UNIVERSITY OF MINNESOTA
MINNESOTA GEOLOGICAL SURVEY
Harvey Thorleifson, Director

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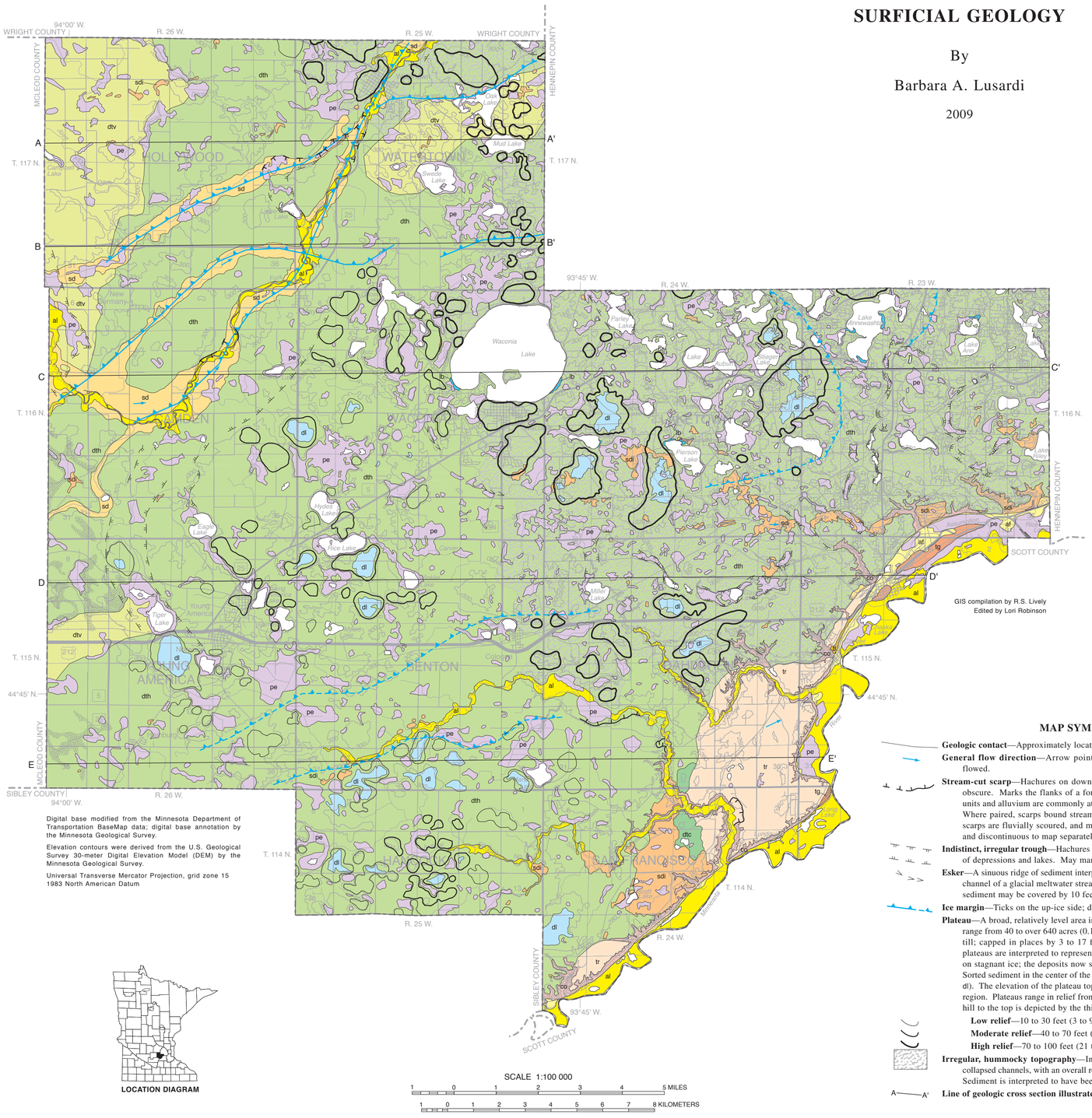
COUNTY ATLAS SERIES
ATLAS C-21, PART A
Plate 3—Surficial Geology

SURFICIAL GEOLOGY

By

Barbara A. Lusardi

2009



Digital base modified from the Minnesota Department of Transportation BaseMap data; digital base annotation by the Minnesota Geological Survey.

