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

SURFICIAL GEOLOGY

BLUE EARTH COUNTY, MINNESOTA

JONATHAN B. ELLINGSON

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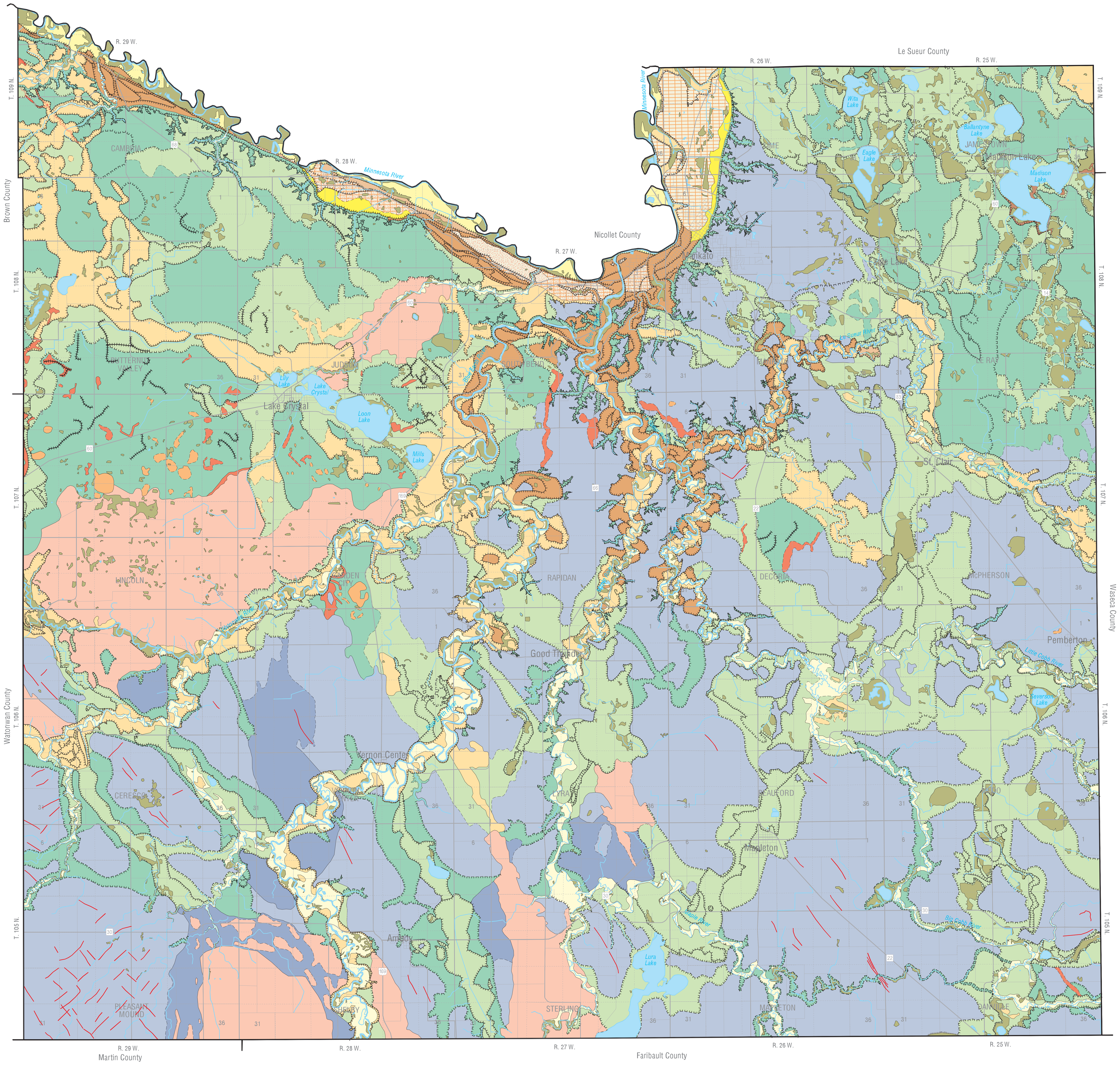


MODERN SEDIMENTS, WATER, AND WETLANDS: Includes features where recent geologic processes have been occurring. Recent geologic processes causing erosion and transportation of sediment by wave action (lakes) and currents (streams) have sorted materials and deposited them as features, such as beaches and alluvial flood plains. These features are Holocene (10,000 years ago until Present) in age and include lakes, streams, wetlands, beaches, and flood plains.

