UNIVERSITY OF MINNESOTA
MINNESOTA GEOLOGICAL SURVEY
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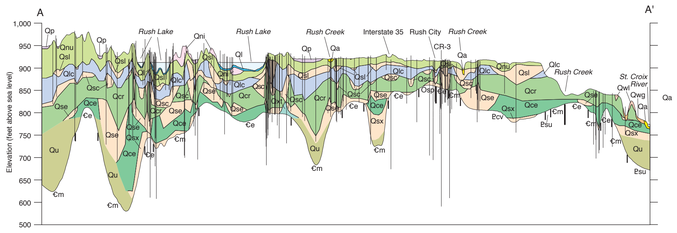
QUATERNARY STRATIGRAPHY

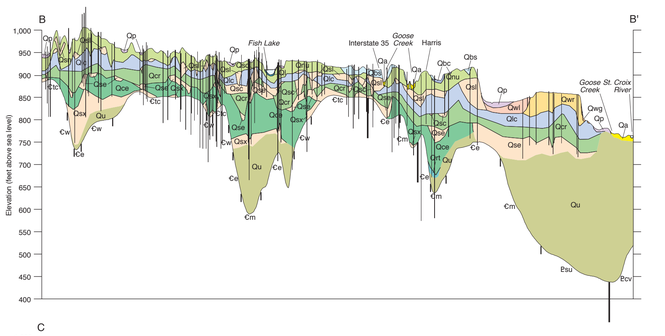
By

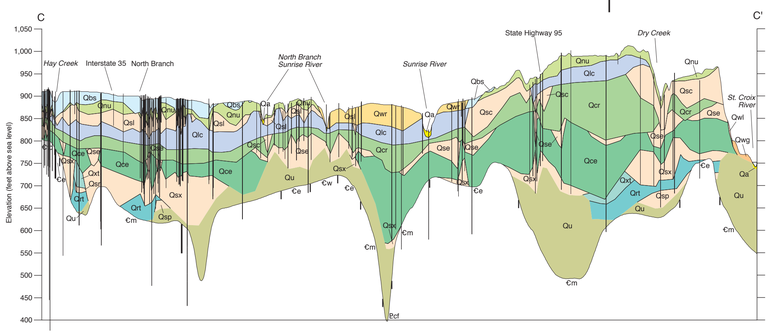
Gary N. Meyer

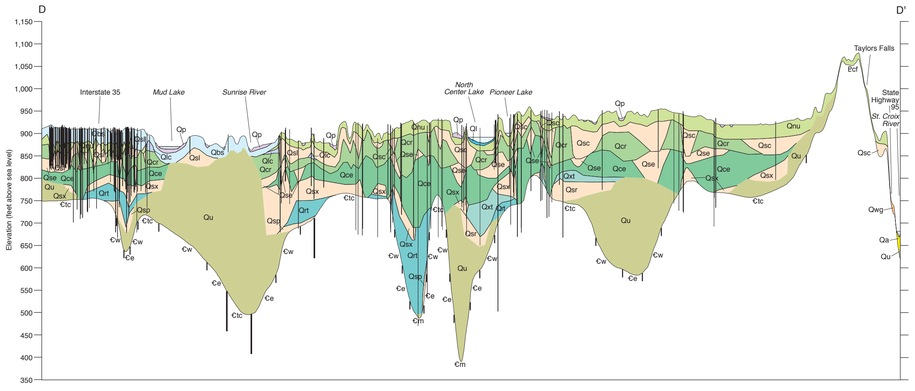
2010

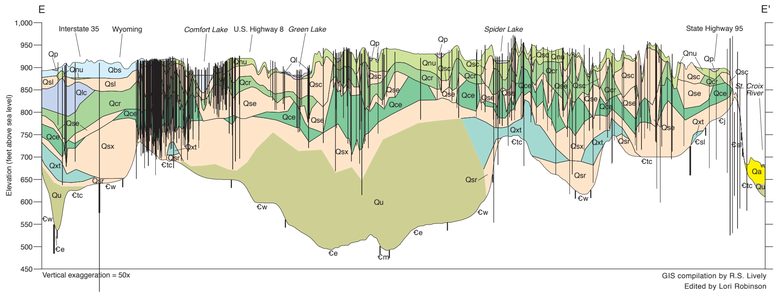
LOCATION DIAGRAM











GIS compilation by R.S. Lively
Edited by Lori Robinson

CROSS SECTION SYMBOLS

Geologic contact—No-line boundaries occur where data are insufficient to reliably extend units. Thick, vertical lines denote bedrock contacts where they touch surficial units, depicted on Plate 2, *Bedrock Geology*.

