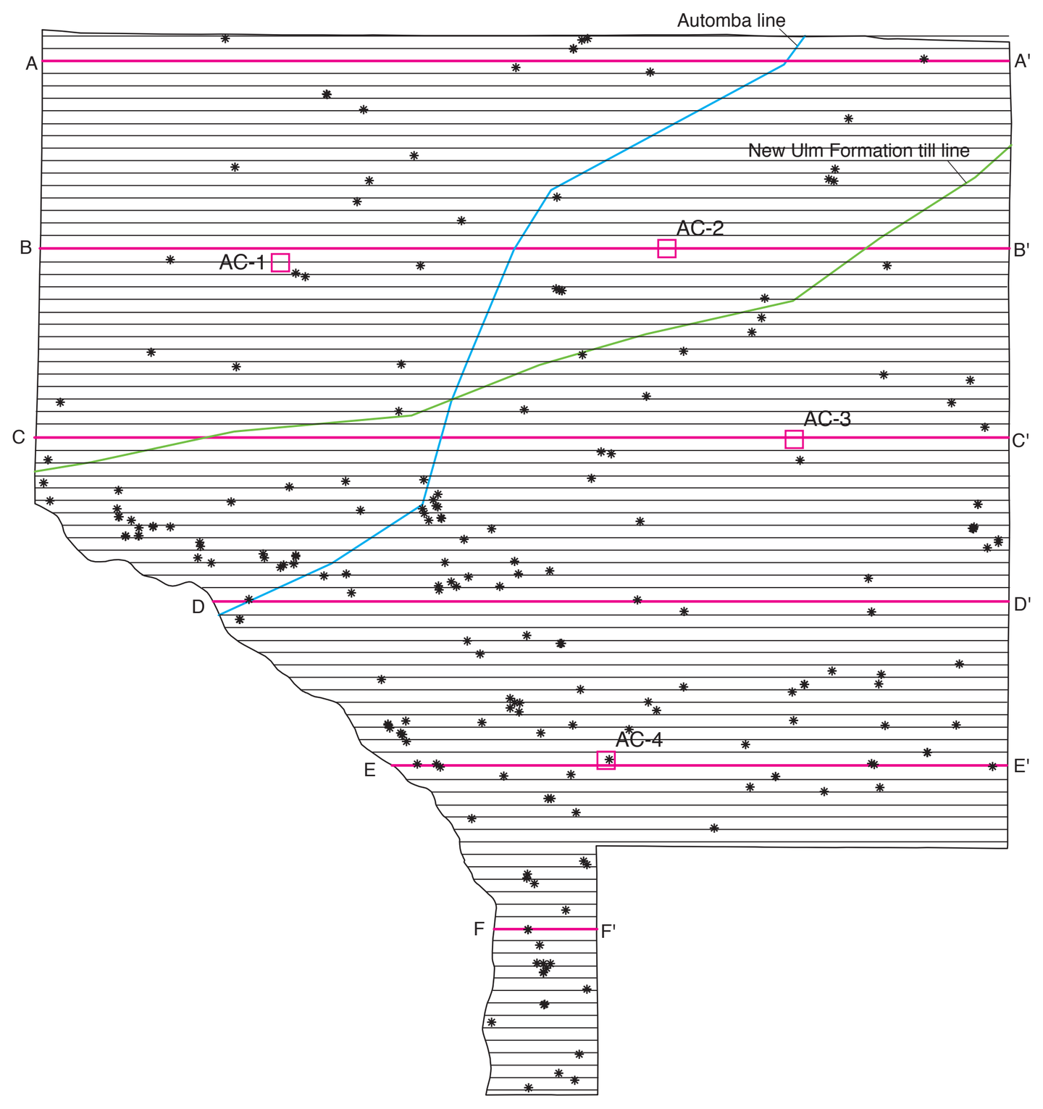
Figure 1. Location of the 87 cross sections, constructed at regular 0.3 mile (0.5 kilometer) intervals, used to create a three-dimensional model of the Quaternary deposits of Anoka County. The locations of cross sections A–A' through F–F' are shown here, and are also shown on Plate 3, *Surficial Geology*. Magenta squares depict the locations of the four Minnesota Geological Survey rotary-sonic core sites, and black asterisks depict the location of drill cutting sites. North of the green line, till of the New Ulm Formation (unit Qnu) is generally sandy textured, whereas south of the green line its texture ranges from loam to fine-grained sandy loam. Northwest of the blue line, till of the Automba phase of the Superior lobe (unit *Qlc*) is generally sandy, whereas to the southeast the till is clayey-textured. Scale is 1:300,000.

