UNIVERSITY OF MINNESOTA
MINNESOTA GEOLOGICAL SURVEY
Harvey Thorleifson, Director

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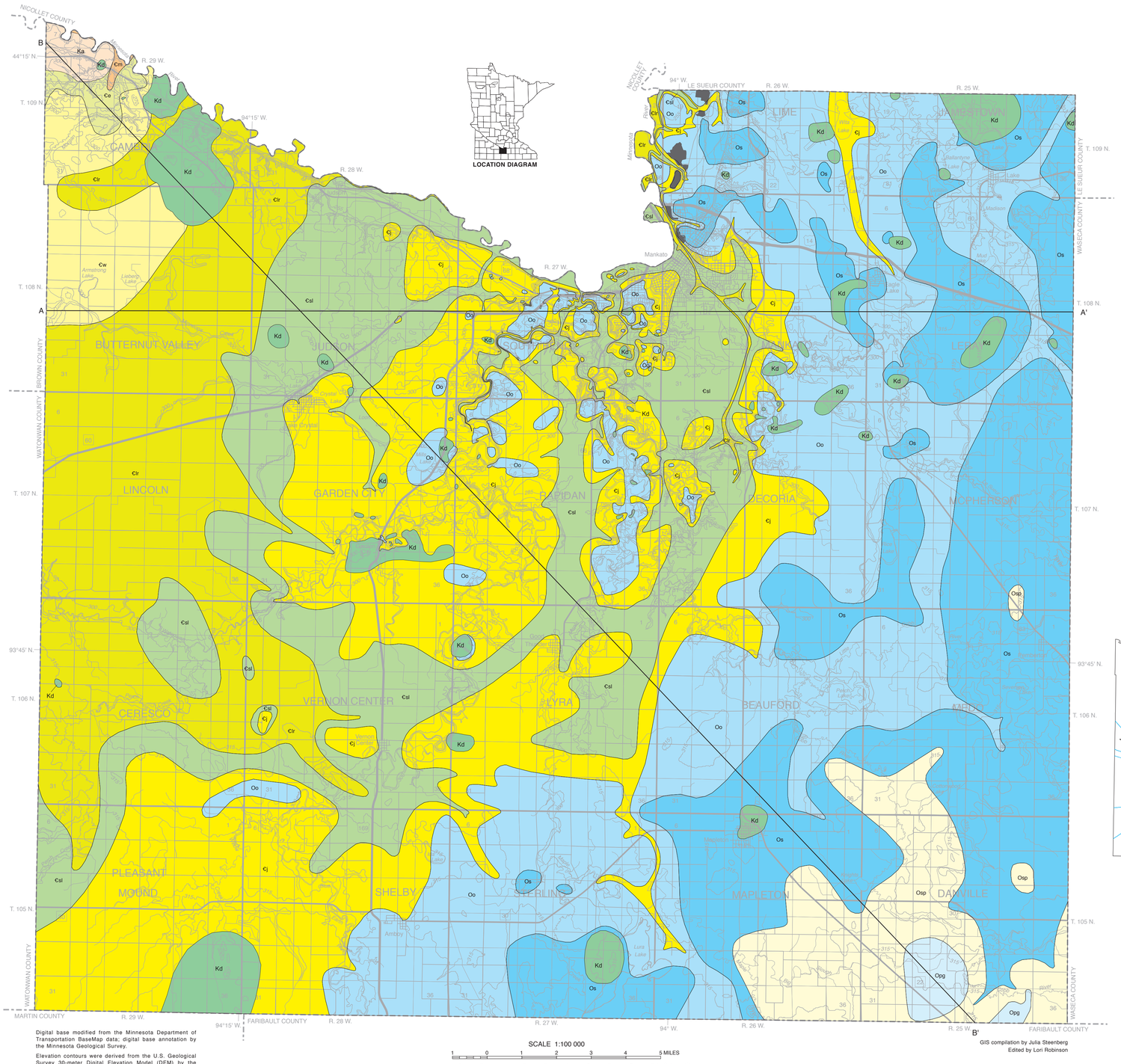
COUNTY ATLAS SERIES
ATLAS C-26, PART A
Blue Earth County
Plate 2—Bedrock Geology

# BEDROCK GEOLOGY

By
Julia R. Steenberg
2012




LOCATION DIAGRAM

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

Elevation contours were derived from the U.S. Geological Survey 30-meter Digital Elevation Model (DEM) by the Minnesota Geological Survey.

