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SURFICIAL GEOLOGY

By

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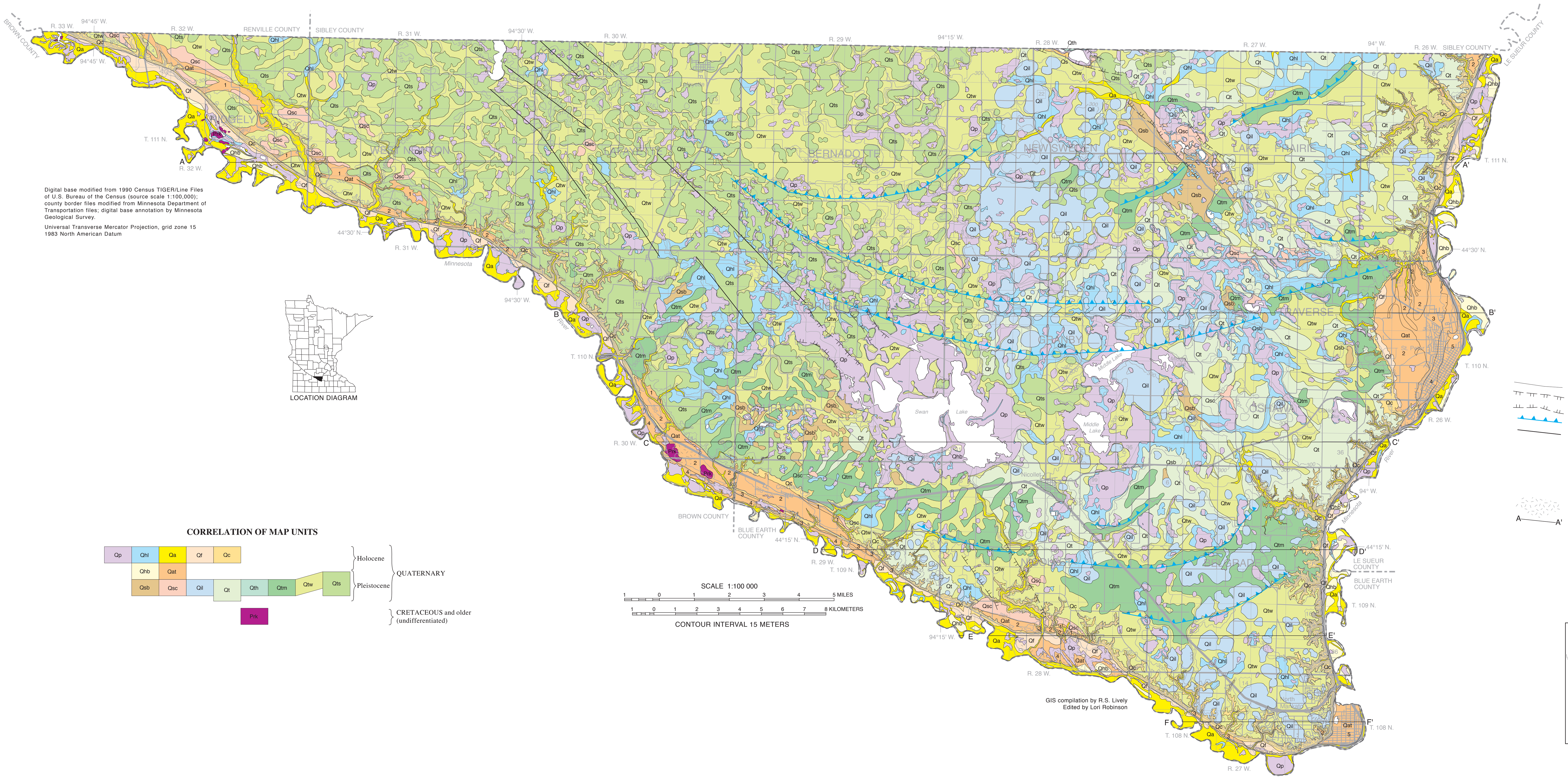

