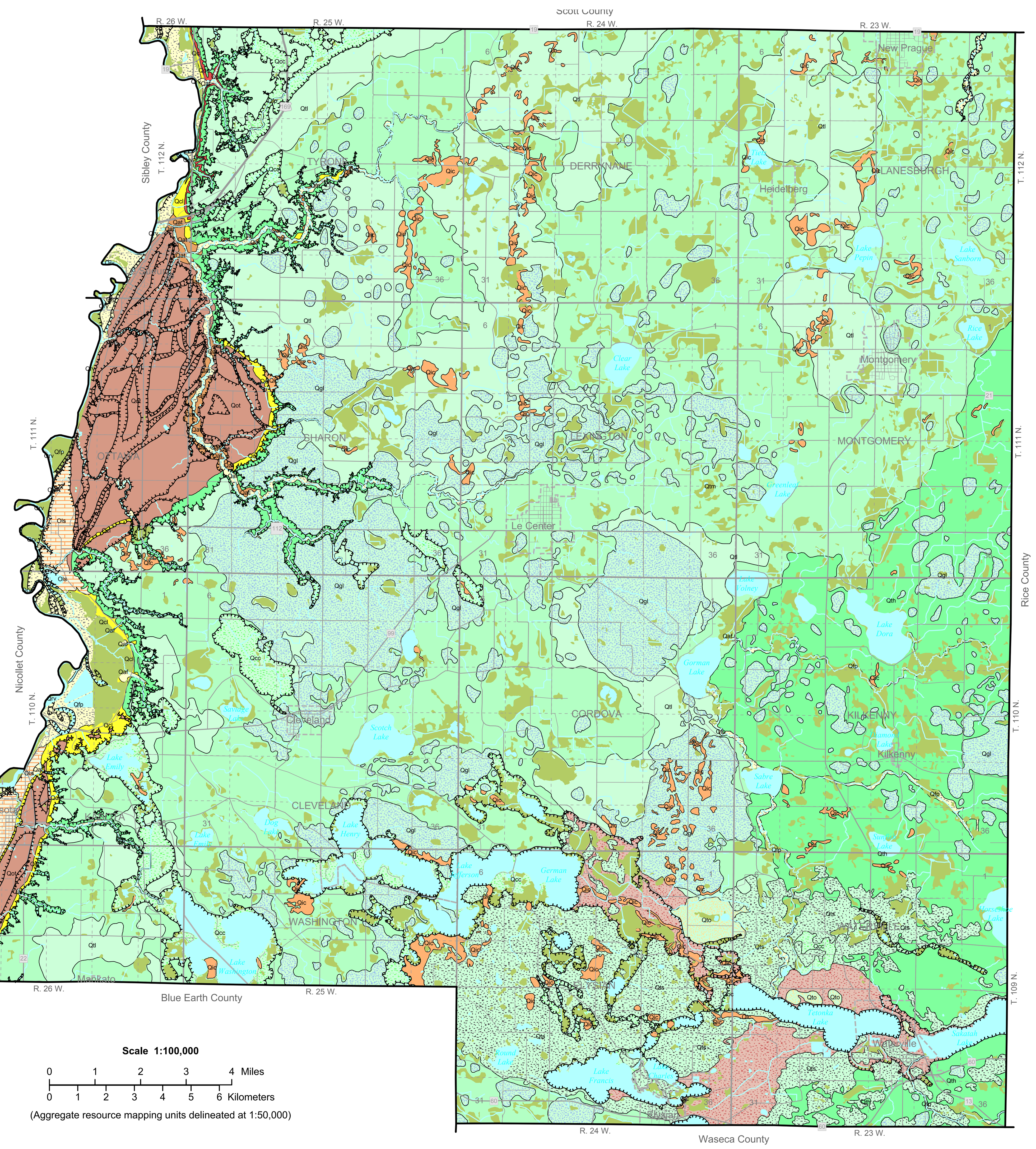
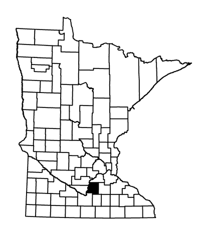
Minnesota Department of Natural Resources
Division of Lands and Minerals
William C. Brice, Director