Universal Transverse Mercator Projection, grid zone 15
1983 North American Datum

SCALE 1:100 000
1 0 1 2 3 4 5 MILES
1 0 1 2 3 4 5 6 7 8 KILOMETERS
CONTOUR INTERVAL 15 METERS

GIS compilation by Julia Steenberg
Edited by Lori Robinson

## CORRELATION OF MAP UNITS

| | | |
|---|---|---|
| Kd | Upper Cretaceous | MESOZOIC |
| unconformity | | |
| Ka | Lower to Upper Cretaceous? | MESOZOIC |
| unconformity | | |
| Opg | Upper Ordovician | PALEOZOIC |
| Osp | Middle Ordovician | PALEOZOIC |
| unconformity | | |
| Os | Lower Ordovician | PALEOZOIC |
| unconformity | | |
| Oo | Lower Ordovician | PALEOZOIC |
| unconformity | | |
| Cj | Upper Cambrian | PALEOZOIC |
| Csl | Upper Cambrian | PALEOZOIC |
| Clr | Upper Cambrian | PALEOZOIC |
| unconformity | | |
| Cw | Middle Cambrian | PALEOZOIC |
| Ce | Middle Cambrian | PALEOZOIC |
| Cm | Middle Cambrian | PALEOZOIC |
| unconformity | | |
| Ehs | MESOPROTEROZOIC | |
| unconformity | | |

## MAP SYMBOLS

**Geologic contact**—Approximately located.
**Bedrock outcrop.**
A A' **Location of geologic cross section.**

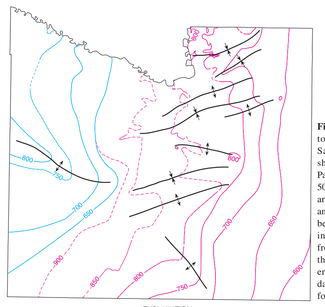



**Figure 1.** Elevation of the stratigraphic tops of the Jordan and Wonewoc Sandstones in Blue Earth County, showing the geologic structure of Paleozoic bedrock. Contour interval is 50 feet (15 meters), scale 1:450,000. In areas where some or all of the Jordan and Wonewoc Sandstones are missing because of erosion, the contours are inferred from projection vertically from other formation contacts, using the estimated full thickness of the eroded formations, and shown with dashed line. The inferred traces of folds are shown.

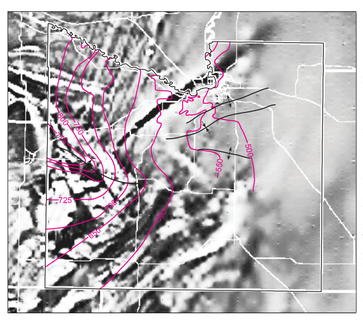
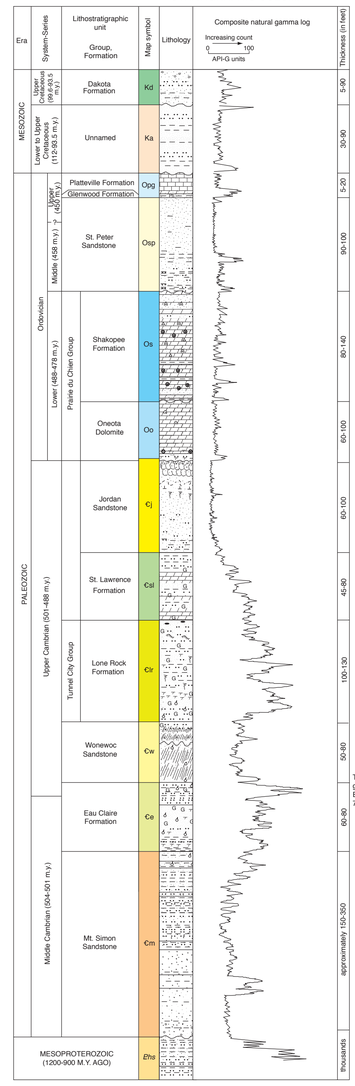


