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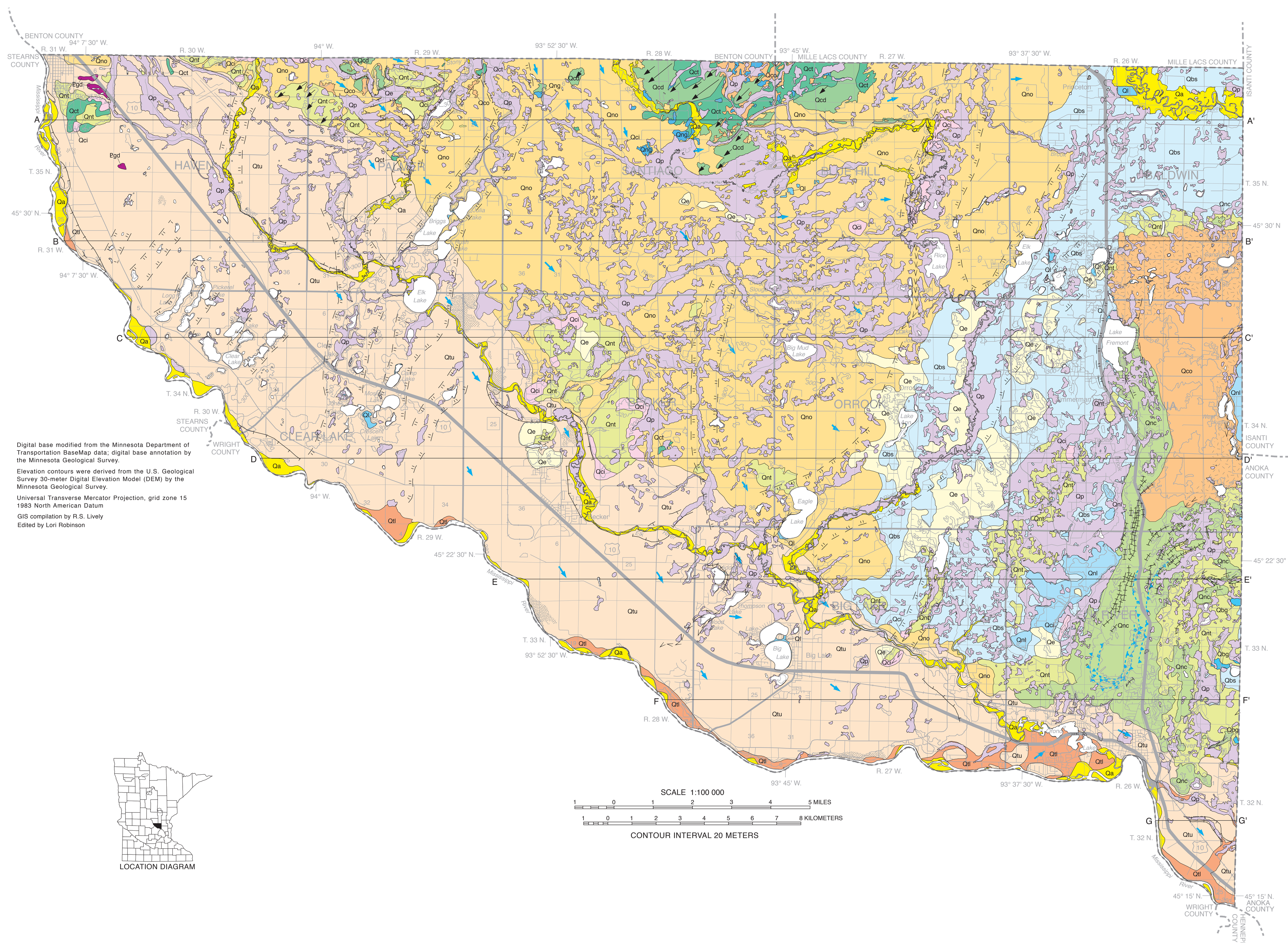


Digital base modified from the Minnesota Department of Transportation BaseMap data; digital base annotation by the Minnesota Geological Survey.