Water: Open water including lakes and streams.

Wetlands - Organic Sediment: Partially decomposed plant material, silt, and clay; includes shallow lakes, marshes and peat. Wetlands can be observed throughout the county.

Colluvial Sediments: Clay, silt, sand, and gravel with occasional cobbles and boulders. The sediment is poorly sorted, however, it has thin (< 6 inches) sorted beds of sand scattered throughout. Colluvium is deposited on the foot of steep slopes along the Minnesota River Valley where till banks collapse and become slightly washed by sheetwash and alluvial processes. This colluvial sediment overlies glacial sand and gravel outwash and limestone bedrock.

Beach Sediments: Fine, medium, and coarse sand with occasional gravel sized particles and layers. The sediment is generally well-sorted and well-rounded and is interpreted as sediments associated with modern lake shores. These sediments can be found along the beaches of Madison Lake in the northeastern corner of the county.

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 interpreted as alluvial overbank deposits. Within this unit, coarser sediment is typically found in abandoned channels, point bars, and river bars. Examples of alluvial sediment exist within the county in and around the Maple, Le Sueur, Cobb, Watonwan, and Blue Earth Rivers.

Minnesota River Valley Flood Plain Sediments/Glacial Outwash Sediments: Quartz rich medium and coarse sands overlying sand and gravel sediments. The sediment is well- to very well-sorted and interpreted as glaciofluvial outwash sediments overlain by modern flood plain sediments of the Minnesota River. Glacial River Warren (which drained Glacial Lake Agassiz) carried large amounts of outwash, however, the modern day Minnesota River is only capable of carrying much finer sediment.

GLACIAL DRIFT: Includes all material (clay, silt, sand, gravel, and boulders) that was transported by glaciers and deposited directly from the glacier, from the ice as the glacier retreated, or by running water associated with the glacier. The glacial drift, which covers almost all of Blue Earth County, is Pleistocene (2.5 million to 10,000 years ago) in age.

Terrace Sediments: Sand and gravel with occasional cobbles and 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 glacial outwash channels such as the ones paralleling the Blue Earth and Minnesota Rivers. Glacial River Warren (which drained Glacial Lake Agassiz) was responsible for the deposition of the large terrace deposits on the banks of the modern Minnesota River.

Thin Terrace Sediments over Bedrock: Thin sand and gravel with an occasional cobble or boulder overlying bedrock. The sediment is generally rounded to well-rounded and well- to very well-sorted. The sediment is interpreted to have been deposited on the bedrock terraces as the erosive behavior of Glacial River Warren decreased, thus causing the sediment load to be deposited as terraces paralleling the Minnesota River.

Ice Contact - Kame Sediments: Stratified fine to coarse sand and gravel with occasional thin silt and clay layers and lenses. The sediment forms low mounds and is interpreted to have been deposited by superglacial streams in low places or holes on the surface of the glacier or as ponded deposits on the surface or at the margin of stagnant ice. These features (kames) can be found on the stagnant ice moraine tills just southwest of Lake Crystal.

Ice Contact - Esker Sediments: Stratified sand and gravel with a very thin till cap in some areas. These esker features form long, narrow, sinuous ridges composed of irregularly stratified sand and gravel due to incorporation of and later melting of ice blocks. They are interpreted to have formed by a subglacial stream flowing between ice walls or in an ice tunnel of the stagnant glacier, then left behind as the ice melted. These esker features can be found on the stagnant ice moraine tills just southwest of Lake Crystal and in the northwestern corner of the county.