**Figure 2.** Map of the first vertical derivative magnetic anomaly data of Blue Earth County (Chandler and Lively, 2007). Lighter colors indicate more magnetic. The structure contours of the stratigraphic top of the Wonewoc Sandstone are overlain on this image showing a prominent anticline feature in the western portion of the map area, based on the current well coverage. There is a subtle contrast in trends of the magnetic anomalies from southwest–northeast in the southwestern portion of the map area to southeast–northwest in the west-central part of the map area, possibly reflecting a deep basement fold or fault structure. This trend appears to coincide with the structural grain of the Wonewoc Sandstone, suggesting that Paleozoic bedrock was displaced by reactivation of the deep basement structural feature. Black line shows county boundary and pink lines show structure contours. Inferred folds are also shown in black; scale 1:500,000.

## STRATIGRAPHIC COLUMN




Lithology Key
Limestone
Dolostone
Sandy dolostone
Sandstone
Very fine- to fine-grained
Fine- to medium-grained
Medium- to coarse-grained
Shaly
Siltstone
Shale
Chert
Oolites
Glauconite
Phosphate grains
Algal domes; stromatolites
Fossils (not used in limestone or dolostone units)
Burrowed
Pebbles (gravel in unconsolidated units)
Flat-pebble conglomerate
Cross-bedded (festoon)
Cross-bedded (planar to tangential)
Ripple cross-laminations
Dolomitic
Calcareous
Contact marks a major erosional surface
Facies change

This gamma log is a compilation of five borehole geophysical logs collected from water wells in Blue Earth and Nicollet Counties; unique numbers 270341, 770449, 213694, 213696, and 209876.

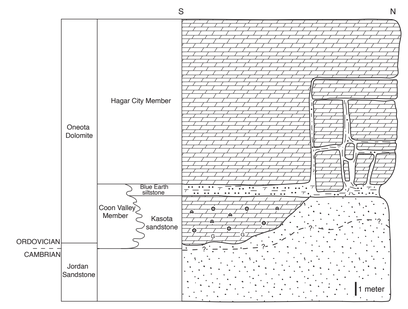
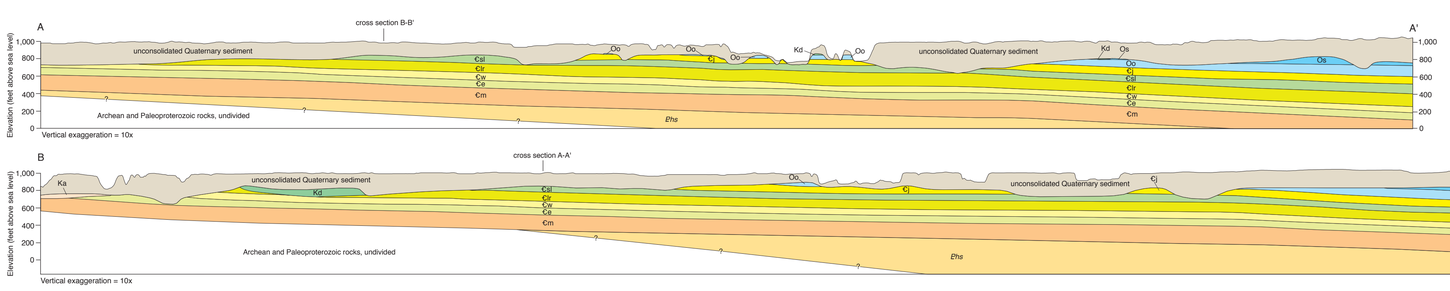