Digital base modified from 1990 Census TIGER/Line Files of U.S. Bureau of the Census (source scale 1:100,000); county border files modified from Minnesota Department of Transportation files; digital base annotation by Minnesota Geological Survey.
Universal Transverse Mercator Projection, grid zone 15
1983 North American Datum

LOCATION DIAGRAM

CORRELATION OF MAP UNITS

Qp
Qhl
Qa
Qf
Qc
Qhb
Qat
Qsb
Qsc
Qil
Qt
Qth
Qtm
Qtw
Qts
Prk
Holocene
Pleistocene
QUATERNARY
CRETACEOUS and older (undifferentiated)

MAP SYMBOLS

Geologic contact—Approximately located.

Broad, irregular trough—Hachures point downslope; may be occupied by aligned depressions and lakes. Indicates that the ice surface collapsed over an ice cavern (tunnel valley).

Ice margin—Ticks on up-ice side.

Linear ridge—Ridge of glacial sediment, or zone of aligned low-relief ridges. Where perpendicular to the inferred direction of flow, feature is interpreted to have been deposited at the ice margin by a combination of processes. Where parallel to flow, feature is interpreted to be the result of shear between two coeval ice streams; a broad, flow-parallel ridge is interpreted to have developed subglacially and is draped with discontinuous deposits that are interpreted to have concentrated in a supraglacial low originating from shear melting (Fig. 2).

Shallow bedrock—Areas where bedrock is within 10 feet (3 meters) of the surface (see Plate 2, *Bedrock Geology*).

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

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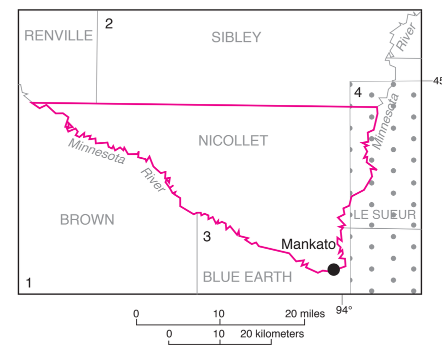

INTRODUCTION

This map emphasizes the distribution and origin of surficial material in Nicollet County. Although soils are derived from this uppermost geologic deposit, this is not a soil map. This map portrays the unaltered sediment—typically of glacial origin—that comprises the upper several meters. Landform distribution and sediment texture were initially based on interpretation of early spring stereo-pair aerial photographs taken in 1977 through 1978 (1:80,000), and 1968 (1:90,000). The interpretations were drawn on 1:24,000 U.S. Geological Survey topographic maps, which were overlain on a 30-meter digital elevation model that covered the area (Fig. 1). These interpretations were compared to a soil map for Nicollet County (Natural Resources Conservation Service, 2009), National Wetlands Inventory maps (U.S. Fish and Wildlife Service, 2009), well logs included in the Minnesota Geological Survey County Well Index, and previous aggregate-deposit mapping (Ellingson, 2000). Fieldwork to verify and augment these interpretations was conducted from 2008 to 2010. Samples were taken from shallow holes created with a shovel where no natural or artificial excavations could be found; artificial exposures included borrow pits, construction sites, road cuts, and 27 soil borings drilled to a depth of about 18 feet (5.5 meters). Three rotary-sonic cores were drilled to depths between 248 and 278 feet (76 to 85 meters). Additional sources that were consulted are shown on the Index to Previous Mapping and listed in the references.

