

**DESCRIPTION OF MAP UNITS**

This map is a compilation of maps completed from 1930 to 1998 by several different authors. Unlike several of the maps from which it is derived, most of the deposits on this map have been placed in lithostratigraphic units that have been modified from units previously defined by Stone (1966), Matsch (1962 and 1972), Wright and others (1970), Hansel and Johnson (1996), and Mickelson and others (1984). The Correlation of Map Units incorporates a new scheme developed by Johnson and others (1997) for the division of the late Quaternary into episodes, emphasizing the diachronic nature of the map units. The Michigan Subepisode of the Wisconsin Episode replaces the late Wisconsin glaciation of earlier publications, and the Hudson Episode is a new name for the current interglacial or postglacial time—the time since Michigan deglaciation in various regions.

**QUATERNARY**

**Qna Floodplain alluvium**—Sediment of modern rivers. Typically coarser (sand and gravel) in the channels, and finer (fine sand and silt) on floodplains. Chiefly sand along the St. Croix and Vermillion Rivers; commonly overlain by about 5 feet (1.5 m) of sandy loam to loamy sand interbedded with organic-rich layers; gravelly in some places. Alluvium of the Mississippi River and its other tributaries is more silt to loamy till. Some depressions on floodplains have been filled with thick silty to clayey sediment. Covered by thick artificial fill in developed areas. Includes minor lakeshore sediment and deltas built into Lake Pepin and Lake St. Croix. Within the Mississippi River valley, includes peat and fine organic-rich sediment deposited in floodplain swamps. Contacts with other map units are commonly scarps.

**Qp Peat**—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, and small bodies of open water. In developed areas, organic sediment commonly has been removed prior to burial under artificial fill.

**Qws West Campus formation** (Meyer and Patterson, 1997)—Sand and gravelly sand of mixed Riding Mountain and Superior provenance (Table 1). Coarsens to cobbly gravel in places. Laid down during early, higher stages of the St. Croix and Mississippi Rivers, and preserved in terraces above the modern floodplain. The original West Campus Sand of Stone (1966), which encompasses fluvial sediment in terraces of the Mississippi River valley, is expanded here to include fluvial sediment deposited within the St. Croix River valley above the modern floodplain. The West Campus formation is mapped at four major terrace levels. A pattern indicates areas where bedrock is generally within 10 feet (3 m) of the surface.

**Qm St. Mary's terrace** (Meyer, 1999)—The terrace is about 10 to 20 feet (3 to 6 m) above floodplain level—ranging in elevation from about 760 feet (232 m) at the northern edge of the map to about 710 feet (216 m) at the southern edge. Most contacts with other map units (except peat) are scarps.

**Qg Grey Cloud terrace** (Matsch, 1962)—The terrace is about 55 to 65 feet (17 to 20 m) above floodplain level—ranging in elevation from about 760 feet (232 m) at the northern edge of the map to about 710 feet (216 m) at the southern edge. Most contacts with other map units (except peat) are scarps.

**Ql Langdon terrace** (Matsch, 1962)—This terrace has two distinct surfaces. The lower surface is about 50 to 95 feet (15 to 29 m) above floodplain level—declining in elevation from about 780 feet (238 m) at Cottage Grove in the Mississippi River valley (T. 27 N., R. 21 W.) and at Lakeland (T. 29 N., R. 20 W.) in the St. Croix River valley, to about 730 feet (223 m) a few miles south of Frontenac. The upper surface is about 80 to 135 feet (24 to 41 m) above floodplain level—declining in elevation from about 840 to 760 feet (256 to 233 m) over roughly the same distance. A scarp symbol separates the two surfaces. 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. A similar channel is mapped at Cottage Grove. Most contacts with other map units (except peat) are scarps.

**Qr Richfield terrace** (Meyer and Jirsa, 1982)—The terrace ranges from about 160 to 200 feet (49 to 61 m) above the floodplain. Its most common elevation, just west of Lakeland (T. 29 N., R. 20 W.), is about 870 feet (265 m), but a small part of it in the same area is at 885 feet (270 m). The Richfield terrace is mapped at 840 to 850 feet (256 to 259 m) along the Mississippi River northwest of Hastings (T. 115 N., R. 20 W.), but is not recognized below Hastings, where it merges with the level of the Mississippi River valley train. Most contacts with other map units are scarps.

