Mississippi National River and Recreation Area

GRI Ancillary Map Information Document

Produced to accompany the Geologic Resources Inventory (GRI) Digital Geologic Data for Mississippi National River and Recreation Area

miss_geology.pdf

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Geologic Resources Inventory Map Document for Mississippi National River and Recreation Area

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This document has been developed to accompany the digital geologic-GIS data developed by the Geologic Resources Inventory (GRI) program for Mississippi National River and Recreation Area, Minnesota (MISS).

Attempts have been made to reproduce all aspects of the original source products, including the geologic units and their descriptions, geologic cross sections, the geologic report, references and all other pertinent images and information contained in the original publication.

National Park Service (NPS) Geologic Resources Inventory (GRI) Program staff have assembled the digital geologic-GIS data that accompanies this document.

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About the NPS Geologic Resources Inventory Program

Background

Recognizing the interrelationships between the physical (geology, air, and water) and biological (plants and animals) components of the Earth is vital to understanding, managing, and protecting natural resources. The Geologic Resources Inventory (GRI) helps make this connection by providing information on the role of geology and geologic resource management in parks.

Geologic resources for management consideration include both the processes that act upon the Earth and the features formed as a result of these processes. Geologic processes include: erosion and sedimentation; seismic, volcanic, and geothermal activity; glaciation, rockfalls, landslides, and shoreline change. Geologic features include mountains, canyons, natural arches and bridges, minerals, rocks, fossils, cave and karst systems, beaches, dunes, glaciers, volcanoes, and faults.

The Geologic Resources Inventory aims to raise awareness of geology and the role it plays in the environment, and to provide natural resource managers and staff, park planners, interpreters, researchers, and other NPS personnel with information that can help them make informed management decisions.

The GRI team, working closely with the Colorado State University (CSU) Department of Geosciences and a variety of other partners, provides more than 270 parks with a geologic scoping meeting, digital geologic-GIS map data, and a park-specific geologic report.

Products

Scoping Meetings: These park-specific meetings bring together local geologic experts and park staff to inventory and review available geologic data and discuss geologic resource management issues. A summary document is prepared for each meeting that identifies a plan to provide digital map data for the park.

Digital Geologic Maps: Digital geologic maps reproduce all aspects of traditional paper maps, including notes, legend, and cross sections. Bedrock, surficial, and special purpose maps such as coastal or geologic hazard maps may be used by the GRI to create digital Geographic Information Systems (GIS) data and meet park needs. These digital GIS data allow geologic information to be easily viewed and analyzed in conjunction with a wide range of other resource management information data.

For detailed information regarding GIS parameters such as data attribute field definitions, attribute field codes, value definitions, and rules that govern relationships found in the data, refer to the NPS Geology-GIS Data Model document available at: http://science.nature.nps.gov/im/inventory/geology/GeologyGISDataModel.cfm

Geologic Reports: Park-specific geologic reports identify geologic resource management issues as well as features and processes that are important to park ecosystems. In addition, these reports present a brief geologic history of the park and address specific properties of geologic units present in the park.

For a complete listing of Geologic Resource Inventory products and direct links to the download site visit the GRI publications webpage http://www.nature.nps.gov/geology/inventory/gre_publications.cfm

GRI geologic-GIS data is also available online at the NPS Data Store Search Application: http://nrinfo.nps.gov/Reference.mvc/Search. To find GRI data for a specific park or parks select the appropriate park
For more information about the Geologic Resources Inventory Program visit the GRI webpage: http://www.nature.nps.gov/geology/inventory, or contact:

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Mississippi National River and Recreation Area Location Map

Greater Minneapolis-St. Paul Seven County Area
Surficial Mapping

Surficial Geology Map Unit List

The surficial geologic units present in the GRI surficial (GRI Map Code of MISS) digital geologic-GIS data produced for National River and Recreation Area, Minnesota are listed below. Units are listed with their assigned unit symbol and unit name (e.g., Qe - Eolian sand) and are listed from youngest to oldest. The source map (M-178) provided no further geologic time divisions (e.g, late, early) for units.

Cenozoic Era

Quaternary Period

Hudson episode

- Qe - Eolian sand
- Qeo - Eolian sand dune
- Qi - Lacustrine deposits
- Qa - Floodplain alluvium
- Qp - Peat and muck
- Qf - Alluvial fan deposit
- Qc - Colluvium

Wisconsin episode

West Campus formation

- Qws - St. Mary’s terrace
- Qwg - Grey Cloud terrace
  - Qwz - Clay facies

- Qwl - Langdon terrace
  - Qwb - Boulder facies
  - Qwc - Clay facies
  - Qwn - Sand overlying yellowish to gray loamy till
  - Qwi - Sand overlying reddish silt and clay
  - Qwt - Sand overlying reddish sandy till

- Qwr - Richfield terrace
  - Qwd - Sand overlying yellowish to gray loamy till
  - Qwh - Sand overlying reddish sandy till
  - Qma - Sandy alluvium and slopewash
  - Qmc - Bedrock colluvium

Peoria Formation

- Qpl - Loess
- Qpe - Eolian sand

New Brighton formation

- Qbs - Sand facies
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Qbc - Silt and clay facies
Qbg - Sand and gravel facies
Qbt - Fine-grained sand overlying yellowish to gray loamy till

New Ulm formation

Qnl - Lake clay and silt
Qns - Lake sand
Qno - Outwash
Qni - Ice-contact stratified deposit
Qnt - Loamy till - low relief
Qnm - Loamy till - moderate relief
Qnh - Loamy till - high relief
Qnr - Loamy till in ridges
Qnc - Clayey till
Qna - Sandy till
Qnb - Low-shale till
Qnbm - Low-shale till underlain by Moland phase outwash sand and gravel
Qnd - Twin Cities member
Qne - Sheldon Creek member
Qnem - Sheldon Creek mbr underlain by Moland phase outwash sand and gravel

Cromwell formation

Qcl - Lake sand and silt
Qco - Outwash
Qci - Ice-contact stratified deposit
Qct - Till

Pre-Sangamon episodes, undivided

River Falls Formation

Qro - Outwash
Qrt - Till
Qrd - Complex of sand, gravel, and till

Pierce Formation

Opt - Till
Opc - Till, colluvium mantle
Qpg - Glaciofluvial deposits

Paleozoic Era

Ordovician Period

Ou - Ordovician bedrock, undivided
Opg - Platteville and Glenwood Formations
Osp - St. Peter Sandstone
Opc - Prairie du Chien Group
Ordovician and Cambrian Periods

**OCu** - Bedrock, undivided

Cambrian Period

**Cj** - Jordan Sandstone

**Cu** - Ironton and Galesville Sandstones and Eau Claire Formation, undivided

**Surficial Geology Map Unit Descriptions**

Information about each geologic unit is present below. No description for water is provided. Unit descriptions were derived from Minnesota Geological Survey Miscellaneous Map M-178. Additional unit information is also presented in the Geologic Unit Information (UNIT) table (missunit) included with the GRI geologic-GIS data. The reader is also referred to the M-178 source map section for additional information concerning the source surficial map and related ancillary source map figures and references.

**Quaternary Period**

**Qe** - Eolian Sand (Quaternary)

Very fine- to medium-grained sand; more than three feet (1 meter) thick; windblown. Generally forms low-lying dunes.

**Qeo** - Eolian Sand Dune (Quaternary)

Dune relief exceeds 30 feet (9 meters).