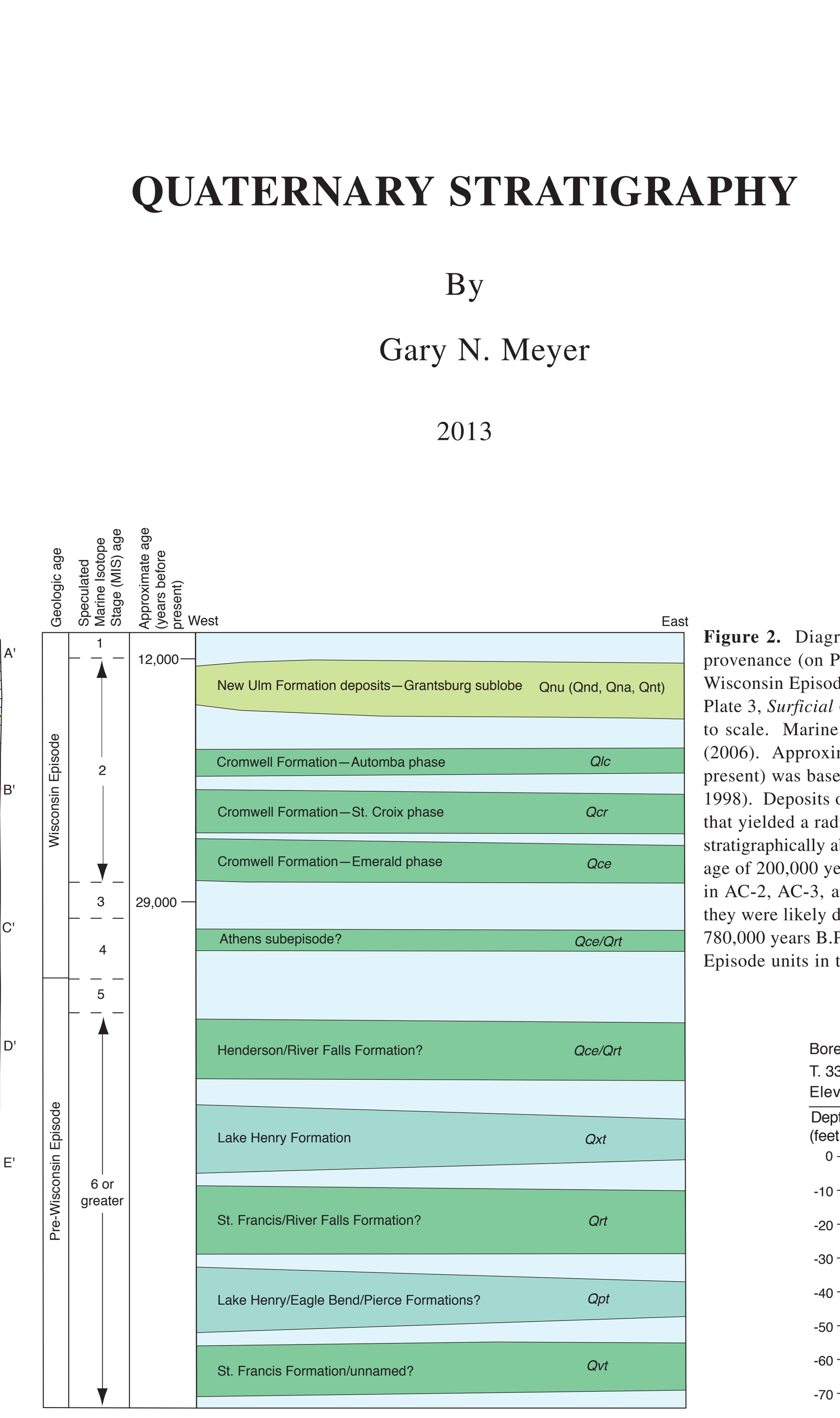
Figure 2. Diagram showing relative age, locations (across Anoka County from west to east), provenance (on Plate 3 see Fig. 3 and Table 1), and related unit labels from the cross sections for Wisconsin Episode and pre-Wisconsin Episode glacial deposits (Table 1); corresponding units from Plate 3, *Surficial Geology*, are shown in parentheses. The age column and deposit drawings are not to scale. Marine Isotope Stage correlations were estimated using figures in Jennings and others (2006). Approximate age shown for deglaciation of the Grantsburg sublobe (12,000 years before present) was based on radiocarbon dates from a half dozen sites in the Anoka County area (Meyer, 1998). Deposits of the Emerald phase bury an organic horizon in core from nearby Chisago County that yielded a radiocarbon date of about 29,000 years before present (Meyer, 2010). Marl deposits stratigraphically above the Lake Henry Formation in central Minnesota had a uranium series minimum age of 200,000 years before present (Knaeble and Meyer, 2007). Core samples from the older units in AC-2, AC-3, and AC-4 (Figs. 4 through 6) all were found to have normal polarity, indicating they were likely deposited after the Bruhnes normal–Matuyama reversed polarity boundary, dated at 780,000 years B.P. (Lisiecki and Raymo, 2005). These inferred dates place the cored pre-Wisconsin Episode units in the Middle Pleistocene, between Marine Isotope Stages 8 and 18.