**Figure 3.** Schematic stratigraphic section through the Late Cambrian Jordan Sandstone and the Early Ordovician Oneota Dolomite depicting the stratigraphic relationships within the Hager City and Coon Valley Members of the Oneota Dolomite from the Mankato area (N) to southeast Blue Earth County (S). The Kasota sandstone, though equivalent in age to the lower part of the Coon Valley Member (Early Ordovician), was mapped as Jordan Sandstone (Late Cambrian) because the units cannot be distinguished from each other based on subsurface data. See stratigraphic column for lithology key.




## INTRODUCTION

This geologic map depicts the type, structure, and distribution of bedrock units in Blue Earth County that are either exposed at the land surface or lie directly beneath unconsolidated Quaternary deposits of variable thickness (see Plate 3, *Surficial Geology*). It shows how the bedrock would appear if it were viewed from above and all the overlying Quaternary deposits were removed. The bedrock units of Blue Earth County consist of sedimentary rocks of Paleozoic and Mesozoic age that form distinguishable and mappable layers designated as formations, such as the St. Lawrence Formation. These units are locally exposed in bluffs, riverbanks, rock quarries, and roadcuts, particularly along the Minnesota River and its tributaries.

Characteristics of each formation are given in the stratigraphic column and in the description of map units. The accompanying bedrock geologic cross sections add the dimension of depth and illustrate stratigraphic relationships of the bedrock units, their structure, topography, as well as the variable thickness of the overlying Quaternary deposits. The geologic formations are thin in relation to their areal extent and would only be one-tenth as thick as shown on the cross sections if no vertical exaggeration were used. The exaggeration needed to show the thin rock formations gives the appearance of steeper slopes on the land surface and bedrock topography. In areas where bedrock is concealed by a thick package of Quaternary sediments, the geology is strongly dependent on borehole records and is generalized where borehole data are sparse.

The production of this map, cross sections, and stratigraphic column relied on several different sources of information including outcrop mapping, water-well and scientific drilling records (including holes drilled for this project), drill cuttings, drill core, borehole geophysical logs (see Plate 1 for distribution of these data), and published geologic maps of parts of Blue Earth and adjacent counties (Sloan, 1964; Rongstad and Wohlfeil, 1991; Mossler, 2003a, b; Runkel and Mossler, 2004a, b; Runkel, 2005a, b).

The Paleozoic rocks of Blue Earth County are characterized by thin, widespread layers of sandstone, shale, and carbonate rock deposited in shallow seas during the Paleozoic era from about 500 to 450 million years ago. The Cambrian age formations are dominated by siliciclastic sedimentary rock including sandstone, siltstone, and subordinate shale. Carbonate rock occurs only as relatively thin layers in these units. Ordovician age formations, in contrast, are dominated by carbonate rock, such as the Prairie du Chien Group and the Platteville Formation. The Paleozoic rocks are unconformably overlain by scattered erosional remnants of unconsolidated clay and sandstone deposits of Mesozoic age. These rocks were probably deposited continuously across the Paleozoic bedrock surface as sediment in a fluvially-dominated delta plain on the shallow, eastern margin of the Western Interior Seaway that covered much of the western interior of North America during the Late Cretaceous period. Due to subsequent erosion, these deposits have been separated into scattered, discontinuous outliers.