**Ql** - Lacustrine deposits (Quaternary)

Sand, loamy sand, and loam, with local organic-rich layers; includes human-made beaches. In places overlies muck or peat. Covered by thick, artificial fill in developed areas. Width of exposure varies depending on the water level in the lake. Many deposits along the edges of lakes and bogs are too narrow to be shown.

**Qp** - Peat and muck (Quaternary)

Partially decomposed plant matter deposited in marshes. Includes fine-grained organic matter laid down in ponded water, and marl (calcareous clay) at depth in places. Also includes narrow deposits of alluvium along streams, narrow beach deposits, and small bodies of open water. In developed areas, many of these deposits have been buried under artificial fill (Meyer, 1985; Meyer and Hobbs, 1989; Lusardi, 1999); the organic sediment is commonly removed prior to filling in areas where major structures are built.

**Qa** - Floodplain alluvium (Quaternary)

Sediment of modern rivers. Typically coarser-grained (sand and gravel) in the channels, and finer-grained (fine-grained sand and silt) on floodplains. Mississippi River alluvium above downtown St. Paul 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. Alluvium downstream from St. Paul and in the Minnesota River valley is generally finer-grained, consisting of a mixture of silt and clay with variable amounts of very fine-grained sand and organic matter. Coarser-grained sediment is present in places along the channel. Sand is chiefly present within the floodplain of the St. Croix and Vermillion Rivers, commonly overlain by about 5 feet (1.5 meters) of sandy loam to loamy sand, with interbeds of organic-rich layers; gravelly in some places. Alluvium of smaller streams is generally sandy but finer-grained than that of the larger streams, and is typically topped and interbedded with thin, organic-rich layers. Some depressions within the floodplains have been filled with thick silty to clayey sediment. Covered by thick artificial fill in developed areas. Contacts with other map units are commonly at the base of scarps.

**Qf - Alluvial fan deposit (Quaternary)**

Slopeswash sediment consisting of loam to loamy fine-grained sand, with beds of silt loam, silty clay loam, fine-grained sand, and gravel. Lithology reflects material upslope from which the sediment was derived. Unit contains variable amounts of disseminated organic debris. Deposited at the base of steep slopes and at the mouths of deep gullies.

**Qc - Colluvium (Quaternary)**

Reworked sediments on steep slopes, consisting of a variable, friable mixture of clay to boulders that resembles the upslope glacial or fluvial sediment from which it was derived. May contain disseminated organic debris. Includes till outcrops, small alluvial fans, and narrow bodies of alluvium.

**West Campus formation**

(Meyer, 1999; Meyer and Patterson, 1999; Meyer and Lusardi, 2000)—Fluvial sand and gravelly sand of mixed provenance. In general, shale clast content increases upstream and up-section. Coarsens to cobbly gravel in places. Laid down during early, higher stages of the Mississippi, Minnesota, and St. Croix Rivers, and preserved in terraces above the modern floodplain. During these early stages, the rivers served as outlet streams for retreating glacial ice lobes and various glacial lakes (Meyer, 1998). The West Campus formation is mapped at four major terrace levels. A pattern indicates areas where bedrock is generally within 10 feet (3 meters) of the surface. Boulder lags are common at the contact with bedrock.

**Qws - St. Mary’s terrace**

The terrace is 10 to 30 feet (3 to 9 meters) above floodplain level, rising from an elevation of about 700 feet (213 meters) at the east edge of the map to about 725 feet (221 meters) in the Minnesota River valley. Upstream from Belle Plaine the terrace merges with and is buried by the modern floodplain. It is not present in the Mississippi River valley above St. Anthony Falls in Minneapolis. Most contacts with other map units (except peat, unit Qp, and alluvium, unit Qa) are scarps. In part, bedrock is generally within 10 feet (3 meters) of the surface. Boulder lags are common at the contact with bedrock (see data layer: MISS - Geologic units overlying other known lithology (missgof) in the GRI geologic-GIS data).
**Qwg - Grey Cloud Terrace**

(Matsch, 1962) — The terrace ranges from about 50 to 80 feet (15 to 24 meters) above floodplain level, ranging in elevation from about 740 feet (216 meters) at the southeast edge of the map to about 770 feet (235 meters) at Belle Plaine to the west and at the north edge of the map in the St. Croix River valley. The terrace is not present in the Mississippi River valley north of St. Anthony Falls. Most contacts with other map units (except peat, unit Qp) are scarps.

**Qwz - Clay facies (Quaternary)**

Slackwater sediment deposited at the Grey Cloud terrace level in downtown St. Paul in what was likely an abandoned waterfall plunge-pool. The clay overlies boulders in places.

**Qwl - Langdon terrace**

(Matsch, 1962) — This terrace has two distinct surfaces separated by a scarp in the St. Croix and lower Mississippi River valleys. Upstream along the Mississippi and Minnesota Rivers, the upper surface is a broad terrace cut by anastomosing channels whose bottoms are at the lower surface. Below St. Anthony Falls, the lower surface is about 90 to 110 feet (27 to 34 meters) above floodplain level, rising in elevation from about 770 feet (235 meters) near the southeast edge of the map to about 800 feet (244 meters) at Shakopee and Marine on St. Croix. The upper surface is about 120 to 150 feet (37 to 46 meters) above floodplain level, ranging in elevation from about 800 feet (244 meters) at Belle Plaine to 840 feet (256 meters) near the southeast edge of the map area to 840 feet (256 meters) at Belle Plaine, and up to 880 feet (268 meters) at the northwest edge of the map. A scarp symbol separates the two surfaces. Most contacts with other map units (except peat, unit Qp) are also scarps. North of St. Anthony Falls the Langdon terrace is only about 10 to 40 feet (3 to 12 meters) above the modern floodplain.

**Qwb - Boulder facies (Quaternary)**

Many boulders and large limestone blocks mixed with silty sand and gravel, deposited at the Langdon terrace level.

**Qwc - Clay facies (Quaternary)**

Primarily soft, silty clay to clay, but commonly includes beds and laminae of clayey silt and silt, and fine-grained sand seams. Silt and organic content generally increase upwards. Commonly covered by 5 feet (1.5 meters) or more of artificial fill. The area mapped near downtown Minneapolis is deepwater lake sediment deposited in an ice-block melt-out lake (Lake Bassett; Meyer, 1996) connected to the Mississippi River when it flowed at the Langdon terrace level. The deposit in southeastern Minneapolis is thinner, generally less than 10 feet (3 meters) thick, and is likely more discontinuous than mapped.

**Qwn - Sand overlying yellowish to gray loamy till (Quaternary)**

Sand and gravelly sand generally less than 10 feet (3 meters) thick over till of the New Ulm formation. Boulder lags are common at the contact.
Qwi - Sand overlying reddish silt and clay (Quaternary)

Sand and gravelly sand generally less than 10 feet (3 meters) thick over lacustrine silt and clay of the Sunrise member of the Cromwell formation (Glacial Lake Lind deposits).

Qwt - Sand overlying reddish sandy till (Quaternary)

Sand and gravelly sand generally less than 10 feet (3 meters) thick over till of the Cromwell formation. Boulder lags are common at the contact.