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

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

LOCATION DIAGRAM

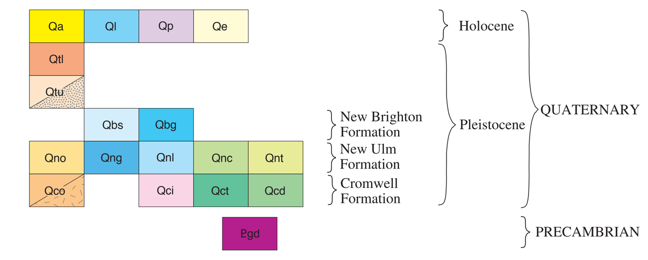
SURFICIAL GEOLOGY

By

Barbara A. Lusardi and Roberta S. Adams

2013

CORRELATION OF MAP UNITS



MAP SYMBOLS

Geologic contact—Approximately located.

Drumlin—A streamlined hill or ridge composed typically of glacial till; in places may include sand and gravel. Feature formed at the base of moving ice; commonly composed of subglacial sediment. Drumlins may be partially covered by superglacial sediment and in places are partially or totally buried by subsequent glacial and fluvial deposits. Oriented in the inferred ice flow direction. Arrow shows the inferred direction of ice movement; the length of the arrow is approximately equivalent to drumlin length. Drumlins in Sherburne County were formed at the base of the Superior lobe ice. Where mapped over unit Qnt, the Superior lobe drumlins are mantled by till of the Des Moines lobe (New Ulm Formation).

Elongate ridge—Sinuous ridge of sand and gravel deposited in an ice-walled channel. The subglacial fluvial sediment may be covered by 10 feet (3 meters) or more of till. Interpreted to be an esker, although no flow direction is inferred.

Esker—Sinuous ridge of sand and gravel deposited in an ice-walled channel. The subglacial fluvial sediment may be covered by 10 feet (3 meters) or more of till. Arrows indicate inferred flow direction. South- and west-flowing eskers are interpreted to be of Superior lobe origin and are buried by a thin drape of Des Moines lobe deposits. Esker ridge may no longer exist due to mining of sand and gravel deposits. Esker position is inferred from the presence of narrow, elongate lakes and from aerial photographs taken prior to excavation.

General flow direction of glacial streams—Arrow points downstream in the direction glacial meltwater flowed.

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

Irregular trough—Hachures point downslope; may be occupied by aligned depressions and lakes. Indicates that the ice surface collapsed over an ice cavern, called a tunnel valley.

Stream-cut scarp—Hachures point down scarp; dashed where discontinuous or obscure. Marks the bank 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.

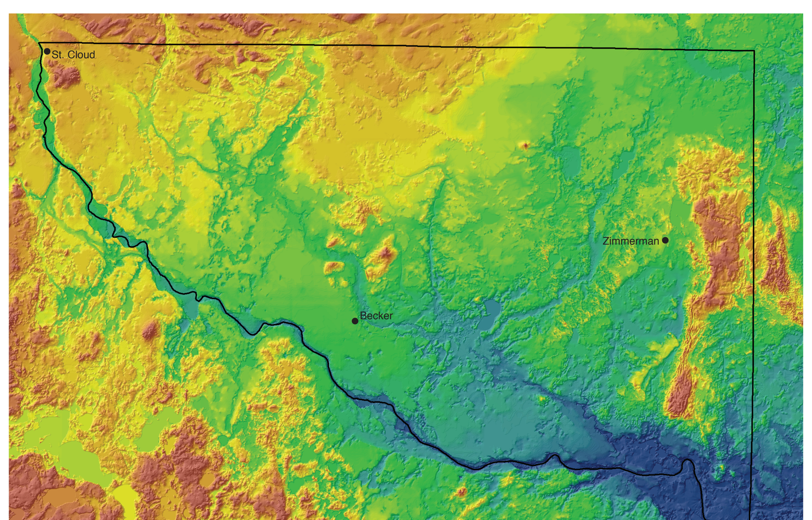


Figure 1. Physical relief of the land surface in Sherburne County (exaggerated 5 times). Elevation is shown by color: red-orange (higher elevation) grading to blue (lower elevation). Elevation ranges from about 842 to 1,117 feet (257 to 340 meters) above sea level. A false sun illumination at an elevation 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 10-meter grid.