SURFICIAL GEOLOGY
LE SUEUR COUNTY, MINNESOTA

Jonathan B. Ellingson
2003





Scale 1:100,000

0 1 2 3 4 Miles

0 1 2 3 4 5 6 Kilometers

(Aggregate resource mapping units delineated at 1:50,000)

MODERN SEDIMENTS, WATER, AND WETLANDS: Includes features where recent geological processes related to erosion and transportation of sediment have been occurring. These map units are Holocene (10,000 years ago until Present) in age and include lakes, streams, wetlands, flood plains, sand bars, fans, and terraces.

Water: Open water, including lakes, streams, and the Minnesota River.

Wetlands - Organic Sediments: Partially decomposed plant material, silt, and clay, found in or around shallow lakes, marshes, and peatlands. Wetlands can be observed throughout the county and overlie other mapped units.

Qcl **Colluvial Sediments:** Clay, silt, sand, and gravel, with occasional cobbles and boulders of varying composition, as well as angular fragments of limestone and sandstone of varying sizes. The sediment is moderately- to poorly-sorted, however, it occasionally contains thin (less than 6-inch) beds of well-sorted alluvial material. Colluvium is deposited at the foot of steep slopes where the bank material has collapsed and become slightly washed by sheetwash and alluvial processes. This colluvial sediment is primarily located at the base of the steep till and bedrock walls running parallel to the Minnesota River.

Qfp **Alluvial Flood Plain Sediments:** Silt, fine sand, coarse sand, gravel, and clay layers, overlying coarser sand and gravel layers and lenses. The sediment is generally moderately- to well-sorted and is interpreted to be alluvial overbank and stream bottom deposits. Within this unit, coarser sediment is typically found in abandoned and modern channels, point bars, and river bars. Alluvial sediments exist throughout the county in valleys, in low lying areas where drainage occurs as channelized flow, and within the current flood plain of the Minnesota River.

Qaf **Alluvial Fan Sediments:** Stratified fine sand, coarse sand, and gravel, with thin layers of silt and clay. The sediment is moderately well- to very well-sorted. Coarser material is typically found at the base of the fan (that is, the bottom of the deposit) and near the mouth of the fan. The sediment is generally deposited at the end of tributary streams where they enter larger valleys, due to the change in slope and slowing of the water flow, forming a cone shaped deposit. Alluvial fan sediments primarily occur in the western part of the county where smaller tributary streams enter the Minnesota River valley.

Qat **Alluvial Terrace Sediments:** Fine sand, coarse sand, and gravel, with occasional layers of silt and clay. The sediment is moderately well- to well-sorted with thin layers, lenses, and pockets of very well-sorted sands and gravels. The terraces are typically covered by 6 inches to 2 feet of silt, clay, and/or fine sand layers derived from flood plain sediments. Alluvial terrace sediments are found along tributary streams that enter the Minnesota River, where moving water has cut through the pre-existing till and glaciofluvial material and redeposited the sorted sands and gravels.

GLACIAL SEDIMENTS: Includes all material (clay, silt, sand, gravel, cobbles, and boulders) that was transported by glaciers and deposited directly from the glacier, from the ice as the glacier retreated, or by meltwater associated with the glacier. The glacial drift, which covers almost all of Le Sueur County, is Pleistocene (1.8 million to ~10,000 years ago) in age.

Qot **Glaciofluvial Outwash Terrace Sediments:** Stratified sand and gravel with occasional cobbles and small boulders scattered throughout. The sediment is generally rounded to well-rounded and well- to very-well sorted. The sediment is interpreted to have been deposited in large distal meltwater channels, such as the ones running parallel to the Minnesota River near Kasota and Le Sueur. Glacial River Warren, which drained Glacial Lake Agassiz, was responsible for the deposition of these large terraces.