**Qmv Mississippi valley train**—Sand, gravelly sand, and gravel. Deposited in the Mississippi River valley by meltwater issuing from both the Superior and Des Moines lobes. Preserved in the highest terrace along the Mississippi River, but also underlies West Campus formation, floodplain alluvium, and sediments of Lake Pepin. May include some sediment of the Richfield terrace downstream from Hastings, where the two surfaces are indistinguishable.

**Qma Sandy alluvium and slopewash**—Sand and gravelly or loamy sand; deposited in valleys and gently sloping plains above the level of outwash plains in response to rising baselevel 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. Pebbles 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. Commonly includes fine slackwater sediment in the lower parts of valleys, where it merges with outwash.

**Qmc Colluvium**—Angular unsorted fragments of local bedrock; commonly overlain by massive to crudely bedded silt, which contains a few angular rock clasts. Rock fragments 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 but generally mapped at the top of the slopes; thickness decreases uplope; in the upper parts of the slopes, both layers are thin and bedrock outcrops are common.

**Qeo Peoria formation** (Peoria Silt of Hansel and Johnson, 1996)—Windblown (eolian) sediment. Fine to medium sand, along with silt and clay, eroded by wind from outwash surfaces and older till surfaces, was transported and deposited generally southeast of its source area. Mapped as a stippled pattern only where thicker than 5 feet (1.5 m). Thin unmapped Peoria formation overlies much of the map area. Loess is the predominant facies of this formation.

**Qlo Loess**—Chiefly silt; includes minor amounts of very fine sand and clay. The latter was probably deposited as silt-sized aggregates. Within a few miles of its western border, the loess is coarse, consisting mainly of very fine sand and coarse silt; contains almost no clay.

**Qes Eolian sand**—Fine to medium grained; lacks gravel. Unmapped sand is interbedded with coarse loess in the border area, and underlies loess in patches elsewhere.

**New Um formation** (Meyer and Patterson, 1997)—Glacial, fluvial, and lacustrine sediment of Riding Mountain provenance (Table 1) deposited by ice and meltwater of the Des Moines lobe and its Grantsburg sublobe. Only the fluvial facies is present in the mapped area.

**Qow Outwash**—Sand, gravelly sand, and gravel. Deposited by meltwater issuing from the glacial ice margin at or near its maximum advance. Includes common to abundant clasts of Superior provenance eroded from older sediment; these clasts are generally more abundant to the north. Shale is absent to fairly common. Commonly capped by a mantle of loess less than 4 feet (1.3 m) thick.

**Qom Crownell formation** (Meyer and Patterson, 1997)—Glacial, fluvial, and lacustrine sediment of Superior provenance (Table 1), deposited by the Superior lobe and its meltwater. The Crownell Formation of Wright and others (1970) is mapped here to include related lake sediment.

**Qol Lake sand and silt**—Primarily deposited in ice-walled lakes in moraine areas following ice stagnation. Chiefly 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 generally are concentrated toward the middle of the larger deposits. Coarse sand and gravel occur locally along edges of the ice-walled lakes. Also includes silty sediment in pitted outwash plains, where the sediment commonly consists of loess redeposited in kettles.

**Qoc Outwash**—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 m) of loess. Laid down by meltwater issuing from the receding glacial ice margin. The surface of the outwash is highly irregular north of the Mississippi River due to the surfacing of buried ice following deposition of the sand and gravel.

**Qci Ice-contact stratified till**—Sand, gravelly sand, and cobbly gravel; commonly includes interbeds of silt, 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 as deltas by meltwater entering ice-walled lakes. Other deposits were laid down along the courses (eskers) or at the mouths (kames) of subglacial streams.

**Qct Till**—Chiefly sandy loam-textured, unsorted sediment (diamicton); pebbles, cobbles, and boulders; silty sand to cobbly gravel lenses are commonly present. Commonly overlain by 2 to 5 feet (0.6 to 1.5 m) of loess. Includes small areas of dark loam to sandy colluvium in small depressions.

**Till, sand and gravel complex**—Sandy till capped by, and/or interbedded with, sand and gravel. Locally patchy till over thick deposits of sand and gravel. Includes complex areas where the separate units are too small to distinguish till from ice-contact deposits at this map scale.

**River Falls Formation** (Mickelson and others, 1984)—Glacial and glaciofluvial deposits of Superior provenance (Table 1), deposited by the Superior lobe and its meltwater. The upper part contains a truncated paleosol in places, indicating deposition prior to the Michigan Subepisode.

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

**Till**—Chiefly sandy loam to sandy clay loam textured diamicton; numerous 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.