Elevation contours were derived from the U.S. Geological Survey 30-meter Digital Elevation Model (DEM) by the Minnesota Geological Survey.

Universal Transverse Mercator Projection, grid zone 15
1983 North American Datum

LOCATION DIAGRAM

SCALE 1:100 000
1 0 1 2 3 4 5 MILES
1 0 1 2 3 4 5 6 7 8 KILOMETERS
CONTOUR INTERVAL 20 METERS

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

MAP SYMBOLS

Geologic contact—Approximately located.

General flow direction—Arrow points in the direction glacial meltwater once flowed.

Stream-cut scarp—Hachures on downslope side; dashed where discontinuous or obscure. Marks the flanks of a former fluvial channel. Boundaries of terrace units and alluvium are commonly at scarps, so are not shown by a scarp symbol. Where paired, scarps bound stream-scoured areas. Till deposits downslope of scarps are fluvially scoured, and mantled in places by sand and gravel too thin and discontinuous to map separately.

Indistinct, irregular trough—Hachures point downslope; identified by the alignment of depressions and lakes. May mark a collapsed and filled channel.

Esker—A sinuous ridge of sediment interpreted to have been deposited in an ice-walled channel of a glacial meltwater stream flowing at the base of the ice. The fluvial sediment may be covered by 10 feet (3 meters) or more of till.

Ice margin—Ticks on the up-ice side; dashed where obscure or speculative.

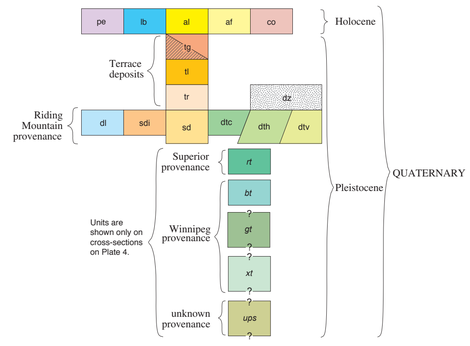
Plateau—A broad, relatively level area in a zone of hummocky topography. Plateaus range from 40 to over 640 acres (0.16 to 2.59 square kilometers). Predominantly till; capped in places by 3 to 17 feet (1 to 5 meters) of lake sediment. The plateaus are interpreted to represent saturated debris that was deposited in lows on stagnant ice; the deposits now stand as topographic highs on the landscape. Sorted sediment in the center of the plateau was deposited in standing water (unit dl). The elevation of the plateau top reflects the thickness of stagnant ice in the region. Plateaus range in relief from low to high. The relief from the base of the hill to the top is depicted by the thickness of the line symbol as noted below.

- **Low relief**—10 to 30 feet (3 to 9 meters).
- **Moderate relief**—40 to 70 feet (12 to 21 meters).
- **High relief**—70 to 100 feet (21 to 30 meters).

Irregular, hummocky topography—Includes circular, flat-topped hills and many collapsed channels, with an overall relief of about 60 to 100 feet (18 to 30 meters). Sediment is interpreted to have been deposited on top of stagnating ice.

Line of geologic cross section illustrated on Plate 4, *Quaternary Stratigraphy*.