This mapping verifies that the near-surface deposits of Nicollet County are dominated by sediment of glacial origin attributed to the Des Moines lobe, a late glacial ice lobe that extended south from the Laurentide ice sheet. The ice derived its sediment load from sources as far west as the Riding Mountain uplands in southwestern Manitoba, where flow originated, and along a flowline oriented generally southeast. The glacial sediment (till) has roughly equal amounts of sand, silt, and clay and contains rocks derived from along the flow path including crystalline, carbonate, and shale fragments. Ice from this general direction crossed Minnesota multiple times, leaving a complex record of similar looking materials of slightly different age and composition (Fig. 2). During at least one episode, two independent ice streams, one from a northerly source and one from a westerly source, advanced into this region at the same time. A broad, flow-parallel ridge is interpreted to have been a shear zone where these two ice streams flowed side by side (Fig. 2). This broad zone migrated as the southern ice stream (carrying Heiberg Member sediment) broadened at the expense of the northern one (carrying Villard Member sediment, a subsurface unit). Subtle differences in texture and composition result from the different source areas and paths of the ice and allow them to be distinguished. The content of distinctive, gray, siliceous shale (Table 1) varies in a predictable way and is helpful for determining the ice flow path. However, these differences cannot be discerned in the field and require laboratory work to define, but are useful for a detailed understanding of the ice behavior and history.

A profound landscape-altering event—the incision of the deep, glacial River Warren channel—followed the Des Moines lobe withdrawal from the region. It was created as a spillway for glacial Lake Agassiz that developed as the ice front retreated north of a low divide in western Minnesota. The valley is incised over 230 feet (70 meters) into the glacial sediment and locally exposes underlying bedrock along the southern boundary of the county. It turns sharply northward where it has excavated a buried bedrock valley in the flat-lying Paleozoic strata. Glacial River Warren did not remain in that broad valley for long; it created or exploited a narrower bedrock gorge and subsequently inscribed a series of low amplitude, long wavelength bends as it maintained a trend to the north–northeast, moving in and out of pre-existing bedrock valleys. Discharges have been estimated in a number of ways and range from 0.07 to 1.03 Sverdrups (Sv, 1 x 10^6 m^3/sec; as compiled in Fisher, 2004), with the duration of the event varying widely because it is merely bracketed by radiocarbon ages of glacial Lake Agassiz strandlines (Teller, 1990) or organics that developed in the valley after all flow ceased (Fisher, 2004; Hudak and Hajc, 2005). Flows are estimated to have ranged from 17,400 m^3/sec (550 km^3/yr) to 98,200 m^3/sec (3,200 km^3/yr; Teller, 1990). Multiple strath and fill terrace levels in the valley (Johnson and others, 1998) most likely involve self-organization and internal dynamics of the stream system rather than distinct time horizons in the evolution of the valley (Hudak and others, 2002; this project).

The sudden creation of this deep valley caused all of the pre-existing tributaries to begin adjusting their gradients to the new local base level, a process that is ongoing. Streams leading directly to the Minnesota River (for example Seven Mile Creek) have a very steep gradient. Slower fluvial and slope processes have altered the sides of the glacial River Warren valley that borders Nicollet County on two sides, creating ravines that lead to fans on the valley floor and in some places, slumps and landslides (unit Qc). Most of Nicollet County is still unaffected by the headcutting ravines and streams, or knickpoints, that originated from this sharp drop in base level. The land would be poorly drained if not drained artificially. Knickpoints continue to naturally work up into the landscape as they move water from upland sources.

Warm and dry conditions persisted through the mid-Holocene epoch (approximately 9,000 to 5,000 radiocarbon years or 10,200 to 5,700 calendar years before present*) and slowed water-driven geologic processes. From 5,700 years ago until the present, climate, and therefore geomorphic processes, were much like today. However, most of the shallow lakes and wetlands were artificially drained as the land was converted for agriculture and artificial drainageways now connect closed depressions and low-relief areas to the natural, steep, and deeply incised streams that lead to the Minnesota River valley.

* Both radiocarbon and calendar years are now commonly reported because the scientific community has become increasingly aware of the variable production rate of ^{14}C caused by the change in strength of the magnetic field (Trumbore, 2000; Fairbanks and others, 2005).