**Sand and gravel, till complex**—Sand and gravel with cobbles (ice-contact stratified drift), and till, as above, undivided. Till is only a minor component in most places. The highland area between the Cannon and Vermillion Rivers where most of this unit was deposited has been called the Hampton moraine (Levert, 1932), but it is also a bedrock high, and its current relief is due to stream dissection.

**Pierce Formation** (Mickelson and others, 1984)—Glacial and glaciofluvial deposits of Winnetong provenance (Table 1). Represents deposits of four or more glaciations, undivided. Most of the Pierce Formation underlies the River Falls Formation, but the uppermost till of the Pierce may be contemporaneous with the River Falls.

**Till**—Chiefly loam to clay loam-textured diamicton; pebbles, cobbles and boulders. Lenses of sorted sand and gravel in places. Originally gray and calcareous, but surface is highly oxidized and deeply leached in places.

**Glaciofluvial deposits**—Sorted sediment ranging from fine sand to coarse gravel. Most commonly a mixture of sand and gravel. Strongly weathered from the top to a depth of about 10 feet (3 m); contains many carbonate clasts below the leached zone; many coarse fragments break apart easily; many grains coated with brown clay. Occurs as eroded remnants of ice-contact stratified drift and outwash, undivided. In places, covered by a layer of till less than 5 feet (1.5 m) thick. Some deposits mapped from secondary sources such as boring logs, which do not specify provenance, may include material of Superior provenance.

**ORDOVICIAN**

**Decorah Shale**—Green-gray shale with thin interbeds of fossiliferous limestone.

**Platteville and Glenwood Formations**—Fine-grained dolomite and limestone of the Platteville Formation is underlain by fine, sandy shale of the Glenwood Formation. The Glenwood is thin and easily eroded, so its outcrop area is insignificant compared to the Platteville.

**St. Peter Sandstone**—Massive, fine- to medium-grained quartzite sandstone. Interbedded with siltstone and shale in its lower part.

**Prairie du Chien Group**—Oolitic sandy dolomite and sandstone of the Shakopee Formation overlies massive dolomite of the Onota Dolomite.

**CAMBRIAN-ORDOVICIAN, UNDIVIDED**

**Bedrock, undivided**—Outcrops and near-surface Cambrian and Ordovician bedrock on steep slopes; not practical to map individual units.

**CAMBRIAN**

**Jordan Sandstone**—Medium- to coarse-grained, friable, cross-bedded sandstone.

**St. Lawrence and Franconia Formations**—Dolomitic siltstone and shale of the St. Lawrence Formation is underlain by fine-grained, glauconitic sandstone, siltstone and shale of the Franconia Formation.

**TABLE 1. GENERAL CHARACTERISTICS OF MAPPED GLACIAL DEPOSITS.**

PROVENANCE	RIDING MOUNTAIN	WINNETONG	SUPERIOR
TILL TEXTURE	Mostly loamy	Loamy to clayey	Loamy to sandy
TILL COLOR	Yellow to olive-brown	Yellow-brown	Reddish-brown
Oxidized	Gray	Gray	Grayish-red
UNSORTED	Common	Common	Common
ROCK TYPES IN TILL AND OUTWASH			
Precambrian	Uncommon	Uncommon	Common
Back to gray-green rock	Absent to rare	Rare to uncommon	Uncommon to common
Red sandstone	Absent to rare	Common to abundant	Uncommon to common
Paleozoic sandstone	Common	Common to abundant	Common
Ordovician			
Gray shale	Uncommon to abundant	Absent to rare	Absent
Limestone & calcareous shale	Rare	Rare to uncommon	Absent

**MAP SYMBOLS**

**Geologic contact**—Arbitrarily located.

**General flow direction of braided streams**—Arrows point downstream in the direction glacial meltwater once flowed.

**Stream-cut scarp**—Fluores on downslope side; only shown as line symbols where not adequately defined by unit boundaries. Where paired, scarps bound stream-scoured areas. Till surfaces on the hatched side of scarps are fluvially scoured and mantled in places by sand and gravel too thin and patchy to map separately.