Qwr - Richfield terrace (Quaternary)

(Meyer and Jirsa, 1982) — This terrace has two distinct surfaces within the St. Croix River valley. Most of the Richfield terrace south of Stillwater, at an elevation of about 870 feet (265 meters), is interpreted to have formed following drainage of Glacial Lake Anoka (Meyer, 1998). All the mapped areas of Richfield terrace north of Stillwater, and a small area west of Lakeland, were formed prior to drainage of the lake when the St. Croix River served as the outlet stream of Glacial Lake Anoka (and possibly even earlier, by the drainage of Glacial Lake Grantsburg). This upper surface rises in elevation from about 885 feet (270 meters) near Lakeland to 900 feet (274 meters) toward the north edge of the map, about 190 to 220 feet (58 to 67 meters) above the modern floodplain. The terrace within the Minnesota River valley and along the Mississippi River below St. Anthony Falls is about 160 feet (49 meters) above floodplain level, ranging in elevation from about 840 feet (256 meters) northwest of Hastings to about 880 feet at the west edge of the map. The terrace is not recognized south of Hastings, where it merges with the level of the Mississippi River valley train (Hobbs, 1999). North of St. Anthony Falls the terrace ranges from 40 to 70 feet (12 to 21 meters) above the modern floodplain, ranging in elevation from about 850 feet (259 meters) to 910 feet (277 meters) at the northwest edge of the map. This portion is younger than, and inset into, deposits of Glacial Lake Anoka. Most contacts with other map units are scarps. In part, bedrock is generally within 10 feet (3 meters) of the surface. Boulder lags are common at the contact with bedrock.

Qwd - Sand overlying yellowish to gray loamy till (Quaternary)

Sand and gravelly sand generally less than 10 feet (3 meters) thick over till of the New Ulm formation. Boulder lags are common at the contact.

Qwh - Sand overlying reddish sandy till (Quaternary)

Sand and gravelly sand generally less than 10 feet (3 meters) thick over till of the Cromwell formation. Boulder lags are common at the contact.

Qma - Sandy alluvium and slopewash (Quaternary)

Sand and gravelly or loamy sand; deposited in valleys and gently sloping plains above the level of outwash plains. Deposited as a response to a rising base level, as the Mississippi River and its tributaries were filling with outwash. Sediment was derived from adjacent uplands, which were eroding in response to reduced vegetation during the Michigan Subepisode. Pebble assemblage is a mixture of local bedrock fragments from valley walls and erratics derived from old glacial sediments on the uplands. Water was supplied by precipitation rather than melting of glacial ice. Commonly stands above modern floodplains as terraces, but also underlies modern alluvium in the same valleys. Where this unit merges downslope with outwash, commonly
includes fine-grained slackwater sediment near the junction.

**Qmc - Bedrock colluvium (Quaternary)**

Angular, unsorted fragments of local bedrock, commonly overlain by massive to crudely bedded silt that contains a few angular rock clasts. Rock fragments were derived by mechanical weathering from the hillslopes above; silt was deposited as mudflow and slopewash from loess on the uplands. Deposited chiefly at the foot of steep bedrock slopes; the thickness of both units typically diminishes upslope. Generally mapped to the top of the steep slopes; in the upper parts of the slopes, both layers are thin and bedrock outcrops are common.

**Peoria formation**

(Peoria Silt of Hansel and Johnson, 1996) — Eolian sediment. Eroded by wind from outwash surfaces and older till surfaces, transported and deposited generally southeast of its source areas. Mapped as a stipple pattern only where thicker than 5 feet (1.5 meters), but thin, unmapped Peoria Formation overlies much of the southeast portion of the map area. Loess is the predominant facies of this formation.

**Qpl - Loess (Quaternary)**

Chiefly silt, but includes minor amounts of very fine-grained sand and clay. The latter was probably deposited as silt-sized aggregates. Underlain and interbedded with eolian sand in places.

**Qpe - Eolian sand (Quaternary)**

Fine- to medium-grained; lacks gravel; unbedded.

**New Brighton formation**

(Meyer and Patterson, 1999) — Mostly fine-grained sand, laid down in Glacial Lake Anoka.

**Qbs - Sand facies (Quaternary)**

Very fine- to medium-grained sand; silty in places; scattered lenses of silt to silty clay at depth. Gravelly sand occurs locally where adjacent to glacial or fluvial sediment. The surface has been modified in places by fluvial processes during drainage of Glacial Lake Anoka. The upper few feet (1 meter) of sand has commonly been reworked by wind action.

**Qbc - Silt and clay facies (Quaternary)**

Silt and clay; interbedded with fine-grained sand in places; locally rhythmically bedded; rare dropstones. Deposited in deeper, quiet water of Glacial Lake Anoka.

**Qbg - Sand and gravel facies (Quaternary)**

Medium- to coarse-grained sand to fine-grained gravel. May overlie coarser-grained fluvial sediment of the New Ulm or Cromwell formations. Deposited in deltaic or shallow-water
environments in Glacial Lake Anoka.

**Qbt - Fine-grained sand overlying yellowish to gray loamy till (Quaternary)**

Till of the New Ulm Formation beneath as much as 20 feet (6 meters) of lake sand. Mapped only in Ramsey and southeastern Anoka Counties.

**New Ulm formation**

(Meyer and Patterson, 1999)—Glacial, fluval, and lacustrine sediment of Riding Mountain provenance deposited by ice and meltwater of the last glacial advance into the area—the Des Moines lobe and its Grantsburg sublobe.

**Qnl - Lake clay and silt (Quaternary)**

Laminated clay to silt; generally less than 15 feet (5 meters) thick. Deposited in small, ice-walled lakes, whose bottoms now rest on top of broad plateaus. Includes a few deposits laid down in depressions created during the final stages of ice-block melt-out. Thin beds of silty, fine-grained sand to gravelly sand occur at boundaries and at or near the base in places.

**Qns - Lake sand (Quaternary)**

Very fine- to fine-grained sand and silty sand, with minor interbeds of silt and medium-grained sand. Capped in places by sandy silt. Coarse-grained, gravelly sand occurs locally along boundaries and at or near the base. Deposited in ponded water in depressions between the margin of the Grantsburg sublobe and the stagnant ice-cored St. Croix moraine, and in small, ice-walled lakes.

**Qno - Outwash (Quaternary)**

Sand, gravelly sand, and gravel. Deposited by meltwater issuing from the ice margin. Includes in the eastern portion of the map area abundant clasts of Superior provenance eroded from older sediment. Shale content generally increases from east to west across the map area (Meyer and Mossler, 1999). The upper few feet (1 meter) have been reworked in many places by wind action. Commonly capped by a mantle of wind-blown silt (loess) less than 4 feet (1 meter) thick. Commonly bounded by scarps where laid down in channels.

**Qni - Ice-contact stratified deposit (Quaternary)**

Sand, gravelly sand, and cobbly gravel. Deposited by meltwater flowing at or behind the ice margin. Sediment can be quite variable and is typically faulted and folded. Commonly includes interbeds of, and in places is capped by, sandy to loamy diamicton (mudflow sediment) and silt (lake sediment). Boulders are present in some deposits. In general, Superior provenance clasts decrease and shale clasts increase from east to west and from north to south across the map area. Many of the deposits toward the north and east consist largely of reworked Superior provenance sediment. Typically forms hills and ridges.
Qnt - Loamy till - low relief (Quaternary)

Chiefly loam-textured, unsorted sediment (diamicton); pebbly, with scattered cobbles and rare boulders. Shale clasts generally compose from 25 to 40 percent of the very coarse-grained (1-2 millimeters) sand fraction. Lenses of stratified sediment are uncommon in most areas. Overlain in some small, low-lying areas by 3 feet (1 meter) or more of loamy to clayey, organic-bearing colluvium. The till deposits form a low, undulating topography with widely-spaced, circular, flattopped hills, with an overall relief of about 10 to 30 feet (3 to 9 meters). Commonly water-washed and overlain in places by a few feet (meter) of lacustrine, fluvial, or eolian sand in the vicinity of sand deposits, within the Glacial Lake Anoka basin, and within areas bounded by scarps.