DESCRIPTION OF MAP UNITS

QUATERNARY

HOLOCENE

Qp **Organic debris, clay, and silt**—Wetlands and low areas containing partially decomposed organic matter (peat) to fully decomposed organic matter with variable amounts of clay and silt (muck). Includes shallow isolated depressions, water bodies such as seasonal or ephemeral ponds, former lakes (peat mats typically form near the shore and grow into deeper water), and slack water areas along the flood plains of low-gradient modern and glacial streams. Locations are scattered across the areas of glacial till because the low infiltration capacity of the fine-grained glacial sediment and irregular topography of glacial stagnation landscapes created many isolated depressions that seasonally held standing water. They are also prominent in the glacial River Warren valley, which is oversized for the modern Minnesota River and infilling in a way that may isolate low-lying areas. *Wetland deposits.*

Qa **Sand and gravel with silt and clay**—Interbedded with layers of predominantly sand and gravel. Fine-grained sediment may also form discrete beds or occur in the upper part of the deposit (fining-up sequences). Deposited by modern streams in channels and floodplains. Many modern streams re-occupy glacial channels so the unit may be coarser-grained in places because of reworking of glacial stream sediment. Also includes areas of decomposing organic material and fine-grained sediment deposited by slack water in a floodplain setting. Channel may be scoured to expose bedrock in some locations (see Plate 2, *Bedrock Geology*). *Floodplain alluvium.*

Qf **Loamy sand and gravel sand**—Includes gravel and beds of silt loam and silty clay loam. Contains variable amounts of translocated and disseminated organic debris. Forms fan-shaped deposits at the base of steep slopes and at the mouths of modern streams. *Alluvial fan sediment.*

Qhl **Silt to clay**—Mapped in depressions, typically characterized by a thick, black, upper soil horizon; may include sand and organic materials near shore; laminated in places. Deposited in ponded water in modern or drained lakes. *Modern lake sediment.*

Qc **Clay to boulders**—Primarily clay to sand and gravel with local rock fragments where bedrock crops out (see Plate 2, *Bedrock Geology*); deposited on steep slopes by wet and dry gravitational failure. Resembles the material from which it was derived—Des Moines lobe and older, loamy tills, and sand and gravel—except where sorting by gravity and water resulted in material with a different texture than the parent material. *Colluvium.*

HOLOCENE AND PLEISTOCENE

Qhb **Sand, loamy sand, and gravel**—Forms low bars or ridges. If in a river, found at a higher elevation than the general alluvial surface and in a streamlined form. Deposited in shallow, moving water along a lake shore or in a river where finer-grained sediment is winnowed and removed. The extent of exposure depends on the water level. Bars formed mainly in the lee of bedrock obstacles in glacial River Warren. *Bar or beach sediment.*

Qat **Sand and gravelly sand with silt and clay**—Well sorted, fining up; forms a nearly level surface with some areas of streamlined bars and shallow channels, locally filled with fine-grained sediment that lies above the modern floodplain; the general elevation of the individual surfaces are expressed numerically from oldest to youngest. Terraces with various elevations are interpreted to have formed during the incision of glacial River Warren. The broad valley was created during one or possibly two catastrophic discharge events from glacial Lake Agassiz and obscured any prior valleys in the same location. Terraces in such spillways do not typically represent long-term stability of the system but rather reflect the complicated internal dynamics of a rapidly cutting spillway. Bedrock and older indurated glacial sediment may be exposed or shallowly buried (up to 10 feet [3 meters]) in places (strath terrace), particularly along steep slopes and scoured surfaces (only larger bedrock outcrops are shown here; for a complete map of bedrock outcrops see Plate 2, *Bedrock Geology*). Areas where bedrock is within 10 feet (3 meters) of the terrace surface are marked with a pattern. *Alluvial terrace deposits.*

1—Surface ranges from approximately 950 to 999 feet (290 to 304 meters)
2—Surface ranges from approximately 900 to 949 feet (274 to 289 meters)
3—Surface ranges from approximately 850 to 899 feet (259 to 274 meters)
4—Surface ranges from approximately 800 to 849 feet (244 to 259 meters)
5—Surface ranges from approximately 750 to 799 feet (229 to 244 meters)

PLEISTOCENE

Non-till sediment associated with northwest-source Des Moines-lobe ice (New Ulm Formation).