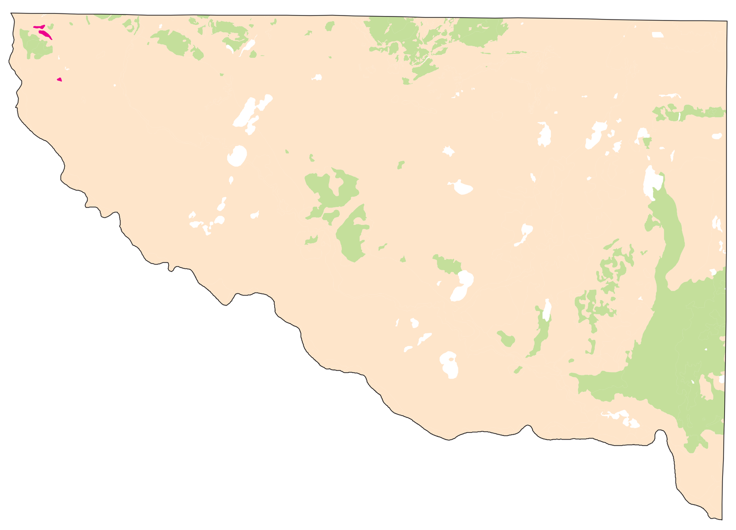


Figure 2. Map derived from the 1:100,000 surficial geology map showing map units combined into three simplified units: green is less permeable diamicton (glacial till) and bedded silt and clay; tan is more permeable, bedded sand to gravel; and purple is bedrock. Lakes are white.

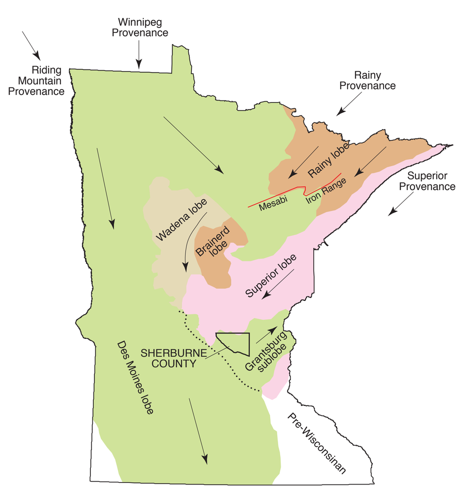


Figure 3. Location of Sherburne County in relation to the major provenances, or source regions, of glacial deposits. The Superior lobe occupied the area of Sherburne County prior to the last glacial advance of the Des Moines lobe from the northwest.

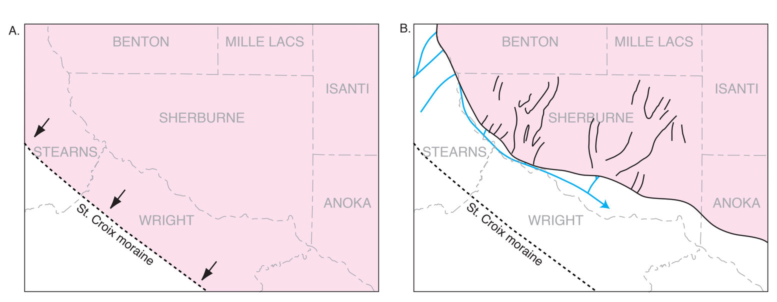


Figure 4. A. Approximate extent of the Superior lobe (pink) to the St. Croix moraine; subglacial (tunnel) valleys cut by meltwater are outlined in black.

B. The Superior lobe (pink) in its retreat from the St. Croix moraine. Meltwater streams (blue) issued from the ice margin through tunnel valleys under the ice (black).