Qnm - Loamy till - moderate relief (Quaternary)

Till as above; deposits generally form round or elliptical hills with an overall relief of about 40 to 70 feet (12 to 21 meters).

Qnh - Loamy till - high relief (Quaternary)

Till as above; deposits form hummocky, irregular topography that includes poorly developed, circular, flat-topped hills and many collapsed channels. Overall relief is about 60 to 100 feet (18 to 30 meters).

Qnr - Loamy till in ridges (Quaternary)

Till as above, forming linear ridges and valleys interpreted to be inactive slump blocks; 10 to 30 feet (3 to 9 meters) of relief. Slumping probably occurred when the valley wall was undercut during river flow at the Grey Cloud terrace level.

Qnc - Clayey till (Quaternary)

Chiefly clay loam-textured, unsorted sediment (diamicton); pebbly, with scattered cobbles and rare boulders. Abundant shale clasts, generally composing more than 50 percent of the very coarse-grained (1-2 millimeters) sand fraction. Pockets of silt, sand, and gravel in places.

Qnb - Low-shale till (Quaternary)

Chiefly coarse-loam-textured, unsorted sediment (diamicton), pebbly, with cobbles and boulders; generally less than 25 percent shale in the very coarse grained (1-2 millimeters) sand fraction. Inclusions of reddish-brown sediment indicate that the coarser-grained texture and low shale content is likely due to dilution with Superior provenance sediment, which occurred when the advancing Des Moines lobe incorporated sediment of the underlying Cromwell and River Falls formations. Only mapped south of the Minnesota River valley.

Qna - Sandy till (Quaternary)

Loam- to sandy loam-textured, unsorted sediment (diamicton), pebbly, with cobbles and boulders; commonly capped by, or interbedded with, thin deposits of silty to gravelly stratified sediment. Includes complex deposits of thick sand and gravel too small to distinguish on the map from adjacent till bodies. Large bodies of sand and gravel are present at depth in places. The unit is commonly less than 20 feet (6 meters) thick over Cromwell formation deposits, with
an intervening layer of the Twin Cities member.

**Qnbm - Low-shale till underlain by Moland phase outwash sand and gravel (Quaternary)**

Patterned area is underlain by Moland phase outwash sand and gravel (Patterson and Hobbs, 1995).

**Qnd - Twin Cities member (Quaternary)**

(Meyer and Patterson, 1999) — Complexly intermixed yellowish-brown to gray and reddish-brown to reddish-gray, loam- to sandy loam-textured unsorted sediment (diamiction); pebbly, with cobbles and boulders. This mixture of both Riding Mountain and Superior provenance sediment formed by the erosion and incorporation of Cromwell and River Falls formation material by the overriding ice of the Des Moines lobe and the Grantsburg sublobe. Small lenses of stratified sediment are common in many areas. Covered in places by as much as 20 feet (6 meters) of the loamy till facies of the New Ulm formation. Cromwell formation deposits are commonly within 20 feet (6 meters) of the surface. Where topography is steeply rolling or gullied, Cromwell formation deposits are locally at or very near the surface. Commonly water-washed and overlain in places by a few feet (1 meter) of lacustrine, fluvial, or eolian sand in the vicinity of sand deposits, within the Glacial Lake Anoka basin, and within areas bounded by scarps.

**Qne - Sheldon Creek member (Quaternary)**

Loam- to sandy loam-textured, unsorted sediment (diamiction), with pebbles and scattered cobbles and boulders; deposited by the Des Moines lobe during the Moland phase. Correlated with the Sheldon Creek Formation of Iowa (Bettis and others, 1996; Bettis, 1997). Composition of the till north of Chub Creek near Randolph is similar to that of the Twin Cities member. Generally less than 10 feet (3 meters) thick over older sediment, mantling pre-existing landforms.

**Qnem - Sheldon Creek member underlain by Moland phase outwash sand and gravel (Quaternary)**

Underlain by Moland phase outwash sand and gravel.

**Cromwell formation**

Cromwell formation (Meyer, 1999)—Glacial, fluvial, and lacustrine sediment of Superior provenance, deposited by the Superior lobe and its meltwater. Where mapped within or in the vicinity of New Ulm formation deposits, Cromwell formation deposits are commonly reworked at the top (by the overriding Des Moines lobe and Grantsburg sublobe) and mantled in places by generally less than 10 feet (3 meters) of younger deposits.

**Qcl - Lake sand and silt (Quaternary)**

Silt to medium-grained sand; interbeds and lenses of silty clay to gravelly sand, including sandy diamicton (mudflow sediment), and scattered dropstones. Rhythmically layered in places. Thick silty to clayey sediments dominate the center of the more extensive deposits. Primarily deposited in ice-walled lakes following ice stagnation. Coarse-grained sand and gravel occurs locally along edges of the ice-walled lake plains. Also includes silty sediment in pitted outwash
plains, where the sediment commonly consists largely of loess washed into ponds formed in ice-block melt-out depressions.

**Qco - Outwash (Quaternary)**

Sand, gravelly sand, and gravel. Cobbly in places, especially near till and ice-contact deposits. Commonly overlain by 2 to 5 feet (0.6 to 1.5 meters) of loess. Laid down by meltwater issuing from the ice margin. The surface of the outwash is irregular in most places behind the maximum margin (Emerald phase) of the Superior lobe, due to the melting of underlying buried ice-blocks following deposition of the sand and gravel.

**Qct - Till (Quaternary)**

Chiefly sandy loam-textured, unsorted sediment (diamicton), with pebbles, cobbles, and boulders; silty sand to cobbly gravel lenses are commonly present. Most of this unit is part of the St. Croix moraine, laid down at the terminus of the St. Croix phase of the Superior lobe, consisting largely of thick, supraglacial sediment deposited as knobs and kettles. Beyond the St. Croix phase margin the unit is thinner, generally lacking the well-developed, hummocky topography. Where beyond the margin of the Grantsburg sublobe, the till is commonly overlain by 2 to 5 feet (0.6 to 1.5 meters) of loess. Commonly water-washed and overlain in places by a few feet (1 meter) of fluvial or lacustrine sand in the vicinity of sand deposits. Includes small areas of thick, loamy to sandy colluvium in depressions.

**Qci - Ice-contact stratified deposit (Quaternary)**

Sand, gravelly sand, and cobbly gravel; deposited by meltwater flowing at or behind the ice margin. Commonly includes interbeds of, and in places is capped by sandy to loamy diamicton (mudflow sediment) and silt (lake sediment). Some deposits contain boulders. Many of the ice-contact deposits were laid down in coalescing fans at the mouths of tunnel valleys at the glacial ice margin, or as deltas in ice-walled lakes. Other deposits (eskers) were laid down along the courses of subglacial streams. After the ice melts, these deposits generally stand as positive features.

**River Falls Formation**

(Mickelson and others, 1984)—Glacial and glaciofluvial deposits of Superior provenance. The upper part contains a truncated paleosol in places, indicating deposition prior to the Michigan sub-episode.