CORRELATION OF MAP UNITS



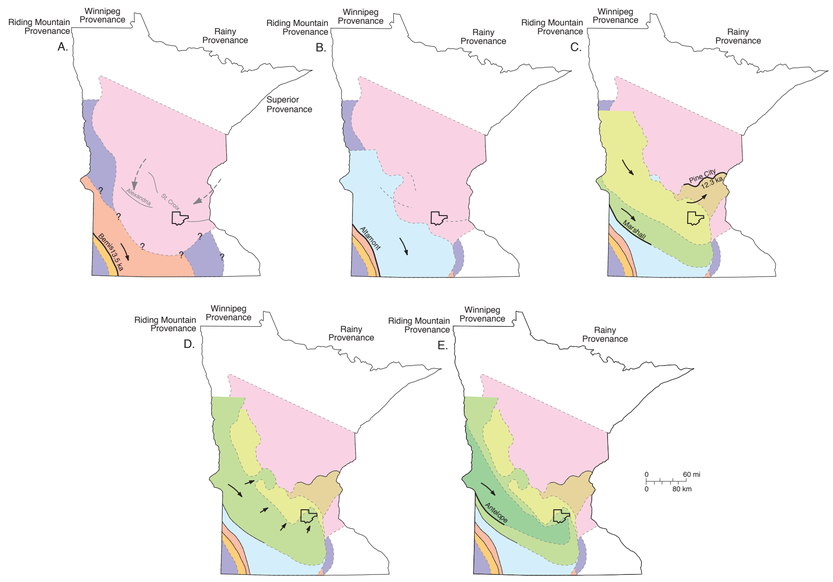


Figure 1. Schematic history of the Des Moines lobe ice advances. Moraine names in southwestern Minnesota are from Patterson and others (1999); dates are from Clayton and Moran (1982).

A. The early record of glacial advances into Minnesota is somewhat speculative because deposits are covered in most places by sediments deposited by more recent ice. Some of the oldest glacial deposits, from the Winnipeg provenance (shown in purple), are likely greater than 50,000 years old (units *bt, gt,* and *xt*). The earliest unit from the northwest (gold) was deposited about 20,000 years ago. Younger sediments were deposited by ice advancing from the north and northeast—Winnipeg, Rainy, and Superior provenances (pink)—between 18,000 and 15,000 years ago. In Carver County, "red" glacial deposits along the Minnesota River valley and in drill cores record the Superior lobe advance (unit *rt*). By 14,000 years ago, ice had advanced again from the northwest, extending southward to Des Moines, Iowa (salmon). Evidence from drill cores suggests that this unit did not extend into the Carver County region.

B. Between 13,500 and 12,500 years ago, ice again advanced from the northwest forming the Altamont moraine, but did not extend into Carver County.

C. Later, two separate ice streams advanced at the same time—one from a mixed Riding Mountain/Winnipeg provenance (unit dtv) and another from the Riding Mountain region (unit dth). The northern ice stream was deflected to the northeast, forming the Grantsburg sublobe and the Pine City moraine.

D. Eventually, the mixed Riding Mountain/Winnipeg ice stream (unit dtv) lost its source, while the ice from the west continued to flow (unit dth). It expanded over and around stagnating ice.

E. Another shift in the upstream source area brought the final pulse of shale-rich till (dark green) from the Riding Mountain provenance into southern Minnesota and the southeast corner of Carver County (unit dtc).

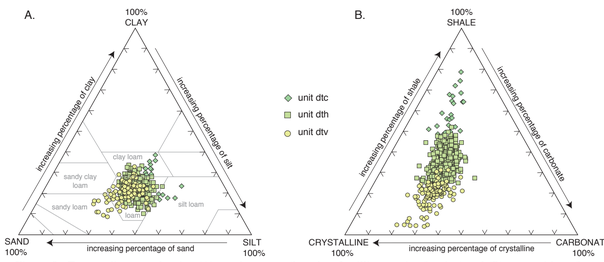


Figure 2. Ternary diagrams showing (A) matrix texture (less than 2 millimeter size fraction) and (B) composition of the very coarse-grained (1 to 2 millimeters) sand fraction of samples in the Des Moines-lobe tills.

DESCRIPTION OF MAP UNITS

This map emphasizes the distribution and origin of surficial materials in Carver County. It was compiled, in part, from sources shown on the Index to Previous Mapping and listed in the references below. Existing work was augmented by fieldwork conducted from 2005 to 2009. Most exposures consisted of excavations including gravel pits, construction sites, and road cuts. Surface samples were supplemented with soil borings drilled to a depth of about 18 feet (5.5 meters). In addition, one rotary-sonic core (CVR-09) was drilled to a depth of 200 feet (61 meters).