Qoc **Glaciofluvial Outwash Channel Sediments:** Stratified fine to coarse sand and gravel, with occasional layers of silt, fine sand, and cobbles scattered throughout. The sediment is generally rounded to well-rounded and well- to very-well sorted. The sediment is interpreted to be derived from large meltwater channels that ran on, within, and/or beneath the retreating glacier and from the drainage channels of large glacial lakes. Much of the sediment is collapsed and discontinuous, which resulted from the melting and collapse of the sediments overlying glacial ice or buried ice blocks. However, large continuous sand and gravel outwash channel sediments are found near Waterville.

Qto **Outwash Channel Sediments Modifying Till Sediments:** Discontinuous, patchy, and thin stratified fine to coarse sand and gravel, with occasional layers of silt, fine sand, and cobbles, typically overlying unsorted till sediments (unsorted clay, silt, sand, gravel, cobbles, and boulders). The outwash sediment is interpreted to have been derived from smaller meltwater channels that ran on, within, and/or underneath the retreating glacier and from the drainage channels of glacial lakes. These outwash modified till sediments are primarily located in the southeast part of the county.

Qgl **Glaciolacustrine Sediments Over Till Sediments:** Alternating silt and clay layers with layers of silt, clay, fine-sand, and medium sand overlying unsorted till sediments (unsorted clay, silt, sand, gravel, cobbles, and boulders). These sediments are typically deposited as thin layers with distinctive summer and winter banding called varves. The sediment is interpreted to be derived from suspended material brought by meltwater streams, running on top of melting glaciers, into ice walled glacial lakes. These glaciolacustrine sediments are scattered throughout the county and vary in size from a few acres to nearly 9,000 acres, and vary in thickness from less than a few feet to roughly 10 feet.

Qic **Ice Contact Sediments:** Stratified silt, fine sand, coarse sand, and gravel, with occasional clay and silt layers. The sediment is generally rounded to well-rounded and poorly- to well-sorted. These sediments are deposited as features called eskers and kames. These eskers are typically long, narrow, sinuous ridges of stratified sand and gravel that were formed as sub-glacial streams flowed between ice walls or in ice tunnels within the stagnant glacier, and were left behind as the ice melted. The kame features are low mounds, knobs, hummocks, or short irregular ridges also composed primarily of stratified sand and gravel that were formed in low areas or holes on the surface of the ice as fans or deltas. The smaller ice contact sediments were not sorted as well and still contain a significant amount of silt and clay within the sand and gravel. These sediments can be found throughout the county, however, well developed eskers can be observed in the southeastern part of the county.

Qcc **Till - Collapsed Channel Sediments:** Till sediment (unsorted clay, silt, sand, gravel, cobbles, and boulders), with occasional, discontinuous and patchy, fine to coarse sand and gravel sediment. The sand and gravel sediment, overlying the till, is all that remains of small outwash channels where supra-glacial meltwater once carried large amounts of sand, gravel, and fine sediments. The sediment has been cleaned out of the channels and is often deposited as outwash channels further down gradient. These collapsed channel sediments can be observed in the southern and southeastern portions of the county.

Qtl **Till - Ground Moraine Sediments - Low Relief:** Unsorted and unstratified clay, silt, sand, and gravel, with scattered cobbles and boulders throughout. This till sediment (also called unsorted drift) was deposited directly by and underneath the glacier without subsequent reworking by meltwater. The random melting of ice and deposition of material produced a relatively flat to gently rolling, slightly hummocky topography that is characteristic of a ground moraine.