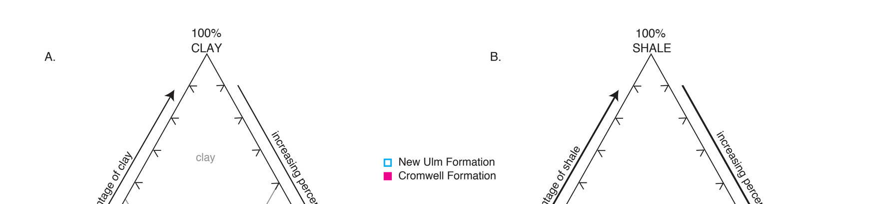
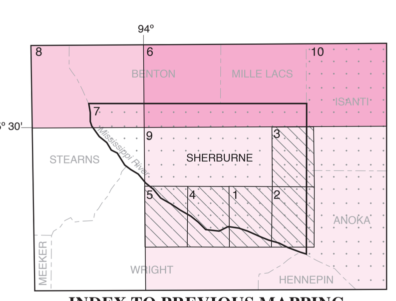


Figure 5. Ternary diagrams showing (A) matrix texture (less than 2 millimeter size fraction) and (B) composition of the very coarse-grained (1 to 2 millimeters) sand fraction of till samples from Sherburne County.



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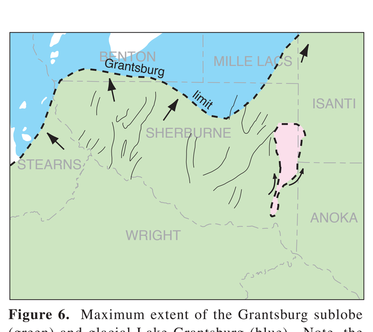

Figure 6. Maximum extent of the Grantsburg sublobe (green) and glacial Lake Grantsburg (blue). Note, the highlands in the eastern part of the county may not have been completely covered by ice of the Grantsburg sublobe. Tunnel valleys from the Superior lobe, although buried by the ice and debris of the Grantsburg sublobe, are still visible at the surface as areas of collapsed topography and aligned lakes and wetlands.

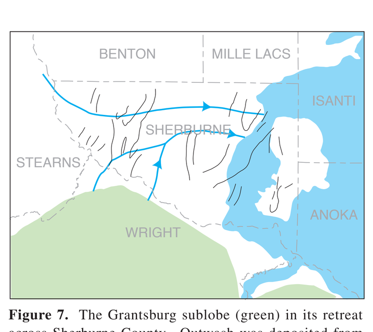

Figure 7. The Grantsburg sublobe (green) in its retreat across Sherburne County. Outwash was deposited from the melting glaciers. Meltwater streams (blue lines) fed and likely merged with glacial Lake Anoka (shown at its approximate maximum extent in blue), blurring the distinction between outwash and lake sediment.

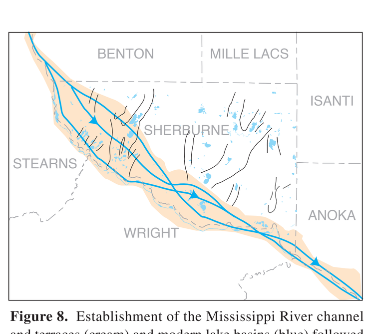

Figure 8. Establishment of the Mississippi River channel and terraces (cream) and modern lake basins (blue) followed the retreat of the ice and the drainage of glacial Lake Anoka.

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

SOURCE AREA	NORTHWEST	NORTHEAST
PROVENANCE	RIDING MOUNTAIN	SUPERIOR
LOBE	Des Moines	Superior
TILL TEXTURE	Loam to sandy loam	Sandy loam to loamy sand
TILL COLOR		
Oxidized	Light olive-brown	Brown to red-brown
Unoxidized	Gray to dark gray	Gray to red-gray
PEBBLE TYPE		
Carbonate	Common	Rare to uncommon
Dark crystalline	Uncommon to common	Common to abundant
Red felsite	Absent to uncommon	Uncommon to common
Gray shale	Uncommon to common	Absent