**Qro - Outwash (Quaternary)**

Sand, gravelly sand, and gravel. Strongly weathered from the top to a depth of about 10 feet (3 meters); contains some carbonate clasts below the leached zone; many coarse-grained fragments break apart easily; clasts coated with reddish clay occur in the upper part of the deposit.

**Qrt - Till (Quaternary)**

Chiefly sandy loam- to sandy clay loam-textured, unsorted sediment (diamicton), with pebbles, cobbles, and boulders. Interbedded in places with sorted sand and gravel. Deeply leached but calcareous below the leaching zone. Not mapped as a separate unit south of the Mississippi
River. Preserved as patches on a stream-dissected landscape.

**Qrd - Complex of sand, gravel, and till (Quaternary)**

Sand and gravel with cobbles (ice-contact stratified sediment), and sandy loam- to sandy clay loam-textured till, undivided. Till is only a minor component in most places. Hillier and higher than nearby outwash unit Qro.

**Pierce Formation**

(Mickelson and others, 1984)—Glacial and glaciofluvial deposits of Winnipeg provenance. Represents deposits of four or more glacial advances, undivided. Most of the Pierce Formation underlies the River Falls Formation, but the uppermost till of the Pierce Formation may be contemporary with the River Falls Formation.

**Qpt - Till (Quaternary)**

Chiefly firm, loam- to clay loam-textured, unsorted sediment (diamicton), pebbly, with cobbles and rare boulders. Contains lenses of sorted sand and gravel in places. Originally gray and calcareous, but the surface is highly oxidized and deeply leached in places. Exhibits stream-dissected topography with no closed depressions.

**Qpc - Till, colluvium mantle (Quaternary)**

Till as above, distinguished from unit Qc where the till is extensively exposed along the steep slopes of the Minnesota River valley. In places the unit is overlain by Superior provenance sediment that may be equivalent to the River Falls Formation, and by sandy-textured till, which may be equivalent to the "Wadena" till of central Minnesota (Meyer and Knaeble, 1996).

**Qpg - Glaciofluvial deposits (Quaternary)**

Sorted sediment ranging from fine-grained sand to coarse-grained gravel. Most commonly a mixture of sand and gravel. Strongly weathered from the top to a depth of about 10 feet (3 meters); contains many carbonate clasts below the leached zone; many coarse-grained fragments break easily; many clasts are coated with brown clay. Occurs as eroded remnants of ice-contact stratified deposits and outwash, undivided. In places, covered by a layer of till less than 5 feet (1.5 meters) thick. Some deposits may include material of Superior provenance.

**Ordovician Period**

**Ou - Bedrock, undivided (Ordovician)**

Rock at and near the surface; Ordovician bedrock units exposed on steep slopes include: the St. Peter Sandstone, Glenwood and Platteville Formations, and at the border of Ramsey and Dakota Counties, the Decorah Shale. Too narrow to map individual units. Discontinuously exposed, with a sandy to rocky mantle generally less than 5 feet (1.5 meters) thick.
Opg - Platteville and Glenwood Formations (Ordovician)

Fine-grained dolostone and limestone of the Platteville Formation is overlain by green, sandy shale of the Glenwood Formation. The Glenwood Formation is thin and easily eroded, so its outcrop area is insignificant compared to that of the Platteville Formation. Discontinuously exposed, with a loamy to rocky mantle less than 5 feet (1.5 meters) thick.

Osp - St. Peter Sandstone (Ordovician)

Massive, very fine- to medium-grained quartzose sandstone. Interbedded with siltstone and shale in its lower part. Discontinuously exposed, with a commonly sandy mantle less than 5 feet (1.5 meters) thick.

Opc - Prairie du Chien Group (Ordovician)

Oolitic sandy dolostone and sandstone of the Shakopee Formation overlies massive dolostone of the Oneota Dolomite; sandy transitional zone at the base. Discontinuously exposed, with a sandy to rocky mantle generally less than 5 feet (1.5 meters) thick. Most areas of this unit mapped within the major river valleys are quarries.

* The Prairie du Chien Group is also included in the unit OCu (Bedrock, undivided), and thus in some areas of the map the unit is mapped with other units.

Ordovician and Cambrian Period

OCu - Bedrock, undivided (Ordovician and Cambrian)

Outcrops and near-surface Cambrian and Ordovician bedrock on steep slopes; not practical to map individual units. Ranges from the Prairie du Chien Group to the Jordan Sandstone, St. Lawrence and Franconia Formations. Discontinuously exposed, with a sandy to rocky mantle generally less than 5 feet (1.5 meters) thick.

* In some areas of the map the Jordan Formation is also mapped as its own unit (Cj), as are the St. Lawrence and Franconia Formations (mapped with Cu), and the Prairie du Chien Group (mapped as Opc). This unit also somewhat differs from the unit with the same unit symbol and name (i.e., Cu - Cambrian rocks, undivided) present in the GRI surficial (MISS) digital geologic-GIS data. Basically, the formations that are considered components of each unit don't fully agree, and thus may reflect a difference in geologic interpretation between the two source maps.

Cambrian Period

Cj - Jordan Sandstone (Cambrian)

Medium- to coarse-grained, friable, cross-bedded sandstone. Discontinuously exposed, with a commonly sandy mantle generally less than 5 feet (1.5 meters) thick.

* The Jordan Sandstone is also included in the unit Cu (Cambrian rocks, undivided), and in the unit OCu (Bedrock, undivided), and thus in some areas of the map the unit is mapped with other units.
**Cu - Cambrian rocks, undivided (Cambrian)**

Quartzose sandstone, feldspathic to glauconitic sandstone and siltstone, and dolomitic siltstone (Jordan Sandstone, St. Lawrence and Franconia Formations). Discontinuously exposed, with a sandy to rocky mantle generally less than 5 feet (1.5 meters) thick.

* In some areas of the map the Jordan Formation is also mapped as its own unit (Cj), as are the St. Lawrence and Franconia Formations (mapped with OCu). This unit also somewhat differs from the unit with the same unit symbol and name (i.e., Cu - Cambrian rocks, undivided) present in the GRI bedrock (MSBR) digital geologic-GIS data. Basically, the formations that are considered components of each unit don't fully agree, and thus may reflect a difference in geologic interpretation between the two source maps.

**GRI Surficial Map Sources and their Ancillary Information**

The GRI digital surficial geologic-GIS map (GRI Map Code of MISS) for Mississippi National River and Recreation Area, Minnesota (MISS) was compiled from the following sources,


Additionally, the following sources were used to enhance the richness of available datasets from M-178:

Mining features (refer to the Mine Features (missmin) data layer in the GRI digital geologic-GIS data) were derived from the [agptsg.e00] ARC export file that accompanied the following report,


Karst features (refer to the Karst Features (misshzp) data layer in the GRI digital geologic-GIS data) were derived from,


Additional information pertaining to each source map is also presented in the Source Map Information (MAP) table (missmap) included with the GRI geology-GIS data.
Stratigraphic Correlation Chart

Adapted from source map: M-178
Source Map Symbols

Geologic contact—Approximately located.

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

Stream-cut scarp—Hachures point downslope; 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 surfaces on the hachured side of scarps are fluviually scoured and mantled in places by sand and gravel too thin and patchy to map separately.