Drill hole—Water-well records from the County Well Index (Plate 1). 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.

Fault in bedrock.

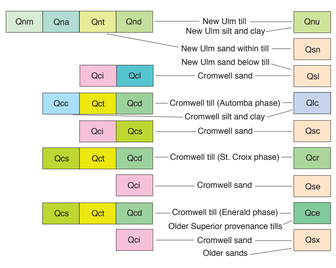


Figure 1. Diagram correlating the units on this plate to those on Plate 3, *Surficial Geology*.

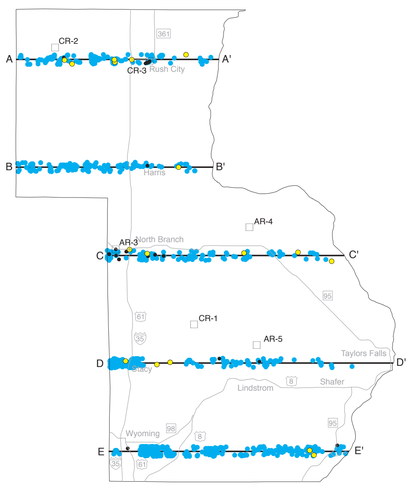


Figure 2. Diagram showing locations of cross sections A–A' through E–E', and the locations of the data points used in compiling stratigraphy for these five cross sections. Blue dots represent water-well drillers' sites with a log recorded in the County Well Index (only shown where within 0.3 mile [0.5 kilometer] of the cross section). Yellow dots include auger borings completed by the Minnesota Geological Survey, the U.S. Geological Survey, and the Minnesota Department of Transportation (not shown on cross sections). Boxes show Minnesota Geological Survey rotary-sonic core sites, and black dots depict drill cutting sites.

INTRODUCTION

The Quaternary Stratigraphy plate shows the unconsolidated sediment expected to be encountered between the land surface and bedrock in Chisago County. 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 (Fig. 1). Outcrops, auger samples, drill core, drill cuttings, and water-well drillers' logs (see Plate 1, *Data-Base Map*) were used to interpret the stratigraphy. The locations of auger, core, and cuttings holes, and water wells are shown on Figure 2, but are undifferentiated on the cross sections. Vertical exaggeration is 50x for all cross sections.

Figure 3 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 supplementary information). Analysis of the texture and rock types of the Quaternary sediments was done for selected geologic units, as listed in Table 1. Figure 4 is a pollen diagram for samples from a rotary-sonic core drilled for this atlas, and logs of six rotary-sonic cores drilled for the Minnesota Geological Survey for this and an earlier study (Meyer, 1993) are shown in Figures 5 through 10.

ACKNOWLEDGEMENTS

Many water well companies contributed valuable subsurface information used in this atlas, but special recognition is given to the George Johnson Well Drilling Company for exceptionally useful well logs.

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 (the new sand and gravel units have the same color to emphasize their status as potential aquifers). All the till units of the New Ulm Formation are combined into one unit, and the Cromwell Formation is depicted differently than on the surficial geology map to emphasize subsurface hydrogeologic characteristics. Deposits of the three phases of the Superior lobe that compose the Cromwell Formation are divided into finer- and coarser-grained sediment, with the till and fine-grained lake sediment combined as aquitards, and the fluvial and coarser-grained 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 Automba phase deposits in Chisago County, the characteristics of the various tills of Superior provenance are quite similar (Table 1). Without the intervening yellow to gray, fine-textured 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*. Faults in the bedrock are also indicated.

QUATERNARY

Hudson Episode deposits

Ql — **Lacustrine sediment** (*Surficial Geology* unit).

Qa — **Floodplain alluvium** (*Surficial Geology* unit).

Qp — **Peat and other organic sediment** (*Surficial Geology* unit).

Wisconsin Episode deposits

West Campus formation

Qwg — **Grey Cloud terrace** (*Surficial Geology* unit).

Qwl — **Langdon terrace** (*Surficial Geology* unit).

Qwr — **Richfield terrace** (*Surficial Geology* unit).