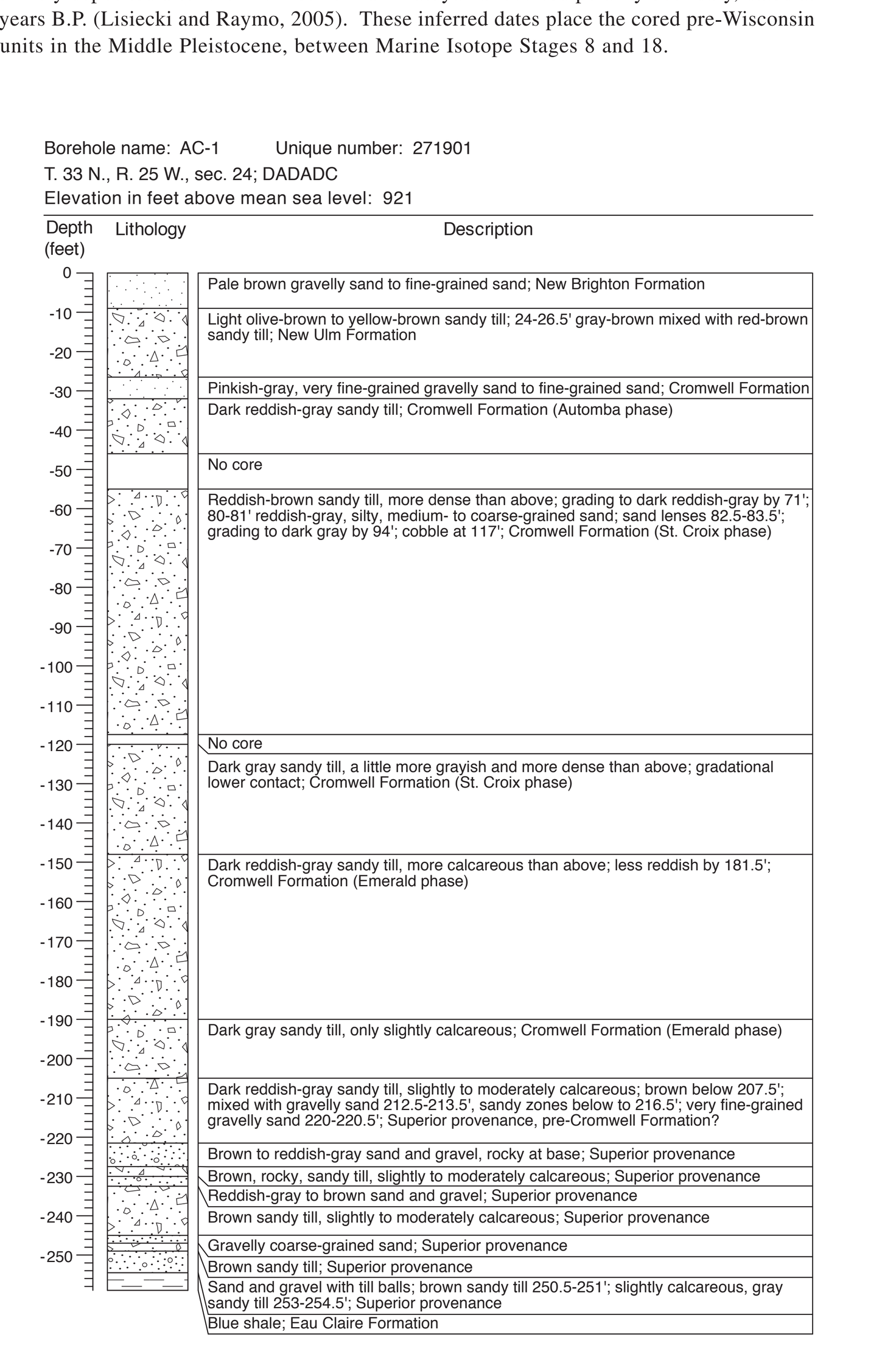
Figure 3. Descriptive log of rotary-sonic core AC-1, drilled by Mark J. Traut Wells for this study. Location of drilling is shown on Figure 1 and Plate 1, *Data-Base Map*.

CROSS SECTION SYMBOLS

Geologic contact—No-line boundaries occur where data were insufficient to reliably extend units. Dots at the base of the cross section denote bedrock contacts (as depicted on Plate 2, *Bedrock Geology*).