Qtm **Till - Stagnant Ice Moraine Sediments - Moderate Relief:** Unsorted and unstratified clay, silt, sand, and gravel, with scattered cobbles and boulders throughout. This till sediment was deposited directly by and underneath the glacier without subsequent reworking by meltwater. The random melting of ice and deposition of material produced a hummocky, undulating, or hilly topography. The topography is also characterized by circular flat-topped hills, or plateaus, which are mostly till, but may be capped with glaciolacustrine sediments.

Qth **Till - Stagnant Ice Moraine Sediments - Higher Relief:** Unsorted and unstratified clay, silt, sand, and gravel, with scattered cobbles and boulders throughout. This till sediment was deposited directly by and underneath the glacier without subsequent reworking by meltwater. The random melting of ice and deposition of material produced a very hummocky, undulating, or hilly topography characteristic of a stagnant ice moraine. The topography is also characterized by circular flat-topped hills, or plateaus, which are mostly till, but are capped with glaciolacustrine sediments. There are several collapsed channels located throughout this unit.

Qts **Till, Sand, and Gravel Complex Sediments:** Till (unsorted clay, silt, sand, gravel, cobbles, and boulders) overlying and mixed with relatively small, patchy, discontinuous, and thinly stratified, fine to coarse sand and gravel, with occasional layers of clay, silt, and fine sand. The area consists of small ice contact and outwash deposits within a stagnant ice moraine. This area is interpreted to have been dominated by meltwater drainage, however, a later glacial event covered the outwash with till creating a complex of sand, gravel, and till. The random melting of ice and deposition of material produced a very hummocky, undulating, or hilly topography characteristic of a stagnant ice moraine. This complex of sediments can be observed in the southeastern corner of the county.

Qos **Glaciofluvial Outwash (Superior Lobe) Sediments:** Stratified sand and gravel, with occasional layers of cobbles, fine sand, and silt scattered throughout. The sediment is generally rounded to well-rounded and moderately well- to very well-sorted. The sediment is interpreted to be derived from the meltwater drainage of the Superior Lobe (a much earlier glacial advance that transported and deposited sediment from the northeast). This sediment is generally coarser than any other outwash sediment in the county. The sand and gravel sediment is primarily composed of igneous rocks from the Lake Superior region, such as gabbros and basalts, whereas every other sand and gravel deposit within the county consists primarily of carbonates, granites, shales, and other indicator rocks from sources to the northwest. This sediment can only be observed in the extreme northwestern portion of the county, where this buried layer was exposed by the down-cutting of Glacial River Warren.

BEDROCK UNITS: Consists of limestone, dolomite, and sandstone bedrock units that were exposed along the Minnesota River as a result of the downcutting by Glacial River Warren through 100-200 feet of material. The sandstone bedrock is Cambrian (545 to 490 million years ago) in age and is interpreted to be part of the Jordan Sandstone. The carbonate (limestone and dolomite) bedrock is Ordovician (490 to 445 million years ago) in age and is interpreted to be part of the Prairie du Chien Group.

Ols **Limestone/Dolomite:** Light brown, brownish gray to buff, fine- to medium-grained dolomitic limestone with a silt-sized dolomite matrix. Thin to thick bedded with variable color and texture both horizontally and vertically. Some of the lower beds are thicker and very well consolidated. This unit is frequently porous and cavernous, with the caverns commonly lined with calcite crystals. Chert nodules and fossils are common throughout. This unit may contain small pockets of weathered carbonate material near the surface.

Css **Sandstone:** White, yellowish to light-brownish tan, and buff colored, medium to thick bedded, poorly cemented, coarse- to medium-grained quartzose sandstone to dolomitic sandstone. The upper unit contains alternating layers of quartzose sandstone, dolomitic limestone, and dolomitic sandstone and grades downward to fairly pure quartzose sandstone, then into well-consolidated sandstone, and finally into loosely consolidated sandstone. The quartz purity of this unit increases downward until it is > 95% pure quartz sandstone. This unit is currently being mined for industrial quality sand within the county.

Geologic Contacts and Landforms

Geological Contact - Boundary between geologic units.