Most of the sediment in this area is glacial in origin and was deposited by Des Moines-lobe ice from the northwest, carrying sediment from the Riding Mountain uplands in southwestern Manitoba and from west of the Pembina escarpment in North Dakota. These glacial deposits include varying amounts of distinctive, gray, siliceous shale fragments (Table 1). Subtle differences in texture and composition of the glacial till—an unsorted mix of sand, silt, clay, and rocks, which is deposited directly by ice—result from the shifting of the source area from which the ice originated. It is likely that ice from this general direction crossed this region multiple times, leaving a complex record of similar looking materials of different ages (Fig. 1).

QUATERNARY

HOLOCENE

lb — **Sand, loamy sand, and loam**—Locally includes organic-rich layers and may overlie muck or peat. The extent of exposure depends on the water level in the lake. Includes artificial fill. *Lacustrine beach deposits.*

pe — **Organic debris, clay, and silt**—Partially decomposed plant matter and relatively fine-grained organic matter and marl (calcareous clay) deposited in marshes and ponded water. Includes minor alluvial deposits along streams, as well as beach deposits. *Wetland sediment.*

al — **Silty clay loam to sandy loam**—Interbedded with layers of sand and gravel. Organic debris may be disseminated in the sediments and/or form discrete peat beds. Sediment in the Minnesota River valley is generally finer-grained and consists of a mixture of silt and clay with variable amounts of very fine-grained sand and organic matter. Coarser-grained sediment may be present within the river channel. Deposited by modern streams in channels and on floodplains. *Floodplain alluvium.*

af — **Loam to loamy fine-grained sand**—Includes beds of silt loam, silty clay loam, sand, and gravel. Contains variable amounts of disseminated organic debris. Forms coalescing fan-shaped deposits at the base of steep slopes and at the mouths of deep gullies. *Alluvial fan sediment.*

co — **Clay to boulders**—A friable mixture reworked from glacial or fluvial sediment, and deposited on steep slopes. May contain disseminated organic debris. Includes till outcrops, small alluvial fans, and narrow bodies of alluvium. *Colluvium.*

PLEISTOCENE

Sand and gravelly sand—Coarsens to cobbly gravel locally. These sediments are mapped at three major levels. Boulder lags are common at the contact with bedrock. *Alluvial terrace deposits.*

tg — ***Grey Cloud terrace***—The terrace is about 50 feet (15 meters) above the present floodplain level at an elevation of about 750 feet (221 meters) near Chaska. A pattern indicates the area where underlying bedrock is within 10 feet (3 meters) of the surface.

tl — ***Langdon terrace***—The terrace, very narrow between Carver and Chaska, is about 100 feet (30 meters) above the present floodplain level at an elevation of about 800 feet (244 meters).

tr — ***Richfield terrace***—The terrace is about 160 feet (49 meters) above the present floodplain, and ranges in elevation from about 850 feet (259 meters) at Chaska to about 870 feet (265 meters) just northeast of Belle Plaine.

Sediment associated with northwest-source Des Moines-lobe ice—Deposits contain various amounts of gray, siliceous shale fragments (Fig. 2). The color of the till is typically yellow-brown where oxidized and dark gray where unoxidized.

dz — ***Silt loam to silty clay***—Loamy to fine-grained sandy loam in places. This unit forms a thin cap—3 to 10 feet (1 to 3 meters)—of sediment on units dth and dtv that is softer and less pebbly than the underlying material (Jennings, 2009). It is interpreted to have been deposited as stagnant ice melted and water ponded in low areas in the landscape.

sd — ***Sand, gravelly sand, and cobbly gravel***—Moderately to poorly sorted; crossbedded to flatbedded; interbedded in places with unsorted sediments, such as till. Isolated cobbles and boulders may be present. Deposited by streams emanating from melting ice commonly in an ice-marginal or ice-proximal setting. *Outwash.*

sdi — ***Sand, gravelly sand, and cobbly gravel***—Stratified; collapsed; typically faulted and folded, and commonly interbedded with, or capped by, sandy to loamy diamicton (mudflow sediment) and silt (lake sediment). Boulders may be present. *Ice contact deposits.*

dl — ***Clay and silt***—Laminated, may include thin beds of silty sand and gravel at contacts, or near the base; generally less than 15 feet (5 meters) thick. *Lake sediment.*