Drill hole—Well records from the County Well Index within 0.16 mile (0.25 kilometer) of the cross section line. Core holes and holes with cuttings from the Quaternary section are labeled by unique number. The top of the drill hole may not coincide with the cross section surface elevation line because the point is located near but not on the cross section line and therefore may have a different surface elevation. In areas of less data, well records (not shown) from 0.3 mile (0.5 kilometer) or more were used to depict the units. Data from auger holes and outcrops were also used in constructing the cross sections—see Plate 1, *Data Base Map*.

Fault in bedrock

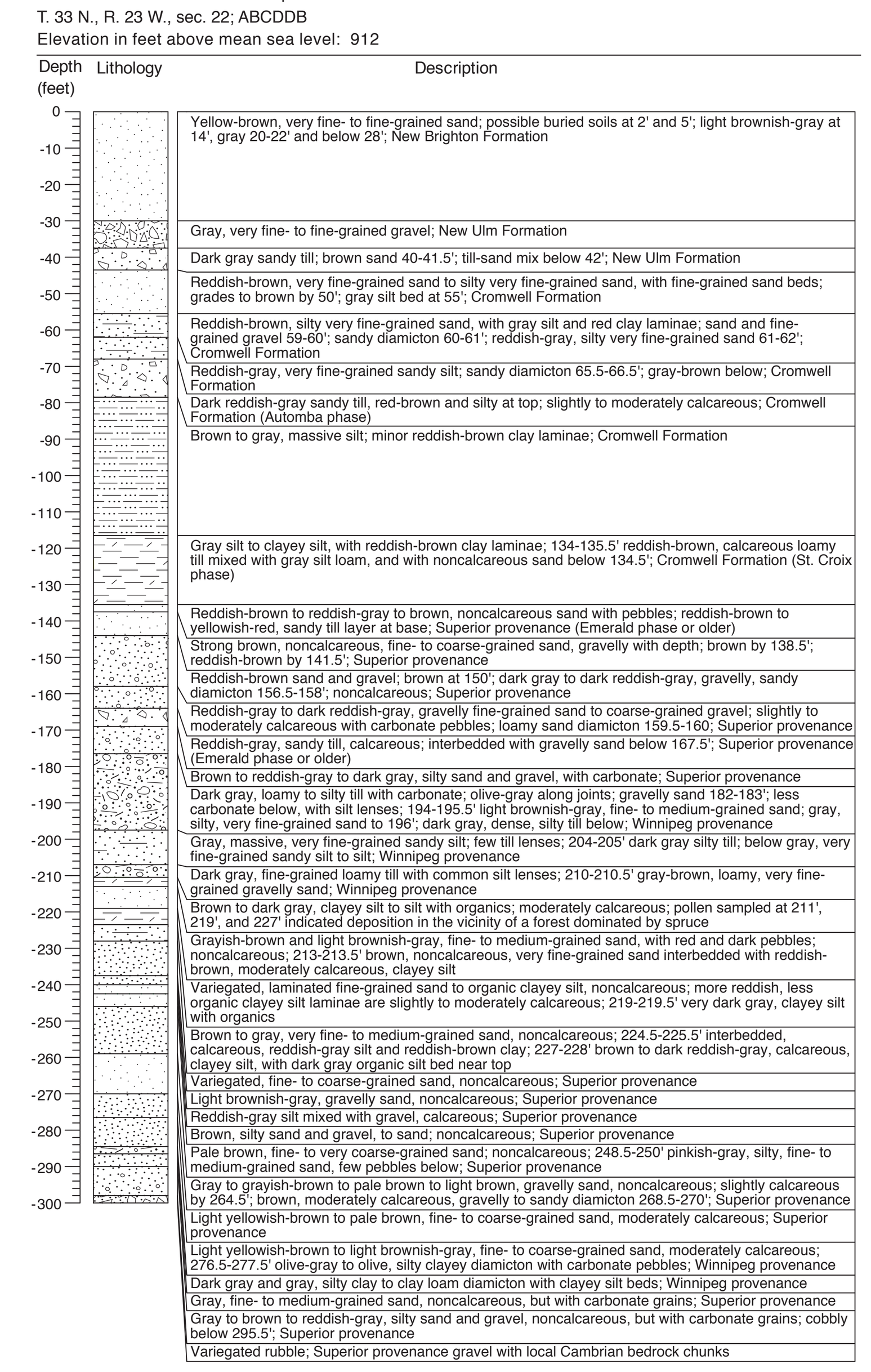
Figure 4. Descriptive log of rotary-sonic core AC-2, drilled by Mark J. Traut Wells for this study. Location of drilling is shown on Figure 1 and Plate 1, *Data-Base Map*.