Paleozoic bedrock units lie disconformably on an eastward-thickening sequence of Mesoproterozoic rocks of the Keweenawan Supergroup that accumulated as part of the development of the Midcontinent Rift System. The rift formed during a thermo-tectonic event 900 to 1,200 million years ago that involved extension of the earth's crust with concurrent faulting, mafic volcanism, plutonism, and later deposition of a thick sequence of sedimentary rocks (Chandler and others, 1989). These rocks are poorly known in Blue Earth County, represented by only a few drill cuttings and gamma logs. Therefore, they cannot be assigned to a particular formation but likely correlate to parts of the Hinckley Sandstone, Fond du Lac Formation, and Solar Church Formation. Outcrops near the Blue Earth County to the west and northwest have a small number of drill cuttings and gamma logs that show Paleozoic bedrock directly overlies several older Proterozoic and Archean rock units, such as the Sioux Quartzite and the Morton Gneiss, marking the western boundary of preserved sediments related to the Midcontinent Rift System.

The distribution of uppermost bedrock units on the map is primarily influenced by the location of deep, buried river channels that are incised into the bedrock (see Plate 6, *Bedrock Topography*), and a gentle, overall eastward dip of the Paleozoic rock (less than 2°). This dip is part of the western margin of the broad structural depression known as the Hollandale embayment. As a result, progressively older bedrock formations subcrop from eastern to western Blue Earth County. The Cretaceous age deposits do not appear to have a similar distribution that corresponds to the structural grain of the Paleozoic units, which may indicate most of the folding predates their deposition. Structure contours drawn on the stratigraphic tops of the Jordan and Wonewoc Sandstones (Fig. 1) show several fold structures in the county and the gentle eastward dip of the Paleozoic rock.

The structural contours of the Wonewoc Sandstone show a broad anticline in western Blue Earth County. This feature appears to coincide with subtle trends in the magnetic anomalies found on the aeromagnetic image of the area (Fig. 2; Chandler and Lively, 2007). The anticline possibly developed in response to adjustments along an underlying deep basement fault structure not related to the Midcontinent Rift System. The apparent absence of faults in Blue Earth County likely reflects its position west of the major faults associated with the Midcontinent Rift System that are known to have affected the deposition and distribution of Paleozoic bedrock units elsewhere (Sims and Zeitz, 1967; Chandler and others, 2004).

## DESCRIPTION OF MAP UNITS

### MESOZOIC ROCKS

**Kd** **Dakota Formation (Upper Cretaceous)**—Variegated clay, siltstone, sandstone, and conglomerate that lies above Paleozoic bedrock and below Quaternary deposits. The sandstone is mostly quartzose, light gray, white, and orange. Grains are fine- to coarse-grained and angular to well-rounded. The sandstone is generally friable and locally well-cemented with calcite and iron-oxide cement. Thin conglomerate beds are interstratified with quartz sandstone and contain highly polished pebbles of vein quartz, Paleozoic chert, and rare claystone clasts. Thin to thick beds of clay and siltstone of variable colors including light to dark gray, white, blue, green, tan, and red are interbedded within the sandstone. Black lignite, leaf impressions, and phosphatic fish material have also been found in outcrops and drill cuttings in the clay, siltstone, and sandstone. These rocks are present throughout Blue Earth County as scattered erosional remnants of variable thicknesses ranging from 5 to 90 feet (1.5 to 27 meters). They have been found to unconformably overlie the Wonewoc Sandstone, Lone Rock Formation, St. Lawrence Formation, Jordan Sandstone, Oneota Dolomite, Shakopee Formation, and the undifferentiated unit (**Ka**) over a wide range of elevations between 750 and 900 feet (229 to 274 meters) above sea level. They are interpreted to represent the easternmost extension of a large, nearly continuous subcrop area of strata generally correlative with the Upper Cretaceous Dakota Formation (Setterholm, 1990).