Collapsed Channel Sediments: Discontinuous and patchy, fine to coarse sand and gravel sediment with walls composed of till (unsorted clay, silt, sand, gravel, cobbles, and boulders). This sand and gravel sediment is all that remains of large outwash channels, where superglacial meltwater once carried massive amounts of sand, gravel, and finer sediments. The sediment has been cleaned out of the channels and is often deposited as a large delta where the channel intersected standing water (Glacial Lake Minnesota). All that remains is collapsed till with small remnants of sand and gravel. An example of one of these channels can be seen in the southwestern corner of the county where this stripped out channel once supplied sediment to a very large delta. Outwash channels also formed as Glacial Lake Minnesota was allowed to drain to the north after the ice retreated.

Outwash Channel Sediments: Fine to coarse sand and gravel with occasional cobble or small boulder layers. The sediment is interpreted to be derived from large meltwater channels that ran on, within, and/or underneath the retreating glacier. These channels also formed as the water from Glacial Lake Minnesota drained due to the retreat of the glacier; these channels carried smaller amounts of sand and gravel. Much of the sediment is collapsed and discontinuous due to melting, buried iceblocks, and deposition on top of the ice, however, large gravel ridges are found within these channels, as in the northwestern corner of the county.

Glacial Lake Sediments: Silt, clay, fine sand, and medium sand layers. These sediments are typically deposited as thin layers with alternating summer and winter components called varves. The sediment is interpreted to be derived from suspended material brought by meltwater streams into Glacial Lake Minnesota, which bordered the receding glacier, as well as from stagnant ice melting within the lake plain. The sediments are therefore coarser (sandier) towards the meltwater and sediment source (meltwater streams/deltas), becoming finer (silt/clay) outward in deeper calm water. These sediments can be found throughout the southern part of the county. The locations of the deltas suggest that the glacial lake was much smaller at one time.

Glacial Lake Sediments over Deltaic Sediments: Silt, clay, fine sand, and medium sand layers overlying stratified medium and coarse sand and gravel with occasional layers of silt, fine sand, and cobbles. These deltaic sediments were deposited as outwash channels entered Glacial Lake Minnesota (when it was much smaller), however, as the lake levels and areal extent of the lake increased, the deltaic sediment was covered be deeper water sediments (silts, clays, and sands). These sediments can be found in the southwestern part of the county.

Deltaic Sediments: Stratified medium and coarse sand and gravel with occasional layers of silt, fine sand, and cobbles. Sediment is deposited in large fan shaped or triangular features, called deltas, as meltwater streams enter standing water. These deltas are typically very large in areal extent. The sediment exhibits stratified layers that have been thrusted, collapsed, and faulted due to the incorporation of ice blocks within the delta as well as the deltas being deposited on top of ice. These deltas formed as outwash channels entered the glacial lake now known as Glacial Lake Minnesota as well as smaller icewalled lakes on the glacier. Several deltas can be observed throughout the county.

Till: Unsorted clay, silt, sand, gravel, cobbles, and boulders. Different till units with different textural characteristics were found within the county, however, for the purposes of this study they were not broken down in any detail. There are several locations along the Le Sueur River where multiple till units are exposed, sometimes with 1-15 feet of gravel between them. The till is also exposed where alluvial valleys have cut through the glaciolacustrine sediment and in collapsed channels. Till is the dominant sediment in the northwestern quarter of the county due to stagnation and ground moraines.

BEDROCK UNITS*: The Oneota Dolomite (dolomitic limestone) and Jordan Sandstone (quartzose sandstone) Formations that are exposed on large benches along the Minnesota River Valley, where Glacial River Warren eroded through the overlying glacial materials, thus exposing the bedrock. The limestone bedrock (Oneota Dolomite) units found within Blue Earth County are Ordovician (500 to 440 million years ago) in age and the sandstone bedrock (Jordan Sandstone) units are Cambrian (570 to 500 million years ago) in age. Thin sand and gravel outwash sediments are commonly found overlying these units.