**Esker**—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 Superior lobe. Arrows show inferred flow direction.

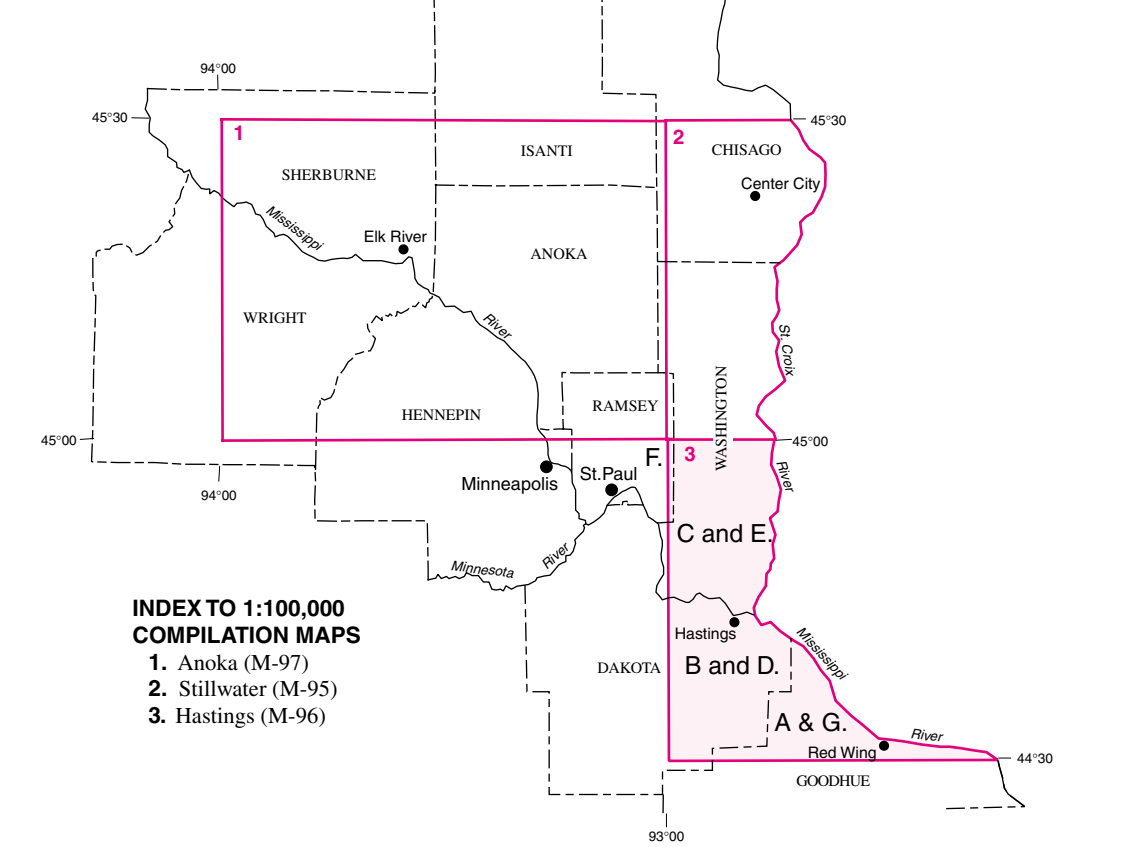
**Sides of a buried tunnel valley**—Large drainage channel interpreted to have formed below Superior lobe ice. In some cases, the actual tunnel valley is deeply buried by younger sediment such as outwash, but the shape can be discerned by the alignment of kettles, which collapsed when the buried ice melted. The northernmost tunnel valley makes a jog at Lake Elmo (T. 29 N., R. 21 W.), where it crosses a buried bedrock valley; apparently the glacial sediments which fill it were easier to erode.

**Glacial diversion channel**—The ice that deposited the River Falls Formation crossed the Mississippi River from the north and blocked it. These channels were cut south of and parallel to the Mississippi River valley. They subsequently have filled with younger sediments.

**Inferred ice margins of the Superior lobe**—Approximate maximum extent of ice advance: labels on up-ice side of margin.

**EMERALD PHASE**—Emerald phase (Johnson and Mooers, 1990)—This earliest and most extensive advance of the Michigan glaciation deposited outwash and till of the Crownell formation. Till is only preserved in patches behind this margin because of subsequent erosion. Some of the highest meltwater paths from the Emerald ice margin were not subsequently used during the St. Croix phase.

**PRE-MICHIGAN ADVANCE**—Extent of ice that deposited the River Falls Formation, mapped by distribution of till and position of glacial diversion channels inferred to have been eroded by this advance.