New Brighton formation

Qbs — **Sand facies** (*Surficial Geology* unit)—Includes unit Qno at depth in places.

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

New Ulm Formation

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

Qnu — **Till** (modified unit)—Map units Qnt, Qnm, Qna, and Qnd from Plate 3. Includes lacustrine silt and clay at the base in places in the northern cross sections.

Qsn — **Sand and gravel lens in New Ulm Formation till** (new unit)—Similar to unit Qni.

New Ulm and Cromwell Formations

Qsl — **Sand and gravel** (new unit)—Consists at lower elevations of mostly fine- to medium-grained sand (map unit Qcl on Plate 3) 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 (map unit Qci on Plate 3) and New Ulm Formations.

Cromwell Formation

Qlc — **Lacustrine clay and silt, to till** (new unit)—At lower elevations units consists mostly of laminated clay and silt (map unit Qcc on Plate 3), but in the higher elevations unit consists mostly of fine-textured till (sandy-textured in the upper portion in places) deposited during the Automba phase of the Superior lobe (Table 1; included in map units Qct and Qcd on Plate 3).

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

Qcr — **Sandy till** (new unit)—Primarily deposited during the St. Croix phase of the Superior lobe (included in map units Qct, Qcd, and Qcs on Plate 3). May be finer-textured towards the base in places, particularly where filling deep valleys. Includes thick deposits of silty to sandy lacustrine sediment in places.

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

Qce — **Sandy till** (new unit)—Primarily deposited during the Emerald phase of the Superior lobe (included in map units Qct, Qcd, and Qcs on Plate 3), but in places likely includes till of the St. Croix phase in the upper portions, and older Superior provenance till in the lower portions. May be finer-textured towards the base in places, particularly where filling deep valleys. Includes thick deposits of silty to sandy lacustrine sediment in places.

Qsx — **Sand and gravel** (new unit)—Included in map unit Qci on Plate 3. Includes older sediment of both Winnipeg and Superior provenance.

Pre-Wisconsin Episode deposits

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). Equivalent to the K2 till in Ramsey County (Meyer, 1992), and correlated with the Lake Henry and/or Eagle Bend formations of central Minnesota (Knaeble and Meyer, 2007). Includes deposits of silty to clayey lacustrine sediment, particularly in the thicker sections. 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.

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

Qrt — **Sandy till** (new unit)—Red-brown to gray, generally sandy loam-textured till (Table 1); may be finer-textured towards the base in places, particularly where filling deep valleys. Includes thick deposits of silty to sandy 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. Where not overlain by unit Qxt, may include Superior provenance sediment equivalent to the Hawk Creek Till (Matsch, 1972; Lusardi, 1998), and sediment deposited during the Athens Subepisode of the Wisconsin Episode (Johnson and others, 1997; Meyer and Stefanova, 2009).

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

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.

CAMBRIAN, MESOPROTEROZOIC

Cambrian and Mesoproterozoic bedrock—Unit codes are from Plate 2, *Bedrock Geology*.

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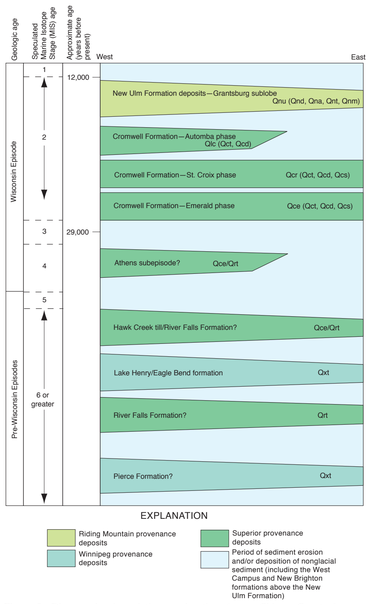

Figure 3. Diagram showing relative age, locations (across Chisago County from west to east), provenance (on Plate 3 see Fig. 3 and Table 1), and related unit labels from the cross sections for Wisconsin Episode and pre-Wisconsin Episode glacial deposits (Table 1); corresponding units from the surficial geology map (Plate 3) 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). The approximate age known for deglaciation of the Grantsburg sublobe (12,000 years before present) was based on radiocarbon dates from six sites in the Chisago County area (Meyer, 1998). Deposits of the Emerald phase bury an organic horizon in rotary-sonic core CR-1 that yielded a radiocarbon date of about 29,000 years before present (Meyer and Stefanova, 2009).