Qsc ***Sand, gravelly sand, and cobbly gravel***—Poorly sorted; collapsed; typically faulted and folded, and commonly interbedded with, or capped by, sandy to loamy diamicton (mudflow sediment) and silt (lake sediment). Boulders are present locally. Deposited by running water and gravity in crevasses or low areas on the ice surface, or within or at the mouth of subglacial tunnels. *Collapsed stream sediment.*

Qsb ***Sand, gravelly sand, and cobbly gravel***—As above but shallowly buried, commonly by diamicton of supraglacial origin that may locally be thick. Close enough to the surface to affect the topography and lighten the color of the overlying unit on black and white aerial photographs, indicating drier conditions. *Buried collapsed stream sediment.*

Qil ***Diamicton with silt, clay, and sand***—Vaguely bedded, loamy glacial sediment (diamicton) with bedded silt, clay, and sand. Deposited as lake sediment or debris flows confined within growing holes in the stagnant ice surface, resulting in circular, flat-topped hills. Margins of this nearly circular unit are commonly coarser textured. *Ice-walled-lake sediment.*

Diamicton associated with the Des Moines lobe (Heiberg Member of the New Ulm Formation)—Unsorted sediment with a loam matrix that contains clasts of gravel, scattered cobbles, and rare boulders; the term *till* is used where the sediment was deposited directly by the ice, *glacial sediment* where modified, *diamicton* where no genesis is implied. Typically yellow-brown where oxidized and dark gray where unoxidized. Deposits contain various amounts of gray, siliceous shale fragments, ranging from 35 to 60 percent of the very coarse-grained (1 to 2 millimeters) sand fraction. Distinctions are also made using topography, which reflects changes in the glacial depositional process and sediment texture.

Qts ***Aligned hillocks***—Predominantly diamicton in a complex terrain with low to moderate relief ranging from 20 to 50 feet (6 to 15 meters). Lows are commonly a loamy, dense diamicton that is capped with fine-grained sediment (unit Qtw), hillocks include sharp-crested bodies of sand and gravel (unit Qsc), and non-aligned, irregular uplands are comprised of diamicton (unit Qth). The complex forms atop a broad, southeast-trending ridge located at the boundary of two, distinct, subglacial till sheets, the Heiberg and Villard Members of the New Ulm Formation. Interpreted to be sediment deposited on the ice surface where the differential flow of adjacent, synchronous ice streams localized drag and frictional melting and created an ice-surface low that focused meltwater and debris, overlying a broad ridge of subglacial origin. *Ice stream shear-zone deposits.*

Qt ***Low-relief***—Dense diamicton as above; forms a surface with generally 10 feet (3 meters) of relief. *Subglacial till.*

Qth ***Hummocky***—Diamicton as above; undulating with 20 to 30 feet (6 to 9 meters) of relief with irregular hills creating isolated depressions. Interpreted to have originated in an unstable, supraglacial sediment layer near a former ice margin that differentially insulated stagnant ice, resulting in uneven downwasting, reconfiguration of the surface slope, and redeposition of the material. May be sorted in places as a result of resedimentation by moving or still water. *Supraglacial, hummocky glacial sediment.*

Qtm ***Aligned hills***—Diamicton as above; forms a discontinuous ridge; interpreted to be a demarcating margin of active ice that formed through a combination of ice-marginal processes including meltout of a basal debris layer, thrusting, and debris flows. *Moraine.*

Qtw ***Washed***—Diamicton as above; surface expression is subdued and may be vaguely streamlined. Interpreted to have been washed by water (rivers and lakes). May be capped with a coarse-grained lag resulting from the removal of finer-grained particles by water and a cover (1 meter) of fine-grained sediment deposited by waning flows. *Washed till.*

CRETACEOUS AND OLDER

Prk **Bedrock**—Cretaceous, Paleozoic, and Precambrian bedrock, undifferentiated, exposed at the surface. Includes saprolith (weathered rock) that may have been reworked in a Cretaceous seaway.