INTRODUCTION

This map emphasizes the distribution and origin of surficial materials in Sherburne County. Landform distribution and sediment texture were initially based on interpretation of early spring stereo-pair aerial photographs taken in 1977 and 1978 (1:80,000). The interpretations were drawn on 1:24,000 U.S. Geological Survey topographic maps that were overlain on a 30-meter digital elevation model that covered the area (Fig. 1). These interpretations were compared to a soil map for Sherburne County (Natural Resources Conservation Service, 2010), National Wetlands Inventory maps (U.S. Fish and Wildlife Service, 2010), and to well logs included in the Minnesota Geological Survey County Well Index. Fieldwork to verify and augment these interpretations was conducted from 2010 to 2012. Most exposures consisted of excavations, including construction sites and road cuts. Surface samples were supplemented with auger borings drilled to a depth of about 11 feet (3.4 meters). Additional data from previous mapping (see Index to Previous Mapping) were included in the analyses and interpretation of map units.

GLACIAL HISTORY

Much of the surficial sediment across Sherburne County is sand and gravel (Fig. 2) deposited during the final stages of glacial retreat. Initially, ice from the northeast crossed this area (Figs. 3, 4). Superior lobe deposits of the Cromwell Formation (Johnson and others, in press) can be seen scattered across the county and are widespread below much of the surficial sand and gravel. These deposits are typically red, sandy, and contain red rock fragments from the Superior provenance (Figs. 3, 5A; Table 1). Many of the landforms visible throughout the county and on the digital elevation image, including the prominent highlands in the eastern part of the county (Fig. 1), were created by Superior lobe ice (units Qct and Qcd) and its meltwater (units Qco and Qci; Fig. 4). It is likely that this older ice was still melting at the time that the Grantsburg sublobe advanced into the region (Figs. 3, 6). Grantsburg sublobe deposits, included in the New Ulm Formation (Johnson and others, in press), are typically brown to gray, sandy, and contain gray shale fragments of Riding Mountain provenance (Figs. 3, 5; Table 1). As it crossed the area, the Grantsburg sublobe incorporated some of the debris left by the Superior lobe. Thus, the till in places is a blend of the northwest and northeast source material (Table 1); in other places, the till is stratified with distinct brown and "red" layers. This is characteristic of the Twin Cities Member of the New Ulm Formation (Johnson and others, in press). Only scattered exposures of Twin Cities Member till can be seen throughout the county. These deposits are relatively thin over deposits of the Cromwell Formation.

The source of the sediment and the mechanism of deposition of the aforementioned highlands in the eastern part of the county are unknown. It appears that the bulk of the feature is made up of outwash sand and gravel from the Superior lobe. At least part of this sediment was deposited on top of stagnant ice because parts of the landscape to the north and east is collapsed and hummocky (patterned area of unit Qco). To the south, there is evidence that the Grantsburg sublobe advanced, and possibly overtopped the feature, burying the Superior-source sediment under thin till of the New Ulm Formation (unit Qnc). Broad flat areas that ring the southern margin of the highlands may represent ice marginal positions (Fig. 6). If the Grantsburg sublobe did cover stagnant ice, that would explain the presence of trace amounts of gray siliceous shale of Riding Mountain provenance that may be found in some of the local gravel pits, in what would appear to be Superior provenance sediment. As the buried ice melted, the sediment intermixed, shifting from highs to lows as the ice settled and melted away. Eskers, which are believed to be predominantly Superior lobe in origin, are indicated without flow direction to leave open the possibility that some meltwater streams may have carried meltwater and sediment northward from the Grantsburg sublobe.

The bulk of sediment within the county is fine-grained sand to sand and gravel that was deposited as fluvial and lake sediment near the end of the glacial episode. The advance of the Grantsburg sublobe blocked the meltwater draining from the Superior lobe and formed glacial Lake Grantsburg (Fig. 6). This lake was short-lived (Johnson and Hemstad, 1998), and only a few isolated pockets of lake sediment are mapped in northern Sherburne County (unit Qng). When meltwater once again was blocked in the St. Croix River valley to the east, glacial Lake Anoka formed across a broad area, including the eastern portions of Sherburne county (Meyer, 1998; Fig. 7). Sediment deposited in this lake is part of the New Brighton Formation (units Qbs and Qbg; Johnson and others, in press).