Linear feature—Identified from aerial photographs. Symbol schematically represents the ridge-and-valley topography of slump blocks within map unit Qnr.

Approximate shorelines of Glacial Lake Anoka—The maximum extent of the lake is difficult to determine, because in many places it was likely ponded against landforms created by buried stagnant ice. The ice-cored landscape was lowered when this ice melted. Till of the New Ulm formation within the mapped shorelines of Glacial Lake Anoka has been wave-washed and covered in places with thin beds of silt, sand, or gravel. The till in some of these areas has subsequently collapsed due to melt-out of underlying ice. Some of the collapsed till areas now lower in elevation than adjacent areas of New Brighton formation sediment were likely islands or peninsulas in Glacial Lake Anoka.

Fridley level—About 915 feet (274 meters) above mean sea level.

Hugo level—About 940 feet (287 meters) above mean sea level.

Maximum extent—About 960 feet (293 meters) above mean sea level where mapped along the eastern shore.

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). Predominant 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.

Esker—A sinuous ridge of sand and gravel, interpreted to have been deposited in an ice-walled channel of a glacial meltwater stream flowing at the base of the ice. The fluviial sediment may be covered by 10 feet (3 meters) or more of till, especially in areas where the New Ulm formation is the surficial unit. Arrows show the inferred flow direction.

Broad, irregular trough—Hachures point downslope; identified by alignment of depressions and lakes. Symbol likely marks collapsed and filled channels. Many of these troughs are interpreted to reflect valleys cut by meltwater flowing beneath Superior lobe ice that were partially buried by subsequent glacial events. Drainage channels beneath the Superior lobe ice locally eroded deeply into the substrate, exploiting pre-existing bedrock valleys in places. These tunnel valleys in places were likely reoccupied by proglacial meltwater of both the receding Superior lobe and the advancing Des Moines lobe.

Ice-marginal ridge of Superior lobe ice—Teeth are on the up-ice side.

Inferred ice margin—Approximate maximum extent of an ice advance; labels are on the up-ice side of the margin.

St. Croix phase (Wright, 1972)—Marks the outside margin of the St. Croix Moraine. Most of the deposits of the Cromwell Formation mapped at the surface in the metropolitan area were deposited by this advance of the Superior lobe during the Michigan subepisode.

Emerald phase (Johnson and Mooers, 1998)—This most extensive advance of the Superior lobe during the Michigan subepisode deposited outwash and till of the Cromwell formation. Till is only patchily preserved between this margin and the St. Croix moraine because of subsequent erosion and burial by outwash of the St. Croix phase.

Pre-Michigan advance—Inferred extent of ice that deposited the River Falls Formation.

Extracted from source map: M-178
Surficial Geology Source Index Map

Sources used by the Minnesota Geological Survey to compile the M-178 map are listed below and referenced to the accompanying map.

Extracted from source map: M-178

Source References

The map above shows the location of previous mapping in the study area. Citations 1 through 10 in the references were used to compile the geology of the map area. An updated version of the Hennepin County soil survey (Steffen, 2004), logs of recently located water wells and soil borings, and unpublished studies by the Minnesota Geological Survey were also used to compile the surficial geology. The thin white strip along the west edge of Carver County was newly mapped for this project.


(3)— — — 2001b, Surficial geologic map of the Watertown quadrangle, Carver, Hennepin, and Wright Counties, Minnesota: Minnesota Geological Survey Miscellaneous Map M-108, scale 1:24,000.

(4)— — — 2002b, Surficial geology of the Elk River quadrangle, Sherburne, Wright, and Anoka Counties, Minnesota: Minnesota Geological Survey Miscellaneous Map M-124, scale 1:24,000.


(6)— — — 2003b, Surficial geology of the Lake Fremont quadrangle, Sherburne, Isanti, and Anoka
Counties, east-central Minnesota: Minnesota Geological Survey Miscellaneous Map M-134, scale 1:24,000.


Extracted from source map: M-178
Bedrock Mapping

Bedrock Geology Map Unit List

The bedrock geologic units present in the GRI (*GRI Map Code of MSBR*) bedrock digital geologic-GIS data produced for National River and Recreation Area, Minnesota are listed below. Units are listed with their assigned unit symbol and unit name (e.g., Cj - Jordan Sandstone) and are listed from youngest to oldest. Further divisions of geologic time (e.g., Upper, Lower, Early) are provided in parentheses at the end of a unit name if present on the source map (*M-104*).

**Mesozoic Era**

**Cretaceous Period**

- **Ku** - Cretaceous, undivided (Upper Cretaceous)

**Paleozoic Era**

**Ordovician Period**

- **Od** - Decorah Shale and Cummingsville Formation, undivided (Upper Ordovician)
- **Opg** - Platteville Formation and Glenwood Formation, undivided (Upper Ordovician)
- **Osp** - St. Peter Sandstone (Upper Ordovician)
- **Opc** - Prairie du Chien Group (Lower Ordovician)

**Cambrian Period**

- **Cj** - Jordan Sandstone (Late Cambrian)
- **Csf** - St. Lawrence Formation and Franconia Formation, undivided (Upper Cambrian)
- **Cu** - Cambrian rocks, undivided (Upper Cambrian)
- **Cig** - Ironton Sandstone and Galesville Sandstone, undivided (Upper Cambrian)
- **Cec** - Eau Claire Formation (Upper Cambrian)
- **Cms** - Mt. Simon Sandstone (Upper Cambrian)

**Mesoproterozoic Era**

- **Y** - Solor Church Formation

Bedrock Geology Map Unit Descriptions

Information about each geologic unit is present below. No description for water is provided. Unit descriptions were derived from Minnesota Geological Survey Miscellaneous Map *M-104*. Additional unit information is also present in the Geologic Unit Information (UNIT) table (msbrunit) included with the GRI geologic-GIS data. The reader is also referred to the *M-104* source map section for additional information concerning the source bedrock maps and related ancillary source map figures and references.
Cretaceous Period

Ku - Cretaceous, undivided (Upper Cretaceous)

Sandstone, white to light-gray, very fine grained to fine-grained; interlayered with white to gray shale beds. Generally less than 30 feet thick. The only mapped occurrence of this unit is in T. 115 N., R. 26 W.

Ordovician Period

Od - Decorah Shale and Cummingsville Fm, undivided (Upper Ordovician)

The Decorah Shale consists of green-gray calcareous shale and lesser amounts of thin-bedded, light-gray limestone. The uppermost limestone bed, marking the top of the formation, contains ferruginous oolites. The Decorah contains abundant fossils, particularly bryozoans, ostracodes, and brachiopods.

The Cummingsville Formation of the Galena Group consists of fine-grained, light-gray, fossiliferous, thin- to medium-bedded limestone and some interbedded green-gray shale. It occurs as patchy remnants less than 20 feet thick that overlie the Decorah Shale. The Decorah crops out in bluffs along the Mississippi River in south and west St. Paul. It may be as much as 90 feet thick but generally occurs as thinner erosional remnants. The Cummingsville crops out in south St. Paul.

Opg - Platteville Fm and Glenwood Fm, undivided (Upper Ordovician)

The Platteville Formation is fine-grained, light-gray to yellowish-gray, very thin bedded to thick-bedded, fossiliferous limestone and dolostone; unit thickness is greater than 30 feet; thin gray-green shale beds in upper few feet. Dolostone in basal one to two feet, contains sand-sized quartz and collophane (phosphate) grains. The Platteville Formation is exposed in bluffs along the Mississippi River in Minneapolis and St. Paul and caps mesas in southeastern Dakota County and southern Washington County.