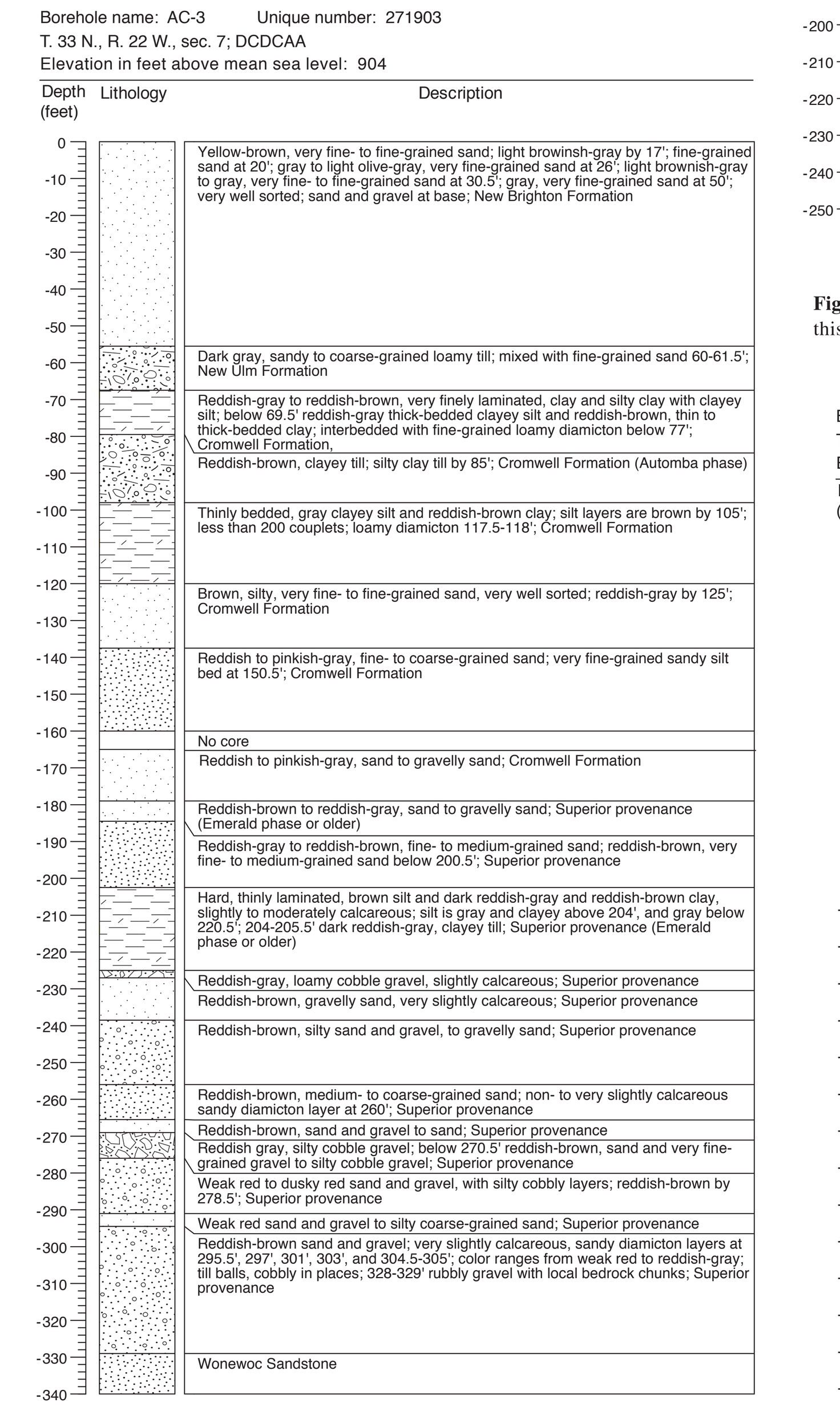
Figure 5. Descriptive log of rotary-sonic core AC-3, drilled by Mark J. Traut Wells for this study. Location of drilling is shown on Figure 1 and Plate 1, *Data-Base Map*.