As the Grantsburg sublobe melted, outwash sand and gravel (unit Qno; Fig. 7) were deposited in a broad plain to the north and east of the retreating ice front. Much of this sediment is fine-grained sand that is difficult to distinguish from the sediments of glacial Lake Anoka. It is likely that portions of the outwash were laid down in shallow standing water or braided streams leading into the lake. Finally, the meltwater-swollen Mississippi River left behind wide terraces of sand and gravel deposits (Fig. 8). In a few places, the terrace sediment may be thin over the underlying glacial till.

POSTGLACIAL HISTORY

While the channels of the Mississippi River and its tributaries were being established (depositing unit Qa), organic-rich deposits (units Qp and Ql) began to accumulate in low-lying areas of the landscape including ice-block melt-out depressions and abandoned drainageways (Fig. 8). Wind mobilized the fine-grained lake sediment and formed sand dunes. A study of sediments cored from Lake Ann in the eastern part of Sherburne County (Keen and Shane, 1990) indicated the eolian sand dunes (unit Qe) may not have formed until an extended dry period beginning about 8,000 years ago.

DESCRIPTION OF MAP UNITS

Holocene

Qe **Very fine- to medium-grained sand**—Forms dunes; relief locally exceeds 30 feet (9 meters). *Windblown sand.*

Ql **Silt, clay, and loamy sand**—Locally includes organic-rich layers and may overlie, or be overlain by, muck or peat. May be sandy at the margins, especially where bordering glacial till; includes human-made beaches. The extent of exposure depends on the water level in the lake. Deposited in modern lakes. *Lake deposits.*

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

Holocene and Pleistocene

Qa **Sand, sandy loam to silt loam**—Generally coarse-grained sediment (sand and gravel) in the channels, and finer-grained sediment (fine-grained sand and silt) on floodplains; coarsens with depth. May be capped by and/or interbedded with organic-rich layers. Low areas may be filled with thick silty to clayey sediment. Along the Mississippi River, unit consists of generally less than 6 feet (2 meters) of silt loam to loamy sand overlying sand, gravelly sand, or cobbly gravel, with scattered wood and shell fragments. Sediment along smaller streams is generally finer-grained. *Floodplain alluvium.*

Sand and gravelly sand—Coarsens to cobbly gravel locally; may be capped in places by loamy fine-grained sand. In places the fine-grained sand has been blown onto the uplands (unit Qe). Variable thickness, although sediment grades into underlying outwash sand and gravel, which is difficult to distinguish. Thins closer to the present river channel. Sediment on lower terrace surfaces grades into floodplain alluvium. Terraces are separated into upper and lower surfaces based on general differences in elevation. In some places, there is a distinct scarp marking the edge of one terrace surface to another. In other places, the slope between surfaces is gradational and the contact line distinguishing the upper and lower surface is drawn to the elevation contour. Unit was deposited during higher stages of flow along the Mississippi River when the river served as an outlet for glacial meltwater. Preserved at higher levels above the modern floodplain. *Alluvial terrace deposits.*

Qtl ***Lower terrace***—Surface ranges in elevation from approximately 870 feet (265 meters) in the southeast corner to 950 feet (290 meters) in the northwestern part of the county.

Qtu ***Upper terrace***—Surface ranges in elevation from approximately 880 feet (268 meters) in the southeast corner to 1,020 feet (311 meters) in the northwestern part of the county. Patterned area indicates places where terrace sediments are thin (less than 10 feet [3 meters]) over underlying glacial till (units Qnt and Qct).

Pleistocene

New Brighton Formation (Johnson and others, in press)—Sediment deposited in glacial Lake Anoka.

Qbs ***Very fine- to medium-grained sand***—Silty in places; may include gravelly sand near the surface; variable thickness generally less than 50 feet (15 meters) over till (unit Qnt). In places the fine-grained sand has been sculpted by wind to form dunes (unit Qe). *Sandy glacial lake deposits.*

Qbg ***Medium- to coarse-grained sand to gravel***—Scattered cobbles in places. Generally less than 20 feet (6 meters) thick over till, but in places may overlie coarser-grained fluvial sediment of the New Ulm or Cromwell Formations. Deposited in deltaic or shallow-water environments in glacial Lake Anoka. *Gravelly glacial lake deposits.*

New Ulm Formation—Twin Cities Member (Johnson and others, in press)—Sediment associated with the Grantsburg sublobe of the northwest-source Des Moines lobe.