**SOURCES OF GEOLOGIC DATA USED TO COMPILE THE MAP**

- The inset map shows the location of the Hastings quadrangle (shaded) relative to surrounding counties. Citations A through G were used to compile the geology.
- A. Hobbs, H.C., and Setterholm, D.R., 1998, Surficial geology and thickness of Quaternary sediments, plate 3 in Setterholm, D.R., project manager, Geologic atlas of Goodhue County, Minnesota: Minnesota Geological Survey County Atlas Series C-12, scale 1:100,000, W93°02'29"-92°14'36"/N44°42'53"-44°11'41" [single printed sheet].
  - B. Hobbs, H.C., Aronow, S., and Patterson, C.J., 1990, Surficial geology, plate 3 in Balaban, N.H., and Hobbs, H.C., eds., Geologic atlas of Dakota County, Minnesota: Minnesota Geological Survey County Atlas Series C-6, scale 1:100,000, W93°19'45"-92°43'53"/N44°55'24"-44°28'19" [single printed sheet].
  - C. Meyer, G.N., Baker, R.W., and Patterson, C.J., 1990, Surficial geology, plate 3 in Swanson, L., and Meyer, G.N., eds., Geologic atlas of Washington County, Minnesota: Minnesota Geological Survey County Atlas Series C-5, scale 1:100,000, W93°01'22"-92°44'25"/N45°17'49"-44°44'45" [single printed sheet].
  - D. Mossler, J.H., 1990, Bedrock geology, plate 2 in Balaban, N.H., and Hobbs, H.C., eds., Geologic atlas of Dakota County, Minnesota: Minnesota Geological Survey County Atlas Series C-6, scale 1:100,000, W93°19'45"-92°43'53"/N44°55'24"-44°28'19" [single printed sheet].
  - E. Mossler, J.H., and Bloomgren, B.A., 1990, Bedrock geology, plate 2 in Swanson, L., and Meyer, G.N., eds., Geologic atlas of Washington County, Minnesota: Minnesota Geological Survey County Atlas Series C-5, scale 1:100,000, W93°01'22"-92°44'25"/N45°17'49"-44°44'45" [single printed sheet].
  - F. Patterson, C.J., 1992, Surficial geology, plate 3 in Meyer, G.N. and Swanson, L., eds., Geologic atlas of Ramsey County, Minnesota: Minnesota Geological Survey County Atlas Series C-7, scale 1:100,000, W93°13'40"-92°59'01"/N45°07'28"-44°53'17" [single printed sheet].
  - G. Runkel, A.C., 1998, Bedrock geology, plate 2 in Setterholm, D.R., project manager, Geologic atlas of Goodhue County, Minnesota: Minnesota Geological Survey County Atlas Series C-12, scale 1:100,000, W93°02'29"-92°14'36"/N44°42'53"-44°11'41" [single printed sheet].