The Glenwood Formation is principally gray-green blocky shale that contains sand-size grains of collophane (phosphate) and thin stringers of fine- to coarse-grained quartz sandstone; unit is as thick as 10 feet in southern Dakota County. It is exposed in bluffs along the Mississippi River in Minneapolis and St. Paul beneath the Platteville Formation.

Osp - St. Peter Sandstone (Upper Ordovician)

The St. Peter is divisible into three lithofacies:

The upper sandstone lithofacies (approximately 100 feet thick) is light-gray, mostly very fine grained to medium-grained quartz sandstone in sedimentation units that coarsen upward. The rock is poorly cemented, lacks well-defined bedding, and generally is massive to thick bedded, but it may be subtly cross-stratified, particularly in the upper part. The shale and siltstone lithofacies is a laterally extensive layer of gray-green shale and siltstone about 6 feet thick; it occurs at slightly below the stratigraphic midpoint of the formation.

The lower sandstone lithofacies (30–60 feet thick) is poorly sorted, fine-grained to very coarse-grained, well-cemented sandstone interlayered with multicolored beds of mudstone, siltstone, and shale. The sandstone beds become progressively finer grained upwards. The contact
between the St. Peter and the underlying Prairie du Chien Group is a disconformity that has significant vertical relief. The St. Peter Sandstone crops out along the lower reaches of bluffs of the Mississippi River in Minneapolis and St. Paul. It is also commonly exposed in sideslopes of mesas capped by the Platteville Formation in Washington and Dakota Counties. The formation is 128 to more than 166 feet thick. It is thinnest in southern Dakota County in the southeastern part of the metropolitan area.

The shale and siltstone lithofacies is not exposed but is well documented in the subsurface.

**Opc - Prairie du Chien Group (Lower Ordovician)**

Dominantly dolostone interlayered with lesser amounts of quartz sandstone. The group is divided into two formations (Shakopee Formation and Oneota Dolomite) that are not separated on this map.

The Shakopee Formation is light-brown to pale-yellow-brown, thin- to medium-bedded dolostone, interlayered with thin beds of fine- to medium-grained quartz sandstone and green-gray shale. The dolostone contains stromatolite layers and locally fossiliferous chert nodules. The Shakopee Formation is separated from the underlying Oneota Dolomite by a disconformity.

The Oneota Dolomite is light-brown to grayish-orange, medium- to thick-bedded dolostone. Commonly oolitic or sandy in the lower 12–13 feet, although this basal sandy layer is missing in some places of eastern Washington County and northeastern Dakota County. The upper part of the Prairie du Chien where exposed at the bedrock surface is rubbly and contains karst solution features. In eastern Dakota and southern Washington Counties, Prairie du Chien dolostone is exposed along river bluffs, in quarries, and in many flat, low outcrops where bedrock is near the land surface. The Prairie du Chien also is exposed along low bedrock terraces of the Minnesota River in northeastern Scott County. It is as thick as 308 feet in southeastern Dakota County but thinner in the northwestern part of Hennepin County, where it was removed before deposition of overlying St. Peter Sandstone. The Prairie du Chien also thins significantly beneath the St. Peter Sandstone in northern Washington County.

**Cambrian Period**

**Cj - Jordan Sandstone (Late Cambrian)**

Dominantly light-gray sandstone; includes numerous coarsening-upward sequences consisting of two interlayered facies. The two facies are not portrayed separately on the map. They are (1) medium- to coarse-grained, cross-bedded, generally friable quartz sandstone and (2) very fine grained, structureless, commonly bioturbated feldspathic sandstone and lenses of siltstone and shale. Some calcite, mostly as nodular concretions, is present near the top of the formation. The Jordan is 66–125 feet thick in the metropolitan area. Jordan Sandstone is exposed along the Mississippi River in Washington and northeastern Dakota Counties, along the St. Croix River in Washington County, and along the Minnesota River in northwestern Scott County.

* Small outliers of this unit maybe included in the unit **Cu** (Cambrian rocks, undivided), and thus in some areas of the map the unit is mapped with other units.
**Csf - St. Lawrence Fm and Franconia Fm, undivided (Upper Cambrian)**

Varially colored red-brown to gray-green or light-gray dolomitic shale, siltstone, and dolostone that overlie fine- to coarse-grained quartz sandstone, very fine grained to fine-grained glauconitic sandstone, and fine-grained nonglaucotic sandstone, dolostone, siltstone, and shale.

The St. Lawrence Formation is composed of silty, very finely crystalline, generally thin bedded, tan to pink dolostone, interlayered with thin intervals of siltstone or, rarely, beds of very fine grained glauconitic sandstone or maroon to green shale. The formation is fossiliferous and contains trilobites and graptolites. In Scott and Carver Counties, the St. Lawrence is as much as 75 feet thick; thickness decreases to 34–59 feet in Ramsey and Washington Counties. It is exposed along steep tributary valleys in the St. Croix valley, mainly by waterfalls. A few small outcrops are present in St. Lawrence Township (T. 114 N., R. 24 W.) in west-central Scott County.

The upper 40–50 feet of the Franconia Formation north of Stillwater in northern Washington County, Anoka County, and in northern Hennepin County is light-gray, thin-bedded and cross-bedded (ripple cross-laminated), fine- to coarse-grained, dolomite-cemented quartz sandstone. The quartz sandstone overlies and interfingers with greenish-gray, medium-bedded, very fine grained to fine-grained, dolomite-cemented, glauconitic and feldspathic sandstone. In the southern and central parts of the map area, where the quartz sandstone is absent, the glauconitic and feldspathic sandstone is as thick as 100 feet. The lower part of the formation consists of green-gray to light-green interbedded shale, siltstone, and lesser amounts of very fine grained feldspathic sandstone as thick as 30 feet, which overlie dark-green, very fine grained to fine-grained, medium to thick beds of highly glauconitic sandstone interlayered with thin beds of gray-orange to pink sandy glauconitic dolostone, also as thick as 30 feet. The quartz sandstone beds in the upper part of the Franconia Formation crop out extensively along bedrock terraces of the St. Croix River in northern Washington County, for example, Boom Hollow north of Stillwater and around Marine on the St. Croix. The lower glauconitic beds rarely crop out in the map area, although some formerly did near Afton in Washington County. The contact with the underlying Ironton Sandstone is sharply defined but apparently conformable. The Franconia Formation is as thick as 165 feet and is generally thickest in the northeastern part of the map area. The St. Lawrence and Franconia Formations have a combined thickness of 180–240 feet.

* Small outliers of the St. Lawrence Formation maybe included in the unit Cu (Cambrian rocks, undivided), and thus in some areas of the map the unit is mapped with other units. The Franconia Formation is mentioned as being included in the Cu unit as well, however, with a more prominent inclusion with other formational units.

**Cu - Cambrian rocks, undivided (Upper Cambrian)**

Primarily the Franconia, Ironton, Galesville, Eau Claire, and Mt. Simon formations but may include small outliers of the St. Lawrence and Jordan formations. The Cambrian formations in northern Anoka County are not formally subdivided because most domestic wells in the area penetrate only a few feet of bedrock. Water well cuttings and geophysical logs from deep wells are scarce.