Qng ***Silt to fine-grained sand***—Minor interbeds of medium-grained sand; discontinuous and patchy. Deposited in the shallow water of glacial Lake Grantsburg. Fine-grained sediment adjacent to outwash (unit Qno) may include slackwater sediments of meltwater streams that deposited the outwash following the draining of the glacial lake. *Glacial lake sediment.*

Qno ***Sand, gravelly sand, and cobble gravel***—Moderately to poorly sorted; cross-bedded to flat-bedded; may be interbedded in places with unsorted sediments (till, cobbles, or boulders) where adjacent to glacial till. Deposits are of variable thickness, generally 10 to 45 feet (3 to 14 meters). Contains sediment from both northeast and northwest sources including abundant crystalline rocks (basalt and granite), few red sandstones, many carbonate rocks, and some gray, siliceous shale fragments. *Outwash.*

Qnl ***Very fine- to medium-grained sand***—Variable thickness 40 to 70 feet (12 to 21 meters). Interpreted to have been deposited in a lake walled by stagnant ice. As the ice melted, the lake sediment remained as a high plateau on the landscape; collapsed in places where the lake formed on top of ice. In places the fine-grained sand has been sculpted by wind to form dunes (unit Qe). *Ice-walled lake deposits.*

Qnt ***Loam to sandy loam***—Pebbly, unsorted; pockets of silt, sand, and gravel in places. Average composition of the very coarse-grained sand fraction includes crystalline rocks (76 percent), carbonate rocks (14 percent), and shale fragments (10 percent; Table 1). Unit is about 30 feet (9 meters) thick. *Glacial till.*

Qnc ***Loam to sandy loam over sand and gravel***—Till as above; unit is thin over Superior lobe ice-contact deposits (unit Qci). Sand and gravel may be at the surface in places. Topographic relief is inherited from Superior lobe deposits that consist of layers of silty sand to cobble gravel with no shale; deposited by meltwater flowing on, under, or adjacent to the ice. The top of the large fan-shaped feature may have little to no till cover. *Till over ice-contact deposits.*

Cromwell Formation (Johnson and others, in press)—Sediment deposited by ice of the northeast-source Superior lobe.

Qco ***Sand, gravelly sand, and cobble gravel***—Moderately to poorly sorted; cross-bedded to horizontally-bedded; interbedded in places with unsorted sediments (till, cobbles, or boulders). Unit is of variable thickness—generally 10 to 45 feet (3 to 14 meters). Contains sediment from northeast sources including abundant crystalline rocks (basalt and granite), many red sandstones, some carbonate rocks, and little to no gray, siliceous shale fragments. Pattern indicates areas of irregular, hummocky topography—interpreted to have formed as sediments were deposited on top of stagnant ice. When the ice melted, the sediments collapsed. *Outwash and collapsed outwash.*

Qci ***Sand, gravelly sand, and cobble gravel***—Poorly sorted; interbedded with unsorted sediments (till, cobbles, or boulders). Unit is of variable thickness—generally 10 to 45 feet (3 to 14 meters). Contains sediment from northeast sources including abundant crystalline rocks (basalt and granite), many red sandstones, some carbonate rocks, and no gray, siliceous shale fragments. *Ice-contact deposits.*

Qct ***Sandy loam***—Pebbly, unsorted; pockets of silt, sand, and gravel in places. Average composition of the very coarse-grained sand fraction includes crystalline rocks (99 percent), carbonate rocks (1 percent [may be as high as 7 percent where unleached]), and no shale fragments (Table 1). About 50 feet (15 meters) thick. *Glacial till.*

Qcd ***Sandy loam***—Glacial till as above; sculpted into drumlin landforms. Interpreted to have been deposited underneath the ice. *Subglacial till.*

Precambrian

Pgd **Bedrock**—Reformatory Granodiorite (see Plate 2, *Bedrock Geology*).

ACKNOWLEDGEMENTS

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

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