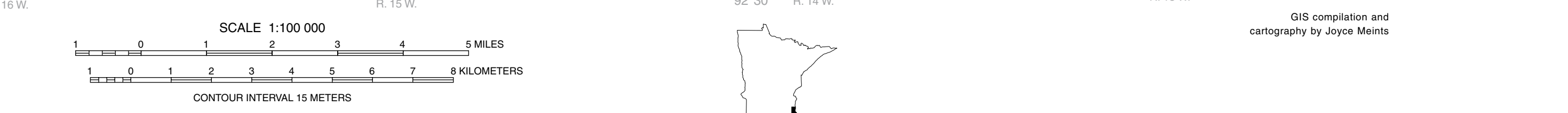
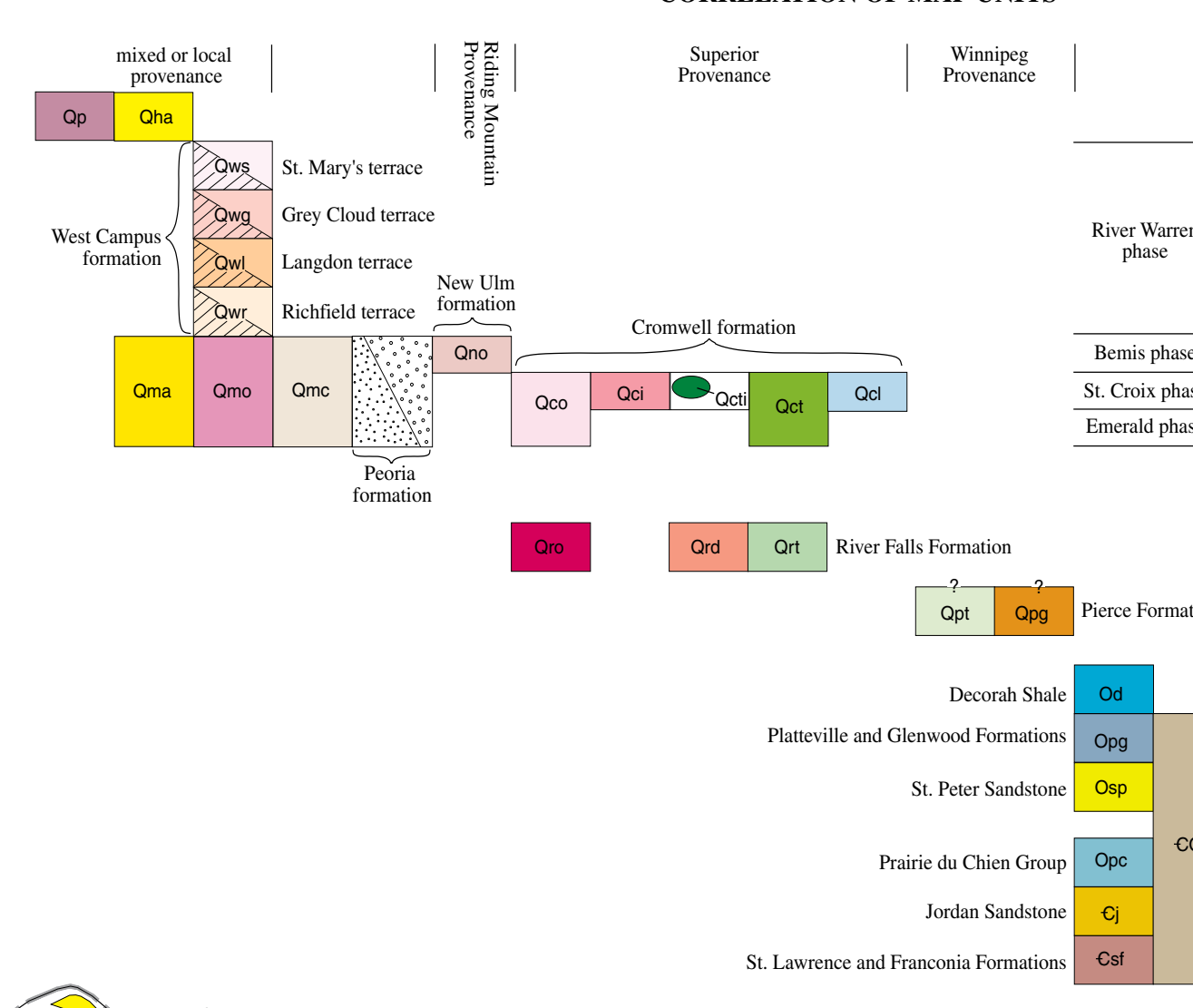
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- Meyer, G.N., 1999, Surficial geology of the Stillwater 30 x 60 minute quadrangle, Minnesota: Minnesota Geological Survey Miscellaneous Map Series M-95, scale 1:100,000, W93°00'-92°38'45"/N45°30'-45°00' [electronic file].
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- Stone, J.E., 1966, Surficial geology of the New Brighton quadrangle, Minnesota: Minnesota Geological Survey Geologic Map Series GM-2, 39 p., 3 plates, scale 1:24,000, W93°15'-93°07'30"/N45°07'30"-45°00' [single printed sheet].
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- Wright, H.E., Jr., Mattonson, L.A., and Thomas, J.A., 1970, Geology of the Cloquet quadrangle, Carlton County, Minnesota: Minnesota Geological Survey Geologic Map Series GM-3, 30 p., W92°30'-92°22'30"/N46°45'-46°37'30" [single printed sheet].

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Every reasonable effort has been made to ensure the accuracy of the factual data on which this map interpretation is based; however, the Minnesota Geological Survey does not warrant or guarantee that there are no errors. Users may wish to verify critical information; sources include both the references listed here and information on file at the offices of the Minnesota Geological Survey in St. Paul. In addition, effort has been made to ensure that the interpretation conforms to sound geologic and cartographic principles. No claim is made that the interpretation shown is rigorously correct, however, and it should not be used to guide engineering-scale decisions without site-specific verification.

**CORRELATION OF MAP UNITS**



**SURFICIAL GEOLOGY OF THE HASTINGS 30 x 60 MINUTE QUADRANGLE, MINNESOTA**

Compiled by  
Howard C. Hobbs