Limestone: 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. Frequently porous and cavernous - commonly lined with calcite crystals. Chert nodules and fossils are common with occasional stromatolitic texture.

Limestone overlying Sandstone: Thin light brown, brownish gray to buff, fine- to medium-grained dolomitic limestone with a silt-sized dolomite matrix overlying white, yellowish to light-brownish tan, and buff colored medium to thick bedded, coarse- to medium-grained quartzose sandstone to dolomitic sandstone. The overlying limestone layers are typically less than 15 feet thick. The upper 10-30 feet of the quartzose sandstone is well consolidated and interfingered or interlayered with the limestone.

Sandstone: White, yellowish to light-brownish tan, and buff colored medium to thick bedded, 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 could be evaluated for industrial sand at depth.

*G.S. Austin, 1972, "Paleozoic Lithostratigraphy of Southeastern Minnesota", in Geology of Minnesota: A Centennial Volume, Minnesota Geological Survey, P.K. Sims and G.B. Morey, eds., pp. 459-473.

GEOLOGICAL HISTORY

The geological units exposed within Blue Earth County consist of bedrock formations, glacial drift, and modern sediments. Two major bedrock formations are exposed within the county, the Jordan Sandstone (Cambrian in age) and the Oneota Dolomite (Ordovician in age). The Cambrian and Ordovician marked a time in geologic history when large shallow seas covered Minnesota. During several episodes of seas advancing and retreating, the sediments that make up the Jordan and Oneota Formations (sandstones and limestones) were deposited. The Jordan Sandstone consists of medium- to coarse-grained, loosely consolidated, cross-bedded, quartzose sandstones; it is interpreted to have been deposited approximately 500 million years ago in near-shore environments such as sand bars, beaches, and sand dunes. The Oneota Dolomite consists of fine- to medium-grained dolomitic limestone with a silt-sized dolomite matrix. This limestone was derived from the remains of invertebrate shells and algae that accumulated approximately 480 million years ago in offshore environments as layers and as reefs. These sands, invertebrate shells, and algae were later buried. Due to heat and pressure, along with groundwater interactions, these materials were gradually consolidated into the sandstone and limestone formations.

Much later in time, during the Quaternary Period (2.5 million years ago to present), 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 both the northeast through the Lake Superior area, and from the northwest, through the Winnipeg area. As these glaciers advanced, they picked up (eroded) bedrock and other surface materials along their path (characteristic of the areas over which the glaciers moved). These glaciers continued to advance, transporting some of this material to the south over Blue Earth County and into Iowa. As the glaciers melted (receded), they deposited the sediment that had been eroded and transported from the northern areas. The last major glacial advance that covered southern Minnesota came from the northwest, where carbonates, granites, mafics, and shale were picked up and subsequently deposited in Blue Earth County. These materials covered the sediments that were previously deposited from the northeast. In general, the sediments from the northeast have higher quality sand and gravel material; the sediments from the northwest have lower quality material due to the presence of the carbonates and shales. Thus, Blue Earth County does have higher quality sand and gravel materials, however, they are typically buried by 50 feet or more of overburden.

As the glacier melted, large streams sorted the materials, carrying away the silt and clay (the fines) and depositing the coarser sand and gravel material, often termed outwash, in large channels. As the glacier continued to melt, large amounts of water were produced. The higher land to the east and south and the glacier to the north temporarily blocked drainage of the meltwater, thus forming Glacial Lake Minnesota, which at its maximum extent covered most of southern Blue Earth County. The outwash channels carrying the meltwater entered this body of water and deposited large sand and gravel deltas; the fine material was carried into deeper water and was deposited at the bottom of this lake. The remaining unsorted material that was incorporated in the ice was deposited as till. The large sand and gravel terraces found next to the Minnesota River were deposited a few thousand years later (about 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 was melted, modern day sediments such as beaches, flood plains, and colluvium began to form. These Holocene (10,000 years ago to present) sediments continue to be deposited as a result of recent geological processes.