Channel Scarp - The boundary separating relatively flat terrain from steeper slopes, created by water erosion.

GEOLOGICAL HISTORY

The geological units exposed within Le Sueur County consist of bedrock formations, glacial drift, and modern sediments (see Figure 1). There are two sedimentary bedrock units exposed within the county: the Jordan Sandstone and part of the Prairie du Chien Group (Oneota Dolomite). The Jordan Sandstone was deposited during the Cambrian (545 to 490 million years ago), a time when large seas and beaches covered much of Minnesota. In the late Cambrian, the sea levels dropped leaving the area (that is now Le Sueur County) similar to that of a tropical beach. Large deposits of quartz sand were deposited in this shallow, nearshore environment. Wave action continued to modify the quartz material into very well-rounded sand grains, creating the sediment that later became the Jordan Sandstone. Much later during the Ordovician (490 to 445 million years ago), the sea levels began to rise and this area was again covered by large continental seas. As the seas became deep and stable, thick deposits of carbonate material were deposited in the calm, deep, offshore environment. This material was later consolidated into the limestones, and through time into the dolomitic limestones and dolomites that make up the Oneota Dolomite and Shakopee Formations (which make up the Prairie du Chein Group).

Much later in time, during the Pleistocene (1.8 million to ~10,000 years ago), large continental glaciers advanced across almost all of Minnesota. These continental ice sheets originated in Canada and slowly moved southward through Minnesota. Several different glacial advances occurred from the northwest, through the Winnipeg area; several other advances came from the northeast, through the Lake Superior area and through northeastern Minnesota. As the glaciers advanced, they picked up (eroded) bedrock and other surface materials along their paths. These glaciers continued to advance, transporting some of this material south while flowing over Le Sueur County and on into Iowa. As the glaciers melted (receded), they deposited the sediments that had been eroded and transported from these northern areas. The oldest glacial material observed in Le Sueur County came from the northeast (Superior Ice Lobe), where indicator rocks, such as gabbros and basalts, were picked up and transported here. The last glacial advance that covered southern Minnesota came from the northwest, where indicator rocks such as carbonates and shale, were picked up and transported to Le Sueur County.

As the glaciers melted, large streams were created that sorted the material, carrying away the silt and clay, and depositing the coarser sand and gravel material (often termed outwash) in landforms such as channels. Some of the finer material was deposited in standing water on the ice, creating ice walled glacial lakes. Remnant glacial lakes can be observed throughout the county where enough fine sediment accumulated. The remaining unsorted material that was incorporated in the ice was deposited as till. Multiple small and large glacial advances/retreats occurred in Le Sueur County, which left behind very different landscapes, as observed by their sediment and topographic expressions. The large sand and gravel terraces (the glaciofluvial outwash terrace sediments), found next to the Minnesota River, were deposited a few thousand years later (about 10,000 to 12,000 years ago) by Glacial River Warren, which was a very large outlet channel from Glacial Lake Agassiz. After all the glacial activity ceased and the ice melted, modern day sediments such as flood plains, alluvial fans, alluvial terraces, and colluvium began to form. These Holocene (10,000 years ago to Present) sediments continue to be deposited today as a result of recent geological processes.

MAPPING METHODOLOGIES AND DATA SOURCES

Identifying the distribution of aggregate resources is largely determined by understanding the surficial geology and the geologic history of an area. The geologic history relates the story, or sequence of events, of when and how the aggregate and other sediments were deposited. By understanding this story, we can determine where the aggregate was deposited as well as some of the general characteristics of the material. Traditional geologic mapping techniques were integrated with GIS (Geographic Information Systems) to interpret the geologic history and identify the distribution of aggregate resources for Le Sueur County. This was accomplished in several phases: 1) preliminary information gathering, 2) compiling, interpreting, and summarizing data, 3) field checking the data, and 4) producing the final maps and data.