The mapped distribution of the Upper Cretaceous rocks on this map is more speculative than for other map units because prediction of the subsurface distribution of these strata is rendered difficult by the presence of profound unconformities bounding these strata, and because information from water-well records alone is typically inadequate to consistently recognize these strata as distinct from quartz-rich Quaternary sand, organic-rich Quaternary lake sediments, or from clay-rich, in situ residuum developed on Paleozoic bedrock. Compared to the patchy strata classified as Late Cretaceous age in eastern Blue Earth County, strata in western Blue Earth County can be assigned to the Late Cretaceous period with some confidence. Interbedded mudstone, siltstone, and medium-grained sandstone from drill core near the town of Cambria is lithologically similar to well-dated mudstones, siltstones, and sandstones from three nearby localities in Nicollet and Brown Counties. Sedimentary rocks from these localities provide a rich and diverse assemblage of palynomorphs containing pollen taxa that are considered to be no older than Late Cretaceous (late Cenomanian) in age (Hu and others, 2008).

**Ka** **Undifferentiated (Lower to Upper Cretaceous?)**—Interbedded pale red-brown to pale olive siltstone, clay, and very fine- to medium-grained sandstone with calcareous and iron-oxide cement occur in the northwesternmost part of Blue Earth County. Similar outcrops across the Minnesota River in Nicollet County also contain concretionary carbonate within dark red and green clay, siltstone, and sandstone beds. This unit ranges from 30 to 90 feet (9 to 27 meters) thick in Blue Earth County and unconformably overlies both the Eau Claire and the Mt. Simon Formations between 700 and 730 feet (213 and 223 meters) above sea level. This unit has not yielded fossils in Blue Earth County, although gymnospermous pollen and dinoflagellate cysts extracted from lithologically similar strata from drill core in McLeod County near Plato, Minnesota are indicative of a latest Albian to Cenomanian age (Early to Late Cretaceous; Ravn, 2009, unpub. data).

### PALEOZOIC ROCKS

Nomenclature has been revised for some of the Paleozoic rock formations in Minnesota, and several formation names formerly in use at the Minnesota Geological Survey have been replaced by names that are widely accepted elsewhere in the region for the same units. Rocks formerly referred to as the Franconia Formation are now named the Tunnel City Group and include the Lone Rock, Mazomanie, and Davis Formations, and the sandstone interval formerly referred to as the Ironton and Galesville Sandstones is now assigned to the Wonewoc Sandstone. More detailed discussion of these revisions is given in Mossler (2008).

**Opg** **Platteville and Glenwood Formations, undivided (Upper Ordovician)**

***Platteville Formation***—Finely crystalline, yellowish-brown to light gray, fossiliferous limestone and dolostone with a maximum eroded thickness of 10 feet (3 meters). The basal dolostone bed contains fine- to coarse-grained quartz sand and phosphate grains. The Platteville Formation is only present in the extreme southeastern part of the county overlying the Glenwood Formation.

***Glenwood Formation***—Greenish-gray, calcareous shale containing fine- to medium-grained, well-rounded quartz sand and sand-sized phosphate grains. The Glenwood shale is estimated to be only 5 to 10 feet (1.5 to 3 meters) thick and at the scale of this map has nearly the same lateral distribution as the overlying Platteville Formation; therefore, they are mapped as one unit.

**Osp** **St. Peter Sandstone (Middle to Upper Ordovician)**—Fine- to medium-grained, well-rounded, white to tan, quartzose sandstone that subcrops in the southeastern portion of Blue Earth County. The unit is 90 to 100 feet (27 to 30 meters) thick where overlain by the Platteville and Glenwood Formations, but may be much thinner where partially eroded. The lower 30 feet (9 meters) includes variegated beds of white to gray shale, siltstone, and poorly sorted quartz sandstone. The basal contact of the formation with the underlying Shakopee Formation of the Prairie du Chien Group is an erosional unconformity representing a significant hiatus (Smith and others, 1993). There appears to be up to 30 feet (9 meters) of erosional relief on the top of the Shakopee Formation based on the limited number of well logs that penetrate this contact in southeastern Blue Earth County.