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

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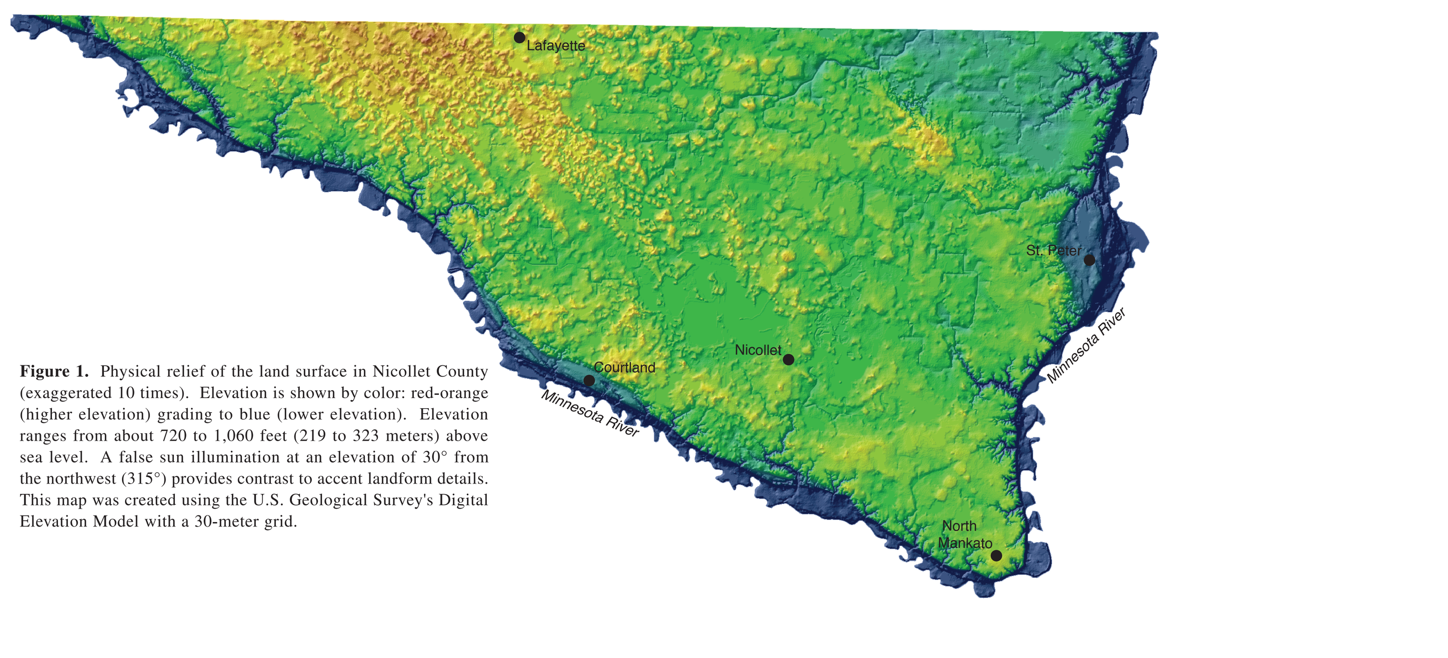

Figure 1. Physical relief of the land surface in Nicollet County (exaggerated 10 times). Elevation is shown by color: red-orange (higher elevation) grading to blue (lower elevation). Elevation ranges from about 720 to 1,060 feet (219 to 323 meters) above sea level. A false sun illumination at an elevation 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.