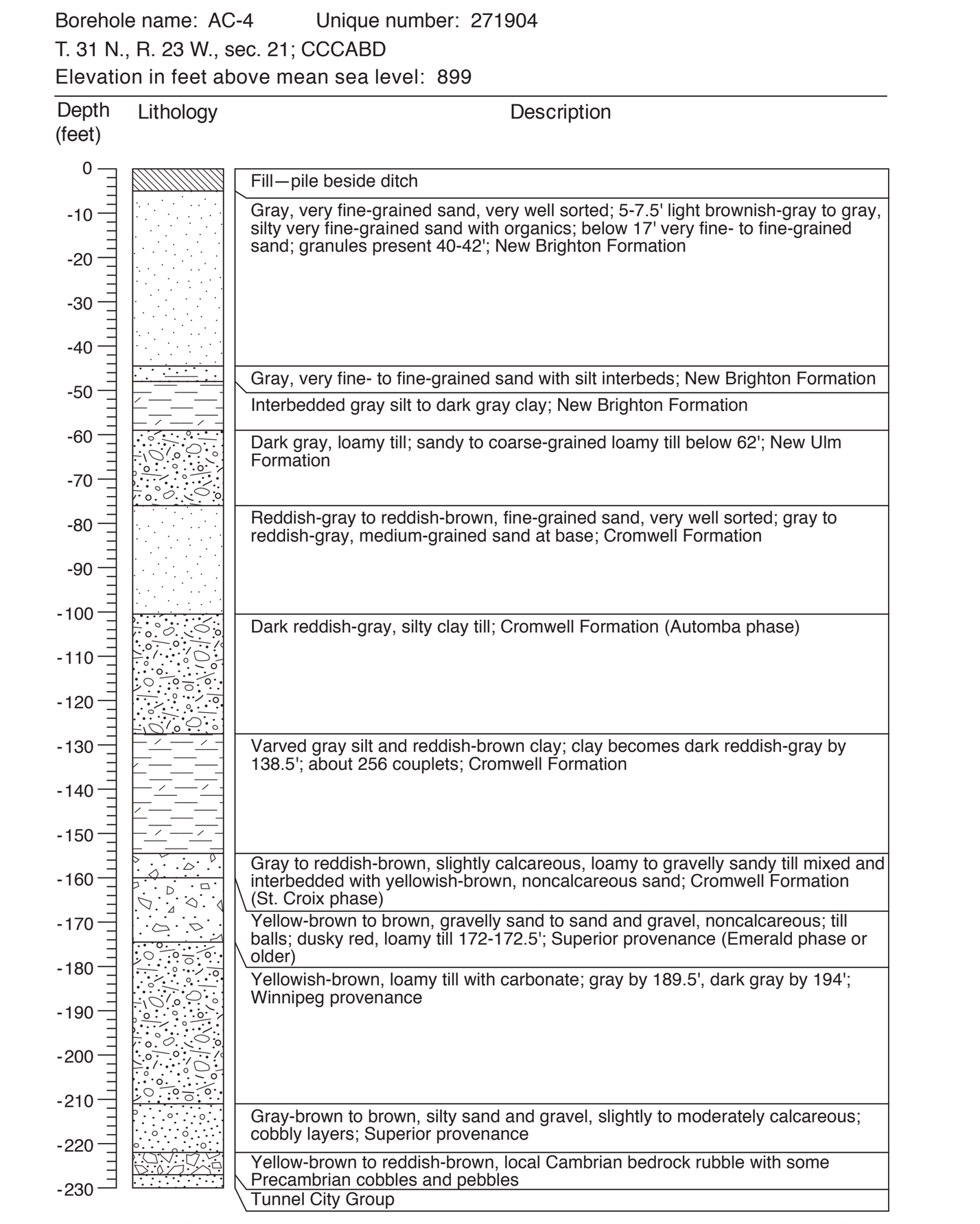
Figure 6. Descriptive log of rotary-sonic core AC-4, drilled by Mark J. Traut Wells for this study. Location of drilling is shown on Figure 1 and Plate 1, *Data-Base Map*.

Table 1. Average values for the matrix texture and composition of tills recognized in Anoka 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 quartz, dark (mafic-rich igneous and metamorphic rocks), red (rhyolite, agate), sandstone, and other; 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 crystalline grains counted					
Deposit description and geologic unit shown on cross sections	Total number of samples	Gravel (percentage of total sample weight)	Sand	Silt	Clay	Total number of samples	Precambrian	Paleozoic	Cretaceous	Light	Monomineralic quartz	Dark	Red	Sandstone	Other
New Ulm Formation till (unit Qnu)	85	5	53	30	17	63 (all)				62	15	16	5	2	T
					(unleached)	58	68	18	14						
(Loam-textured portion of unit Qnu)	32	5	46	34	20	24	59	21	20	65	16	15	3	1	T
(Sandy-textured portion of unit Qnu)	53	6	59	27	14	39 (all)				60	15	17	5	3	T
					(unleached)	34	75	16	9						
Cromwell Formation till (clayey till portion of unit *Qlc*)	22	2	20	41	39	11	97	3	T	26	13	35	19	6	1
Cromwell Formation till (sandy till portion of unit *Qlc*, and units *Qcr* and *Qce*)	63	9	64	25	11	46 (all)				33	13	31	16	6	1
					(unleached)	42	98	2	T						
Pre-Wisconsin Episode, Winnipeg provenance till (units *Qxt* and *Qpt*)	20	3	33	45	22	18	69	30	1	61	20	15	3	1	T
Pre-Emerald phase, Superior provenance till (unit *Qrt*)	31	16	66	23	11	26 (all)				28	26	27	14	4	1
					(unleached)	21	98	2	T						