RELATIONSHIP BETWEEN GEOLOGIC AGES AND MAPPING UNITS

QUATERNARY PERIOD: Representing 2.5 million years ago until Present.

HOLOCENE EPOCH: Representing 10,000 years ago until Present.

- Water
- Wetlands - Organic Sediment
- Colluvial Sediments
- Beach Sediments
- Flood Plain Sediments
- Minnesota River Valley Flood Plain Sediments/Glacial Outwash Sediments

PLEISTOCENE EPOCH: Representing 2.5 million to 10,000 years ago.

- Terrace Sediments
- Thin Terrace Sediments over Bedrock
- Ice Contact - Kame Sediments
- Ice Contact - Esker Sediments
- Collapsed Channel Sediments
- Outwash Channel Sediments
- Glacial Lake Sediments
- Glacial Lake Sediments over Deltaic Sediments
- Deltaic Sediments
- Till

ORDOVICIAN PERIOD: Representing 500 to 440 million years ago.

- Limestone (Dolomitic Limestone)
- Limestone overlying Sandstone

CAMBRIAN PERIOD: Representing 570 to 500 million years ago.

- Sandstone

GEOLOGIC CONTACTS AND LANDFORMS

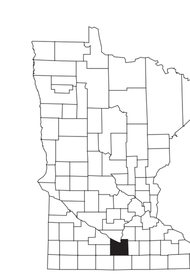
- Geologic Contact - Well defined geologic contact.
- Geologic Contact - Inferred, gradational, or approximately located geologic contact.
- Channel Scarp - Well defined channel scarp or boundary of outwash channel.
- Channel Scarp - Inferred or approximate location of channel scarp or boundary of channel.
- Esker - Well defined sand and gravel ridge deposited by glaciofluvial processes.
- Crevasse Fill - Short, straight, sand and gravel ridge (parallel or perpendicular to ice flow direction).
- Till Ridge - Distinct till ridge (unsorted clay, silt, sand, gravel, and boulders).

Scale 1:100,000

0 1 2 3 4 Miles

0 1 2 3 4 5 6 Kilometers

(Surficial geology mapping units were delineated at 1:50,000)



Surficial Geology:
Aerial photograph interpretation, field work, and delineation of mapping units by Jonathan B. Ellingson, 1998-1999, County Aggregate Mapping Program, Division of Minerals, Minnesota Department of Natural Resources. Source information included aerial photographs from NAPP (National Aerial Photography Program), 1991-1992, 9" x 9" color infrared photos at 1:40,000; DOQs (Digital Orthophoto Quadrangles) at 1:12,000 from USGS (United States Geological Survey); DRGs (Digital Raster Graphics) at 1:24000 from USGS; 7.5-minute USGS quadrangles at 1:24,000 from USGS; 7.5-minute USGS topographic quadrangles at 1:24,000; and Soil Survey of Blue Earth County from USDA-SCS (United States Department of Agriculture, Soil Conservation Service), 1978.
Base map data sources:
Lakes, wetlands, and major 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. Minor rivers from State of Minnesota Basemap, 1996, Department of Transportation Surveying and Mapping BaseMap Development Group.
Public Land Survey - PLS Project, 1999, Minnesota Department of Natural Resources, Division of Minerals.
Roads from State of Minnesota Basemap, 1996, Department of Transportation Surveying and Mapping BaseMap Development Group.

GIS database design and cartography by Renee Johnson (1999). Digitizing by Jeff Nyquist (1999).

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Projects are determined by a committee composed of Governor-appointed members from the public and private sectors.