* In some areas of the map the Jordan Formation is also mapped as its own unit (Cj), as are the St. Lawrence and Franconia Formations, undivided (mapped as Csf), the Ironton Sandstone and Galesville Sandstone, undivided (mapped as Cig), the Eau Claire Formation (mapped as Cec), and the Mt Simon Sandstone (mapped as Cms). This unit also somewhat differs from the unit with the same unit symbol and name (i.e., Cu - Cambrian rocks, undivided) present in the GRI surficial (MISS) digital geologic-GIS data. Basically, the formations that are considered
components of each unit don't fully agree, and thus may reflect a difference in geologic interpretation between the two source maps.

**Cig - Ironton SS and Galesville SS, undivided (Upper Cambrian)**

The Ironton Sandstone and Galesville Sandstone consist of light-gray, very fine to fine-grained feldspathic sandstone and medium- to coarse-grained and very-coarse grained, commonly cross-laminated quartz sandstone interlayered with scattered thin beds of maroon or green shale. Although separated by a disconformity representing a hiatus of long temporal duration, the two formations cannot be distinguished with certainty where geologic control consists of water-well cuttings alone. The Ironton and Galesville Sandstones do not crop out in the map area. Total combined thickness of the two formations commonly is 42–56 feet, but it reaches a maximum of 75 feet in the area of the map.

* The Ironton Sandstone and Galesville Sandstone are also included in the unit Cu (Cambrian rocks, undivided), and thus in some areas of the map the units are mapped with other units.

**Cec - Eau Claire Formation (Upper Cambrian)**

The formation can be divided into three broad intervals, but they are not portrayed separately on the map. The upper one-third to one-fourth of the formation is feldspathic sandstone that is light gray to yellow gray, very fine to fine grained, finely laminated to ripple cross-laminated, and slightly glauconitic; it is interlayered with scattered thin partings of gray-green shale. The middle one-fourth to one-third of the formation is light-gray siltstone, very fine grained, slightly glauconitic, feldspathic sandstone, and gray-green shale. Shale and sandstone generally alternate in wavy to lenticular beds. Some shale beds, particularly those at the bottom of the interval, are as thick as several feet. Overall, the middle and upper parts of the Eau Claire form a coarsening-upward sequence. The basal one-third to one-half of the formation forms a coarsening-upward sequence of gray-green, very fine grained to fine-grained, glauconitic, feldspathic sandstone and glauconitic, feldspathic siltstone. The finely laminated to ripple cross-laminated, and slightly bioturbated interval is marked by scattered gray-green shale partings, especially near the base. The Eau Claire Formation has a conformable contact with the underlying Mt. Simon Sandstone. The formation ranges in thickness from 63 to 118 feet but is most commonly 65 - 80 feet thick.

* The Eau Claire Formation is also included in the unit Cu (Cambrian rocks, undivided), and thus in some areas of the map the unit is mapped with other units.

**Cms - Mt. Simon Sandstone (Upper Cambrian)**

The upper one-fifth of the formation consists of medium to thick, locally cross-stratified beds of fine- to medium-grained, moderately sorted to well-sorted quartz sandstone interbedded with lesser beds of gray-green shale, very fine grained feldspathic sandstone and siltstone, and fine-to coarse-grained, silty, poorly sorted, thick-bedded to massive quartzose to feldspathic sandstone that is intensively worm burrowed by *Skolithos*. The middle one-third to two-fifths of the formation consists of (1) thick, crudely planar or cross-stratified beds of fine- to coarse-grained, moderately sorted quartz sandstone interlayered with (2) thin to very thick (as thick as 8 feet) beds of very fine grained to fine-grained, well-sorted, feldspathic sandstone. The feldspathic sandstone is, in turn, inter-layered with thin intervals of green-gray, silty shale. Granule-sized grains of quartz or, rarely, intraclasts of siltstone and very fine grained sandstone define the lower parts of the thick, coarser grained sandstone beds. The lower one-half of the formation consists of medium to thick cross-stratified beds of medium- to very coarse-grained,
moderately sorted to well-sorted quartz sandstone. The interval contains thin intercalated lenses of granule- to pebble-sized quartz and scattered thin beds of light-gray siltstone and red-brown to pale-red to green-gray shale. A basal conglomerate as thick as 6 feet marks the base of the formation. In the map area, the Mt. Simon Sandstone is less than 150 feet to more than 335 feet thick. It is thinnest in the west and northwest and thickest toward the southeast.

* The Mt. Simon Sandstone is also included in the unit Cu (Cambrian rocks, undivided), and thus in some areas of the map the unit is mapped with other units.

**Mesoproterozoic Era**

**Y - Solor Church Formation (Mesoproterozoic)**

Intercalated intervals of red, maroon, or brown shale and fine- to coarse-grained quartz and lithic sandstone. The formation includes locally abundant conglomerate layers that contain clasts of mafic igneous derivation.

**GRI Bedrock Map Sources and their Ancillary Information**

The GRI digital bedrock geologic-GIS map (GRI Map Code of MSBR) for Mississippi National River and Recreation Area, Minnesota (MISS) was compiled from the following sources,

Mossler, J.H., Tipping, R.G., 2000, Bedrock geology and structure of the Seven-County Twin Cities Metropolitan Area, Minnesota, Minnesota Geological Survey, Miscellaneous Map Series M-104, 1:125,000 scale (GRI Source Map ID 33858).

Additionally, digital data used to correct and refine specific spatial locations of some faults and folds features (see the the Faults (msbrflt) and Folds (msbrfld) data layers in the GRI digital geologic-GIS data) were derived from the following sources.

Aronow, Saul, Patterson, C.J., Palen, B.M., Walsh, J.F., Olsen, B.M., 1990, Geologic atlas, Dakota County, Minnesota, Minnesota Geological Survey, County Atlas Series C-6, 1:100,000 scale (GRI Source Map ID 23301)


Additional information pertaining to each source map is also presented in the Source Map Information (MAP) table (missmap) included with the GRI geology-GIS data.
Stratigraphic Correlation Chart

INDEX SHOWING SOURCES OF GEOLOGIC DATA
(Numbers refer to entries in the source data list below)
Extracted from source map: M-104

Source Map Symbols

- **Geologic contact**—Approximately located.

- **Fault**—Approximately located; U, upthrown side; D, downthrown side.

- **Approximate erosional edge of Prairie du Chien Group.**

- **Anticline**—Showing crest line and general direction of plunge of fold.

Adapted from source map: M-104

Source References


6 Mossler, J.H., 2000, unpublished mapping, Anoka County, Minn.

7 Mossler, J.H., 2000, unpublished mapping, southwestern Hennepin County and adjoining north-central Carver County, Minn.

8 Mossler, J.H., 2000, unpublished mapping, T. 113 and 114 N., R. 25 W., eastern Sibley County, Minn.

9 Mossler, J.H., 2000, unpublished mapping, western Scott County, Minn.


*Not shown on the index map showing major sources of geologic data.

Extracted from source: M-104
GRI Digital Data Credits and Acknowledgements

This document was developed and completed by Jack Garner (NPS, GRD, Lakewood, Colorado) for the NPS Geologic Resources Division (GRD) Geologic Resources Inventory (GRI) Program. Document quality control and GRI standardization by Jim Chappell and Stephanie O’Meara (Colorado State University).

The information contained herein was compiled to accompany the digital geologic-GIS maps and other digital data for Mississippi National River and Recreation Area, Minnesota (MISS) developed by Jack Garner and Jim Chappell.

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