The first step was to conduct a literature and data search to obtain a basic understanding of the geology in the area and to compile a list of existing data. Much of this information was already available in a digital format or was incorporated into digital datasets. Some of the datasets used include aerial photographs, topographic maps, digital elevation models, shaded relief, subsurface data, gravel pit and quarry data, surficial and bedrock geology, wetlands, streams, lakes, vegetation, soils, land-use, as well as several datasets of background information, including roads, railroads, township-range-section boundaries, and others.

The subsurface data used for this study included the County Well Index (CWI) database and the Minnesota Department of Transportation's (MN/DOT) files. The CWI is an online database maintained by the Minnesota Geological Survey (MGS, 2001) that contains basic information for over 300,000 wells drilled throughout Minnesota. As of 2001, when the CWI data were obtained, approximately 950 of these wells are located in Le Sueur County. Almost two-thirds of the wells contained geological descriptions that were found to be useful for the study. The MN/DOT Aggregate Source Information System (ASIS) digital files consist of quality and textural (i.e., sieve or particle size) data, and where pit sheets were available, shallow test hole logs, and a diagram of test hole locations (the associated data were summarized in a database). The subsurface information was used to look for buried sand and gravel deposits, determine the depth to bedrock, and identify the type of bedrock encountered.

Once all of this information was digital, a computer program by ESRI called ArcView©, was used to help interpret, compile, and summarize the data. This information was then incorporated into the development of a working geologic model for Le Sueur County. Color infrared and black-and-white aerial photographs were then used in conjunction with geological modeling to delineate geological landforms and aggregate resources. Stereoscopic pairs of color infrared aerial photographs (NAPP, 9"x 9" at 1:40,000 scale, April 1991 and 1992) were used along with reconnaissance-level, high-altitude, black-and-white photographs (1:80,000 scale). Aerial photographs, available as Digital Orthophoto Quads (DOQs), were also available digitally and used within ArcView© (1:12,000 scale).

Aerial photographic interpretation was completed with a glacial mapping technique known as the landsystems approach. This technique relies on the principle that depositional glacial landforms are composed of a predictable range of sediments, some consisting of sorted sand and gravel and others consisting of silts, clays, or unsorted materials. In addition to the landsystems approach, several other general characteristics helped determine the nature of the material, such as tonal contrasts, texture, context, shape, size, trend, association, and patterns. These characteristics can help determine the properties of the surface material (e.g., certain vegetation grows on well drained soils, such as sand and gravel, which on an aerial photograph has a distinctive texture, tone, pattern, etc.).

The landform recognition approach (part of the landsystems approach) was also used when interpreting the topography within Le Sueur County; glacial landforms have distinct and unique shapes and patterns that can be observed in their topographic expression. Topographic maps (USGS 1:24,000), digital elevation models, and shaded relief maps were all used to help delineate these sand and gravel bearing features. The topographic expression of a feature can also be observed by looking at the distribution of lakes and wetlands. For example, a string of lakes and/or wetlands may be the signature of a glacial outwash channel or collapsed channel, which may host sand or gravel deposits. Several aggregate bearing features (outwash channels, collapsed outwash, alluvial fans, and terraces) were located using this technique.

The aerial photographs, subsurface data, topographic expressions, and soils were all compiled and the inferred geologic and aggregate resource contacts were digitized on-screen, using ArcView©, generally with a digital version of the 7.5 minute topographic maps (1:24,000) or the aerial photography (DOQs at 1:12,000) used as a backdrop. The mapping units were then ready to be field checked.

Fieldwork consisted of driving every accessible road in the county looking for outcrops and exposures of geological sediments, as well as drilling test holes where needed. Sediments exposed in road cuts, stream exposures, excavations such as basements, judicial ditches, construction projects, trenches (cable, pipe, tiling), and even animal holes offered several places where the surficial materials, glacial stratigraphy, and bedrock formations were observed. A total of 1,151 observation sites were logged in Le Sueur County. Some of the already mined aggregate resources were exposed at 326 gravel pits and bedrock quarries found in the county. These locations supplied additional quality data and good stratigraphic cross-sections to help interpret the modes of deposition. Test holes were also drilled, with the permission of the landowner, where additional data was needed to confirm the presence of sand and gravel.