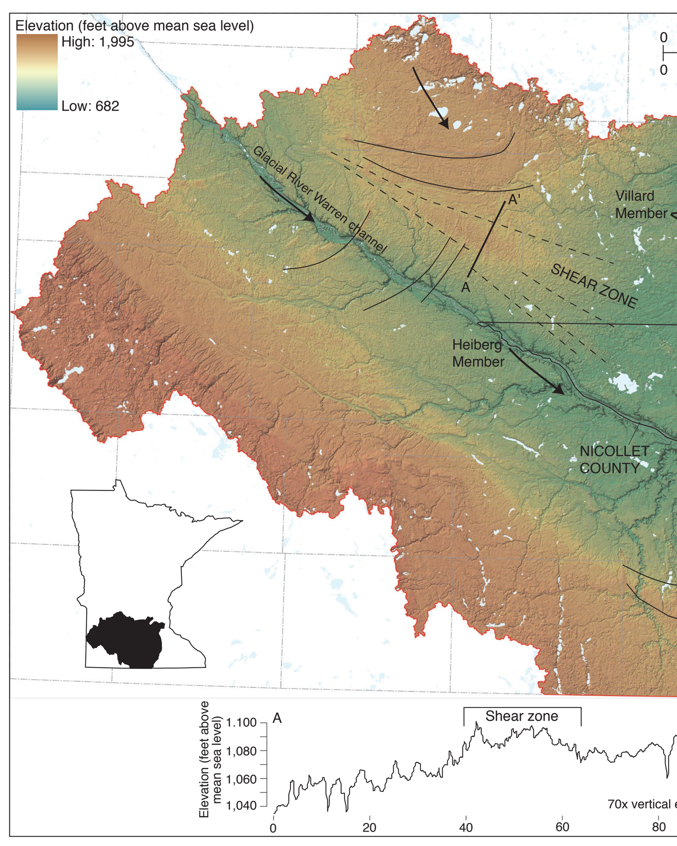

Figure 2. Digital elevation model (U.S. Geological Survey, 2008) of the middle Minnesota River watershed in south-central Minnesota showing a subtle, flow-parallel ridge interpreted to be a shear zone between two dynamically independent ice streams. The ice that deposited the Villard Member of the New Ulm Formation flowed on the north side of the shear zone. Ice that deposited the Heiberg Member flowed south of the shear zone from a more westerly direction. Moraine ridges (perpendicular to ice flow) are indicated to illustrate the difference in flow direction north and south of the shear boundary and the scalloping in the outermost moraine. The topographic profile along line A–A' illustrates the broad nature of the shear-zone ridge.

Table 1. Physical characteristics of glacial deposits in Nicollet County.

SOURCE AREA	NORTHWEST	NORTH–NORTHWEST	NORTH	NORTHEAST
PROVENANCE	RIDING MOUNTAIN	WINNIPEG	RAINY	SUPERIOR
LOBE	Des Moines	Pre-Wisconsin	Pre-Wisconsin	Pre-Wisconsin
TILL TEXTURE	Sandy loam to clay loam	Sandy loam to silt loam to clay loam	Loam to sandy loam	Sandy loam to loamy sand
TILL COLOR				
Oxidized	Light olive-brown	Light olive-brown	Yellow-brown	Brown to red-brown
Unoxidized	Gray to dark gray	Gray to dark gray	Gray to brown-gray	Gray to red-gray
PEBBLE TYPE				
Carbonate	Common	Common to abundant	Uncommon	Rare to common
Mafic	Uncommon to common	Uncommon to common	Uncommon to common	Common to abundant
Red felsite	Absent to rare	Absent to uncommon	Rare to uncommon	Uncommon to common
Gray shale	Uncommon to abundant	Absent to uncommon	Absent	Absent