Table 1. Average values for the matrix texture and composition of tills recognized in Chisago 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 to 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 to 2 millimeter fraction is further differentiated by rock type—light (granite and gneiss), monomineralic quartz, dark (mafic-rich igneous and metamorphic rocks), red (rhyolite and 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 and Plate 3	Total number of samples	Gravel (percentage of total sample weight)	Sand	Silt	Clay	Percentage of sand greater than 1 mm	Total number of samples	Precambrian	Paleozoic	Cretaceous	Unknown	Light	Monomineralic quartz	Dark	Red	Sandstone	Other
New Ulm Formation till (unit Qnu)	115	5	48	33	19	7.0	29	64	18	18	3	69	9	15	4	2	1
Cromwell Formation till (Automba phase; till portion of unit Qlc)	26	4	35	42	23	4.6 (unleached)	12 (all) 6	99	1	0	1	22	16	38	16	5	3
Cromwell Formation till (St. Croix and Emerald phases; units Qcr and Qce)	115	9	63	25	12	6.6 (unleached)	64 (all) 44	98	2	T	1	30	20	31	14	4	1
Pre-Wisconsin Episode, Winnipeg provenance till (unit Qxt)	12	3	34	43	23	7.2 (unleached)	8 (all) 5	65	35	T	T	61	18	14	4	1	1
Pre-Emerald phase, Superior provenance till (unit Qrt)	17	9	65	23	12	7.9 (unleached)	15 (all) 8	99	1	0	2	32	20	28	13	4	2

Borehole name: CR-1 Unique number: 763777
T. 34 N., R. 21 W., sec. 12; CDDCBA
Elevation in feet above mean sea level: 875

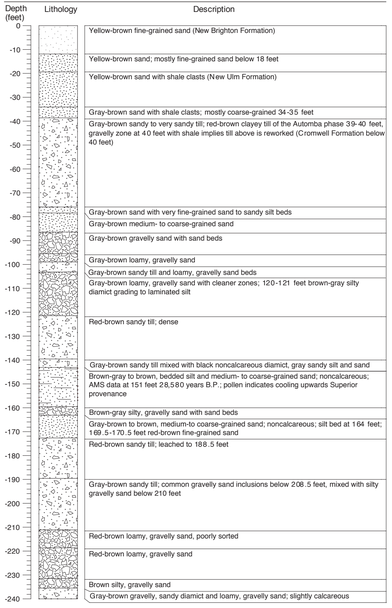

Figure 5. Descriptive log of rotary-sonic core CR-1, drilled by Mark J. Traut Wells for this study. Location of drilling is shown on Figure 2 and Plate 1, *Data-Base Map*.

Borehole name: CR-2 Unique number: 763776
T. 37 N., R. 22 W., sec. 16; ACCDDC
Elevation in feet above mean sea level: 924

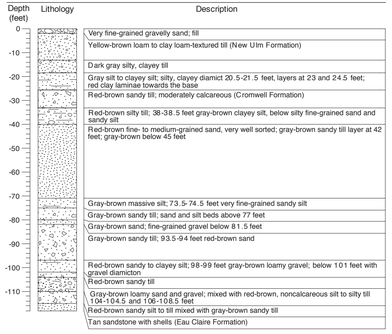

Figure 6. Descriptive log of rotary-sonic core CR-2, drilled by Mark J. Traut Wells for this study. Location of drilling is shown on Figure 2 and Plate 1, *Data-Base Map*.

Borehole name: CR-3 Unique number: 270111
T. 37 N., R. 21 W., sec. 21; ACACDD
Elevation in feet above mean sea level: 910

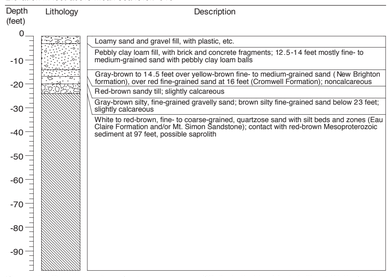

Figure 7. Descriptive log of rotary-sonic core CR-3, drilled by Mark J. Traut Wells for this study. Location of drilling is shown on Figure 2 and Plate 1, *Data-Base Map*.