INTRODUCTION

The Quaternary Stratigraphy plate shows the unconsolidated sediment expected to be encountered between the land surface and bedrock in Anoka County. Cross sections A–A' through F–F' are representative of 87 cross sections (Fig. 1) that were constructed to create a three-dimensional model of the Quaternary deposits of Anoka 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 data from previous studies completed in the area (see Plate 3, Introduction) and through the interpretation of new data collected for this study. Some units match those on Plate 3, *Surficial Geology,* some new units appear only on the cross sections, others are a combination of multiple units from Plate 3, and still others are the result of dividing a unit from Plate 3. Outcrops, auger samples, drill core, drill cuttings, and water-well and soil boring drillers' logs (Plate 1, *Data Base Map*) were used to interpret the stratigraphy. Drill cuttings from the Quaternary section of about 150 wells were examined for this study (Fig. 1). Cuttings and split spoon cores had been described and sampled from four holes drilled for an earlier study (Meyer and Falteisek, 1993), and four continuous rotary-sonic core holes were drilled and the cores described and sampled for this project. 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 Summary of Glacial History section for additional information). Analyses of the texture and rock types of the Quaternary sediments were done for selected geologic units, as listed in Table 1. Logs of the four rotary-sonic cores drilled for the Minnesota Geological Survey for this study are shown in Figures 3 through 6.

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. The till units of the New Ulm Formation are combined into one unit, which is divided by pattern into a coarser- and finer-grained facies (Fig. 1). Deposits of the three phases of the Superior lobe that compose the Cromwell Formation (see Plate 3, Summary of Glacial History) are divided into finer- and coarser-grained sediment, with the till and fine-grained lake sediment combined as aquitards, and the fluvial and coarser lake sediment combined as potential aquifers. Sand bodies were assumed to divide the deposits of the different phases of the Superior lobe. Except for the finer-grained texture of some Automba phase deposits in Anoka County (Fig. 1), the characteristics of the various tills of Superior provenance are similar (Table 1). Without the intervening yellow to gray, fine-grained till of unit *Qxt*, it was difficult using primarily water-well records to distinguish the Cromwell Formation from older deposits of Superior provenance. It is likely that deposits from three (or more) pre-Emerald phase advances of the Superior lobe are included in units *Qce* and *Qrt*.

Underlying bedrock units are indicated by unit boundaries and labels corresponding to those described on Plate 2, *Bedrock Geology*. A fault in the bedrock is also indicated.

QUATERNARY

Hudson Episode

Qa **Alluvium** (*Surficial Geology* unit)

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

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

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

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

Wisconsin Episode

Qt **Terrace sand and gravelly sand** (*Surficial Geology* unit)

West Campus formation

Qwl ***Langdon terrace sand and gravelly sand*** (modified unit)—Map units Qwl, Qwn, Qwi, and Qwt from Plate 3.

Qwr ***Richfield terrace sand and gravelly sand*** (modified unit)—Map units Qwr and Qwd from Plate 3.

Qwf **Silt and clay facies** (*Surficial Geology* unit)

New Brighton Formation

Qbs ***Sand facies*** (modified unit)—Map units Qbs and Qbt from Plate 3. In the lower portion includes sand and gravel of unit Qbg and fluvial sediment of the New Ulm Formation in places. Also includes silt to silty clay lenses of unit Qbc in places.

Qbc ***Silt and clay facies*** (*Surficial Geology* unit)

Qbg ***Sand and gravel facies*** (*Surficial Geology* unit)

New Ulm Formation

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

Qnu ***Till to sandy till*** (modified unit)—Map units Qnt, Qna, and Qnd from Plate 3. Includes lacustrine silt and clay of unit Qbc in the upper part in a number of places where underlying unit Qbs. The patterned portion of the unit consists primarily of sandy till, with a texture commonly as coarse-grained as that of sandy till of the Cromwell Formation (Fig. 1; Table 1). The remainder of the unit is generally finer-grained, ranging from loam to fine-grained sandy loam.

New Ulm and Cromwell Formations

Qsl ***Sand and gravel*** (new unit)—Consists at lower elevations of mostly reddish, fine- to medium-grained sand of the Cromwell Formation, overlain in places by sand and gravel of the New Ulm Formation, but at higher elevations in the northwest and southeast portions of the county includes gravel of both the Cromwell (included in map unit Qci on Plate 3) and New Ulm Formations.