**Prairie du Chien Group (Lower Ordovician)**—Dominantly dolostone interbedded with lesser amounts of quartz sandstone. The group is divided into two formations, the Shakopee Formation and the underlying Oneota Dolomite. Together they range in thickness from 230 to 250 feet (70 to 76 meters), but commonly are much thinner where they are present as uppermost bedrock and have been partially eroded. These formations were subdivided in the map area based mainly on well cuttings and geophysical logs and to a lesser degree on drilling logs.

**Os** ***Shakopee Formation***—Yellow-gray to grayish-orange, thin to thickly bedded, sandy, oolitic dolostone divided into two members. The Willow River Member is composed of a light brown to grayish-orange, thin to medium bedded, sandy, oolitic, intraclastic dolostone. Meter-scale microbial mounds, chert nodules, fine- to coarse-grained quartz sandstone beds, and gray-green shale partings are common. The underlying New Richmond Member is a yellow-gray, fine- to coarse-grained quartz sandstone and sandy dolostone. As much as 16 feet (5 meters) of the New Richmond Member was once exposed in quarries east of the Minnesota River from Mankato to Le Sueur County (Stauffer and Thiel, 1933; Austin, 1971). In eastern Blue Earth County the Shakopee Formation ranges from 80 to 140 feet thick (24 to 43 meters) and appears to thicken eastward toward the center of the Hollandale Embayment.

**Oo** ***Oneota Dolomite***—Mostly very thick to thickly bedded, light brown to grayish-orange, finely crystalline, microbial dolostone that except in its lowermost part generally lacks sedimentary features such as oolites and quartz sand characteristic of the Shakopee Formation. Exposures of the Oneota Dolomite are common in Blue Earth County where bedrock is at or near the surface. The Oneota Dolomite ranges from 60 to 100 feet (18 to 30 meters) thick, thickening to the east toward the center of the Hollandale embayment in a manner similar to the Shakopee Formation.

The Oneota Dolomite in this area has been divided into a number of formal members and informal beds (Fig. 3). Its carbonate dominated upper part, the Hager City Member, consists of very thick to thickly bedded, finely crystalline dolostone that has been extensively quarried for building stone near Mankato (Stubblefield, 1971). It ranges from 55 to 80 feet (17 to 24 meters) thick. The underlying Coon Valley Member is a heterolithic unit containing dolostone, siltstone, shale, and sandstone reaching thicknesses of 20 feet (6 meters). Throughout most of Blue Earth County the Coon Valley Member is represented by a thinly bedded, sandy, oolitic, and intraclastic dolostone with microbial laminations, mounds, and minor amounts of glauconite. Outcrops of this dolostone can be found along the Watonwan River near Garden City. This unit is overlain by a 1 to 3 foot (1 meter) bed of white to green, thinly laminated, glauconitic, feldspathic, dolomitic siltstone informally referred to as the Blue Earth siltstone.

The dolomitic facies of the Coon Valley Member is absent along the Minnesota River near Mankato in Blue Earth and Nicollet Counties and instead a light gray, medium- to coarse-grained, quartz sandstone informally referred to as the Kasota sandstone overlies the Jordan Sandstone (Fig. 3). The Kasota sandstone ranges from a few inches to 7 feet (2 meters) thick; it disconformably overlies the Jordan Sandstone and conformably underlies the Blue Earth siltstone. The Kasota sandstone contains Ordovician-age fauna (Powell, 1935; Stauffer and Thiel, 1941) equivalent in age to the lower part of the Coon Valley Member. The lithic similarity of the Kasota sandstone to the Jordan Sandstone makes it impractical to map as a separate unit using subsurface data, therefore it was mapped as the Jordan Sandstone (unit **Cj**). The Blue Earth siltstone along the Minnesota River is generally not thicker than 3 feet (1 meter) and contains a high abundance of Ordovician-age conodonts equivalent in age to the upper Coon Valley Member.