dtc — ***Clay to silt loam***—Pebbly, unsorted, with scattered cobbles and rare boulders. Shale clasts generally compose more than 50 percent of the very coarse-grained (1 to 2 millimeters) sand fraction. Pockets of silt, sand, and gravel occur in places. *Glacial till.*

dth — ***Loam to clay loam***—Pebbly, unsorted, with scattered cobbles and rare boulders. Shale clasts generally compose from 35 to 45 percent of the very coarse-grained (1 to 2 millimeters) sand fraction; includes rare lenses of stratified sediment. Covered in places by a cap (up to 10 feet [3 meters]) of soft, silty sediment (unit dz). *Glacial till.*

dtv — ***Clay loam to sandy loam***—Pebbly, unsorted, with scattered cobbles and rare boulders. Shale clasts generally compose from 10 to 25 percent of the very coarse-grained (1 to 2 millimeters) sand fraction; includes lenses of stratified sediment. Covered in places by a cap (up to 10 feet, 3 meters) of soft, silty sediment (unit dz). This unit was deposited by ice from a north–northwestern direction. It, therefore, includes material from both the Riding Mountain and Winnipeg provenances (Fig. 1; Table 1). *Glacial till.*

Older glacial sediments (shown only on Plate 4, cross sections)—It is likely that ice from previous glaciations was still melting when the Des Moines lobe moved into this region. Thus, the landscape records not only the most recent glacial events in the sediments described above, but the history of earlier glacial events is reflected in the landforms and sediments just beneath the surface. Collapsed hummocky topography, elongate ridges, mounds of debris, and the alignment of river valleys, may be attributed to these earlier advances (Fig. 3). At least one of these subsurface units, unit *rt,* was derived from a northeast source, deposited by Superior-lobe ice. Where exposed along deep ravines in the Minnesota River valley (too narrow to map at this scale), the sediment is distinctly red and contains fragments of red sandstone, as well as of rhyolitic and intrusive igneous and metamorphic rocks. The other deposits were derived from a more northerly source and contain abundant crystalline rocks (basalt and granite) and various amounts of carbonate rock fragments (limestone, dolostone, and fossil fragments; Fig. 4). These unoxidized, older deposits were sampled in the subsurface and therefore do not appear on the map. They are mantled by younger deposits of the Des Moines lobe. A description of these older deposits is included herein for comparison with those overlying deposits and for use when interpreting the cross sections (Plate 4, *Quaternary Stratigraphy*).

rt — ***Sandy loam*** (shown only on Plate 4, cross sections)—Pebbly, unsorted, with scattered cobbles and rare boulders. Contains no gray shale clasts. Typically associated with sand and gravel deposits. *Glacial till.*

bt — ***Loam*** (shown only on Plate 4, cross sections)—Sandy, pebbly, unsorted, with scattered cobbles and rare boulders. Shale clasts generally compose less than 2 percent of the very coarse-grained (1 to 2 millimeters) sand fraction. Contains abundant limestone and fossil fragments. Pockets of silt, sand, and gravel occur in places. This unit was sampled in rotary-sonic core CVR-09 (Plate 4, Figs. 1, 2). *Glacial till.*

gt — ***Loam to sandy loam*** (shown only on Plate 4, cross sections)—Pebbly, unsorted, with scattered cobbles and rare boulders. Shale clasts generally compose less than 2 percent of the very coarse-grained (1 to 2 millimeters) sand fraction. Pockets of silt, sand, and gravel occur in places. *Glacial till.*

xt — ***Loam*** (shown only on Plate 4, cross sections)—Pebbly, unsorted, with scattered cobbles and rare boulders. Shale clasts generally compose less than 2 percent of the very coarse-grained (1 to 2 millimeters) sand fraction. Pockets of silt, sand, and gravel occur in places. *Glacial till.*

ups — **Undifferentiated Pleistocene sediment** (shown only on Plate 4, cross sections)—This unit includes all sediment below the lowermost identified till unit. Although some water wells extend below this boundary, the data are too sparse to make meaningful correlations.

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Numbers in parentheses correspond with those shown on the Index to Previous Mapping.