Cromwell Formation

Qlc ***Lacustrine clay and silt and/or clayey till, to sandy till*** (new unit)—At lower elevations, unit is mostly reddish, laminated clay and silt (glacial Lake Lind sediment, Sunrise Member; Johnson and others, in press) overlain or interbedded with fine-grained till; at higher elevations, unit is mostly reddish, fine-grained till (sandy-textured in the upper portion in places) deposited during the Automba phase of the Superior lobe (Fig. 2; Table 1; Coon Creek till of Meyer, 1998). Includes reddish clayey sediment reworked by the Grantsburg sublobe in places. The unit generally coarsens to the northwest (Fig. 1), with the patterned portion consisting primarily of sandy till similar to that of units *Qcr* and *Qce*.

Qsc ***Sand and gravel*** (new unit)—Included in map units Qci and Qco on Plate 3.

Qcr ***Sandy till*** (new unit)—Reddish, sandy loam-textured till (Table 1) primarily deposited during the St. Croix phase of the Superior lobe (Fig. 2). The upper part may include lacustrine clay and silt where unit Qsc occurs between Automba phase till and glacial Lake Lind sediment. May be finer-grained towards the base in places, particularly where filling deep valleys. Includes thick deposits of silty lacustrine sediment in places.

Qse ***Sand and gravel*** (new unit).

Qce ***Sandy till*** (new unit)—Reddish, sandy loam-textured till (Table 1) primarily deposited during the Emerald phase of the Superior lobe (Fig. 2), but likely includes in places till of the St. Croix phase in the upper portions, and older Superior provenance till in the lower portions. May be finer-grained towards the base in places, particularly where filling deep valleys. Includes thick deposits of silty lacustrine sediment in places.

Qsx ***Sand and gravel*** (new unit)—Includes older sediment of both Winnipeg and Superior provenances (see Plate 3, Fig. 3).

Pre-Wisconsin Episode

Qxt **Loam till** (new unit)—Yellow-brown to gray, generally silt-rich, loam-textured till of Winnipeg provenance, with common clasts of Paleozoic carbonate (Table 1; see Plate 3, Fig. 3). Equivalent to the K2 till of Ramsey County (Meyer, 1992), and correlated with the Lake Henry Formation (Fig. 2) of central Minnesota (Johnson and others, in press), and the upper two tills of the Good Thunder formation of south-central Minnesota (Lusardi and others, 2012). Includes deposits of silty to clayey lacustrine sediment, particularly in the thicker sections. In the western portion of the town of Ramsey and likely elsewhere, includes or consists of fine-grained basal sediment of the Cromwell Formation. This sediment is apparently mostly reworked interglacial sediment.

Qsr **Sand and gravel** (new unit)—Sediment of both Winnipeg and Superior provenances.

Qrt **Sandy till** (new unit)—Red-brown to gray, generally sandy loam-textured till of Superior provenance (Table 1); may be finer-grained towards the base in places, particularly where filling deep valleys. Includes thick deposits of silty lacustrine sediment in places. Correlated, at least in part, with the River Falls Formation (Baker and others, 1983; Mickelson and others, 1984; Attig and others, 1988; Meyer, 1992; Johnson, 2000), which has an uncertain relationship to unit *Qxt* (Fig. 2). Where not overlain by unit *Qxt*, may include Superior provenance sediment equivalent to the Henderson Formation (Johnson and others, in press), and/or sediment deposited during the Athens Subepisode of the Wisconsin Episode (Johnson and others, 1997; Meyer and Stefanova, 2009). Where overlain by unit *Qxt*, correlates with the St. Francis Formation of central Minnesota (Johnson and others, in press) or with older, unnamed units of Superior provenance.

Qsp **Sand and gravel** (new unit)—Sediment of Superior provenance, and also of Winnipeg provenance in places.

Qpt **Loam till** (new unit)—Yellow-brown to gray, generally loam to clay loam-textured till of Winnipeg provenance, with common clasts of Paleozoic carbonate (Table 1). Correlated with till of the lower (Meyer Lake) member of the Lake Henry Formation or in places till of the Eagle Bend Formation of central Minnesota (Fig. 2; Johnson and others, in press), and tills 2 and 3 of the Good Thunder formation of south-central Minnesota (Lusardi and others, 2012). Although not identified in the county, sediment of the older, Winnipeg provenance Pierce Formation (Baker and others, 1983; Mickelson and others, 1984; Attig and others, 1988; Johnson, 2000) is likely included in this unit in places. Includes deposits of silty to clayey lacustrine sediment, particularly in the thicker sections.

Qsv **Sand and gravel** (new unit)—Sediment of Superior provenance, and probably also of Winnipeg provenance in places.

Qvt **Sandy till** (new unit)—Red-brown to gray, generally sandy loam-textured till of Superior provenance. Correlates with the lower member of the St. Francis Formation of central Minnesota (Johnson and others, in press) or with older, unnamed units of Superior provenance.

Undifferentiated

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

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