After completing the fieldwork, a very detailed interpretation of the aerial photographs was done to finalize the geologic map units, incorporate the field data, and classify the potential aggregate resources (further defined on Plate A).

GENERAL REFERENCES

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Palmer, A.R. and J. Geissman, 1999, The 1999 Geologic Time Scale, The Geological Society of America, Product Code CTS004.
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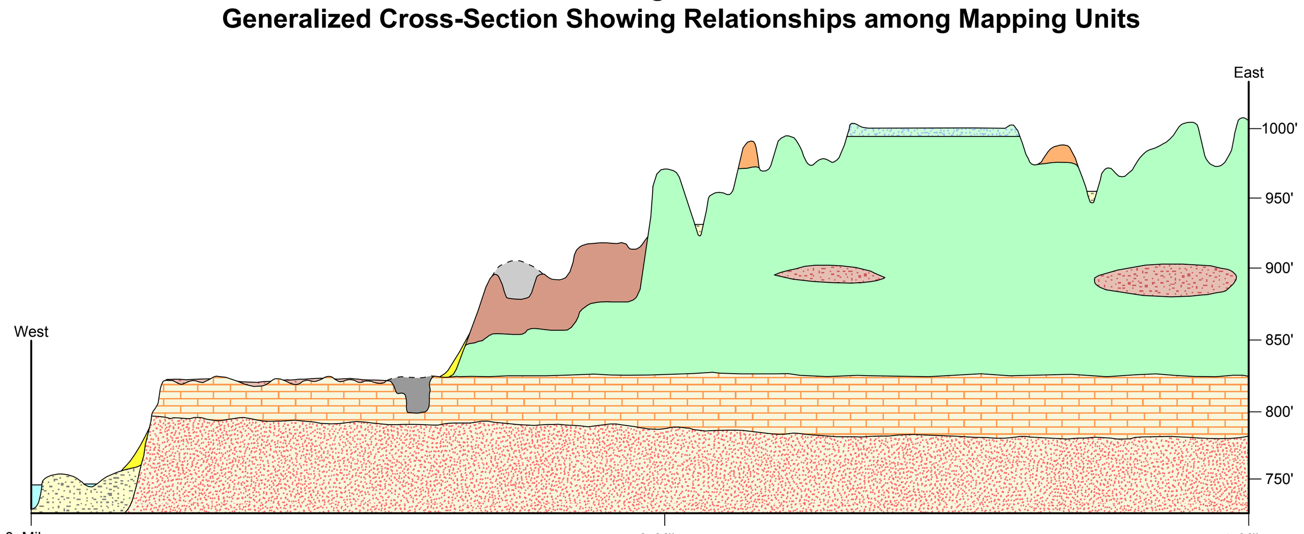
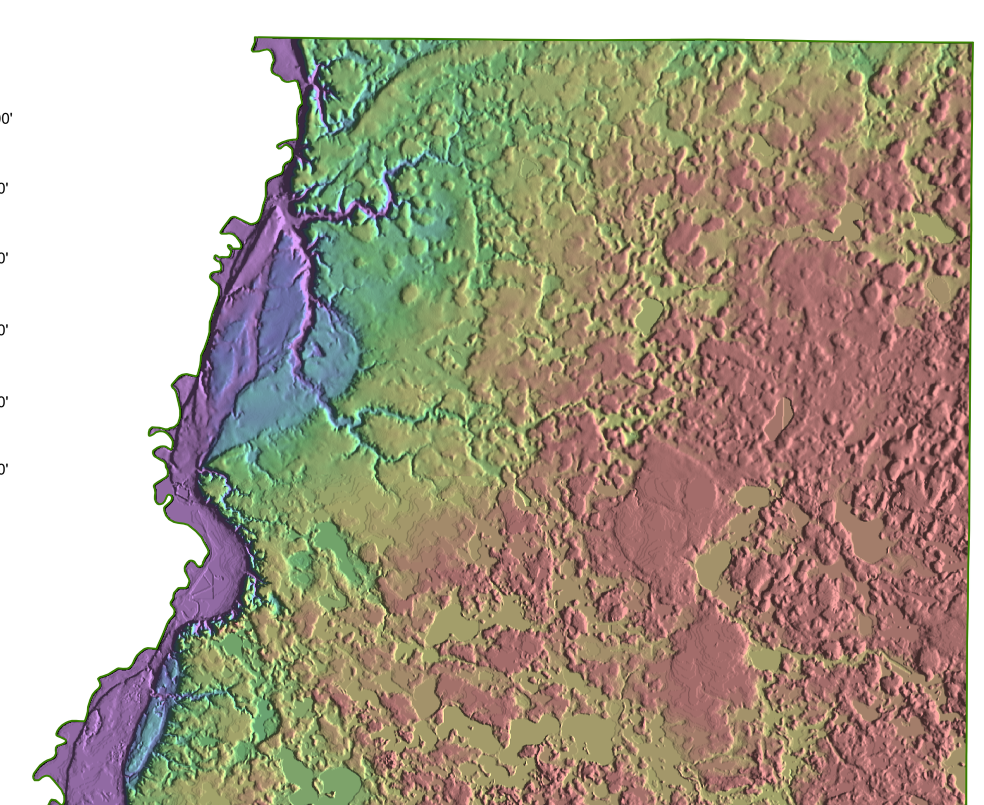
Smith, M.R. and L. Collis, 1993, Aggregates: Sand, Gravel, and Crushed Rock Aggregates for Construction Purposes, The Geological Society Engineering Geology Special Publication No. 9, second edition, 339 p.