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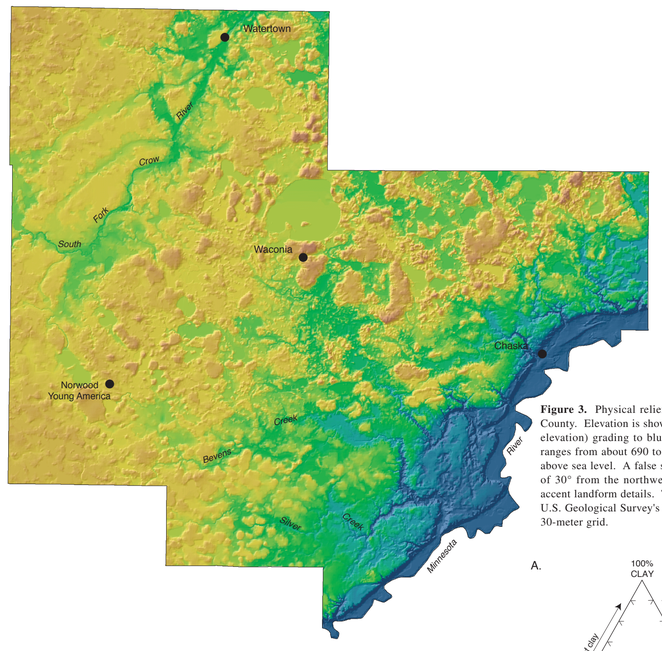
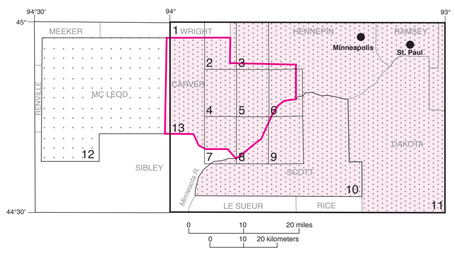


Table 1. Physical characteristics of glacial deposits in the Carver County region.

SOURCE AREA	NORTHWEST	NORTH–NORTHWEST	NORTHEAST
PROVENANCE	RIDING MOUNTAIN	WINNIPEG	SUPERIOR
LOBE	Des Moines (units dth, dtv)	Pre-Wisconsin (*units bt, gt, xt*)	Superior (unit *rt*)
TILL TEXTURE	Sandy loam to clay loam	Loam to silt loam to clay loam	Sandy loam to loamy sand
TILL COLOR			
Oxidized	Light olive-brown	Light olive-brown	Brown to red-brown
Unoxidized	Gray to dark gray	Gray to dark gray	Gray to red-gray
PEBBLE TYPE			
Carbonate	Common	Common to abundant	Rare to common
Gray-green rock	Uncommon to common	Uncommon to common	Common to abundant
Red felsite	Absent to rare	Absent to uncommon	Uncommon to common
Gray shale	Uncommon to abundant	Absent to uncommon	Absent



INDEX TO PREVIOUS MAPPING

Index of previous geologic mapping in and near Carver County. Numbers correspond to those listed in the references.

Figure 3. Physical relief of the land surface in Carver County. Elevation is shown by color: red-orange (higher elevation) grading to blue (lower elevation). Elevation ranges from about 690 to 1,090 feet (210 to 331 meters) above sea level. A false sun illumination at an elevation of 30° from the northwest (315°) provides contrast to accent landform details. This map was created using the U.S. Geological Survey's Digital Elevation Model with a 30-meter grid.

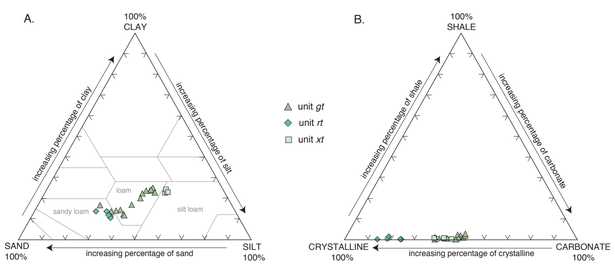


Figure 4. Ternary diagrams showing (A) matrix texture (less than 2 millimeter size fraction) and (B) composition of the very coarse-grained (1 to 2 millimeters) sand fraction of samples in the older till units (shown only on Plate 4, cross sections).

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.

GEOLOGIC ATLAS OF CARVER COUNTY, MINNESOTA