Borehole name: AR-3 Unique number: 247207
T. 35 N., R. 21 W., sec. 19; ACBBBC
Elevation in feet above mean sea level: 890

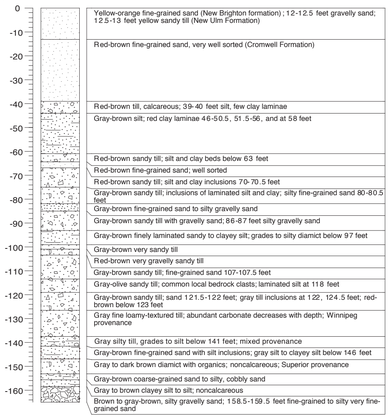

Figure 8. Descriptive log of rotary-sonic core AR-3, drilled by North Star Drilling for an earlier study (Meyer, 1993). Location of drilling is shown on Figure 2 and Plate 1, *Data-Base Map*.

Borehole name: AR-4 Unique number: 247208
T. 35 N., R. 20 W., sec. 9; DDADAB
Elevation in feet above mean sea level: 863

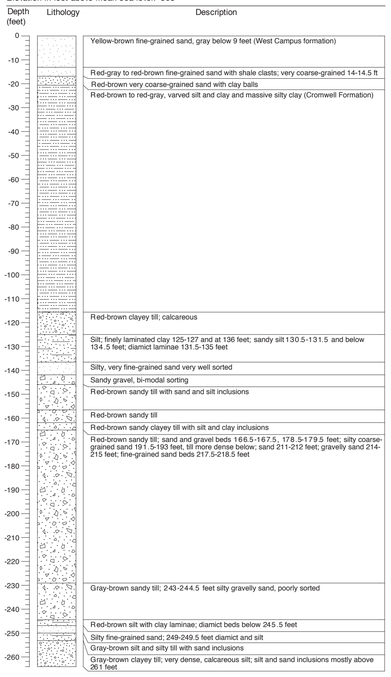

Figure 9. Descriptive log of rotary-sonic core AR-4, drilled by North Star Drilling for an earlier study (Meyer, 1993). Location of drilling is shown on Figure 2 and Plate 1, *Data-Base Map*.

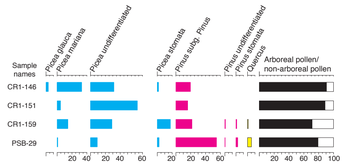

Figure 4. Diagram showing percent of pollen in an organic-bearing interval in core CR-1 (Fig. 5) with emphasis on spruce (Picea, blue), pine (Pinus, magenta), and oak (Quercus, yellow). Sample CR1-146 was taken at a depth of 146 feet (45 meters), CR1-151 at 151 feet (46 meters; and radiocarbon-dated at about 29,000 years before present), and CR1-159 at 159 feet (48 meters). Sample PSB-29 was taken from a similar stratigraphic setting in a hole in Ramsey County, and was radiocarbon-dated at about 32,000 years before present (Meyer, 1992). Pollen in sample PSB-29 indicates a warmer climate at that time, with low amounts derived from spruce and high amounts from pine and oak. A little oak pollen is present in the lower (older) sample in core CR-1, but increased spruce pollen and less pine pollen indicates a cooling climate from 32,000 to 29,000 years ago (Meyer and Stefanova, 2009), reflecting the onset of the last glaciation, the Michigan Subepisode of the Wisconsin Episode.

Borehole name: AR-5 Unique number: 247209
T. 34 N., R. 20 W., sec. 22; BDAACC
Elevation in feet above mean sea level: 915

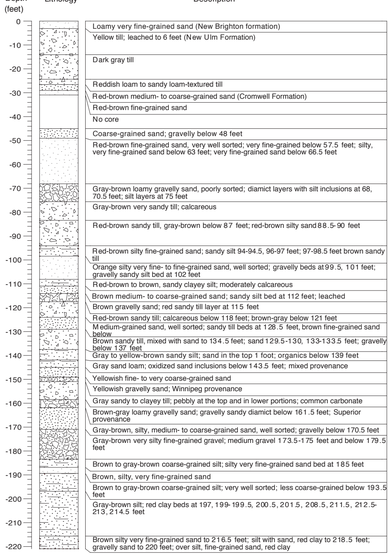

Figure 10. Descriptive log of rotary-sonic core AR-5, drilled by North Star Drilling for an earlier study (Meyer, 1993). Location of drilling is shown on Figure 2 and Plate 1, *Data-Base Map*.

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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