Figure 1.
Generalized Cross-Section Showing Relationships among Mapping Units



This generalized cross-section, with a vertical exaggeration of 35x, relates the various mapping units seen in the map above to the various landforms that can be seen in the shaded relief image of the county (Figure 2).

Figure 2.
Shaded Relief



The shaded relief plot of Le Sueur County was derived from Digital Elevation Model data and the use of a hillshading command to make the elevations appear 3-dimensional by adding bright spots and shadows as they might be cast by the sun. Digital Elevation Models (DEMs) are digital files storing terrain elevation at regularly spaced, horizontal intervals derived from U.S. Geological Survey (USGS) 7.5-minute quadrangles. The DEM data used in this case are available at 30-meter spacing from USGS. In general, the purple colors are lower elevations and the brown colors are higher elevations. Darker shades of the colors are those in shadow, due to hillshading.

Base map data sources:
Lakes, wetlands, and rivers from National Wetland Inventory, U.S. Fish and Wildlife Service, compiled at 1:24,000 from aerial photography (1979-1988) and spot field checked.
Public Land Survey - PLS Project, 2001, Minnesota Department of Natural Resources, Division of Lands and Minerals.
Roads from MN/DOT Basemap 2001 - Roads, Minnesota Department of Transportation, BaseMap Development Group, Surveying and Mapping Section.
Civil Townships and Municipal Boundaries from MN/DOT Basemap 2001 - Civiltwp and Muni, Minnesota Department of Transportation, BaseMap Development Group, Surveying and Mapping Section.

GIS database design and cartography by Renee Johnson. Database assistance by Jason Barnum and Erika Rowe. Field and drilling assistance by Ricco Riihiluoma and Jason Barnum.

Prepared with support from Le Sueur County.

This project includes a CD/ROM of maps, data, and metadata in a digital format and the following plates:
Plate A, Report 360, Aggregate Resources
Plate B, Report 360, Surficial Geology