Large, meter-scale, solution-enlarged vugs and fractures are particularly common in exposures of the lowermost Hager City Member along the Minnesota River from Mankato to St. Peter. These features are entirely filled with a gray to white shale, siltstone, and sandstone (Fig. 3). The similarity of this material to the underlying Blue Earth siltstone, Kasota sandstone, and Jordan Sandstone, as well as the deformational fabrics in these units in some outcrops, suggests much of the fill was injected upward into the lower Hager City Member voids (Graham, 1933; Powell, 1935). Other outcrops show a clear gradational contact between the cavity fill and weathered carbonate rock of the Hager City Member, representing a residuum of dissolved carbonate. A high abundance of conodonts in some samples of fill might reflect a concentration of phosphatic material as part of the residuum. The origin of the fill material remains problematic and most likely has no single origin.

**Cj** **Jordan Sandstone (Upper Cambrian)**—Dominantly white, light gray and tan, fine- to coarse-grained, quartz sandstone, siltstone, and shale. The Jordan Sandstone is characterized by two interlayered facies (Runkel, 1994). They are a medium- to coarse-grained, cross-stratified, friable, quartzose sandstone more common near the top; and a very fine-grained, bioturbated, feldspathic sandstone with lenses of siltstone and shale most common near the base. The Jordan Sandstone is 60 to 100 feet (18 to 30 meters) thick where it is undissected by erosion. Abundant exposures of the Jordan Sandstone can be seen along the Minnesota, Blue Earth, and Le Sueur Rivers. The Jordan Sandstone subcrops in the central portion of the map area and within deeply incised and buried bedrock valleys. An unconformity exists between the Jordan Sandstone and the overlying Oneota Dolomite that represents a major hiatus (Runkel and others, 1999, 2007). However, due to the complex stratigraphic relationship at this contact (Fig. 3), the medium- to coarse-grained Ordovician-age Kasota sandstone is mapped as Jordan Sandstone in Blue Earth County because the two units cannot be distinguished on subsurface data alone.

**Csl** **St. Lawrence Formation (Upper Cambrian)**—Light gray, pale yellowish-green to light pink, dolomitic, feldspathic siltstone with interbedded, very fine-grained sandstone and shale. Dolostone and dolomitic sandstone beds typically have shale and sandstone intraclasts at the base. Laminated green shale and pink to red dolomite interbeds are particularly abundant in the lower half of the formation. The glauconite content in the dolostone decreases toward the top of the formation and the contact with the Jordan Sandstone is conformable and gradational. The contact with the underlying Lone Rock Formation is also gradational. The St. Lawrence Formation is typically 45 to 80 feet (14 to 24 meters) thick where it is undissected by erosion. It subcrops west of the erosional edge of the Jordan Sandstone and occurs at the base of several deeply incised bedrock valleys throughout Blue Earth County. Exposures can be seen along the Minnesota River near Judson.

**Clr** **Lone Rock Formation (Upper Cambrian)**—Variegated sandstone, siltstone, and shale with subordinate beds of dolostone ranging from 100 to 130 feet (30 to 40 meters) in thickness. Sandstone is yellowish-gray to green, very fine- to fine-grained, quartzose, feldspathic, and glauconite-rich. It is commonly interbedded with greenish-gray shale partings. Mica is abundant along laminations in the sandstone and siltstone. Dolostone is light tan to pink, contains sandstone intraclasts, and becomes more abundant toward the base of the formation. Glauconite is present throughout but is most abundant in the basal part of the formation. Linguliform brachiopod fragments are rare but do occur in the lower half of the formation. This unit subcrops across the westernmost part of Blue Earth County. The uppermost part of the formation is exposed in small outcrops near Judson on the north banks of the Minnesota River. The upper contact of the Lone Rock Formation with the St. Lawrence Formation is conformable and gradational, and the lower contact is conformable with the underlying Wonewoc Sandstone.

**Cw** **Wonewoc Sandstone (Upper Cambrian)**—Fine- to coarse-grained, moderately sorted, friable, white to tan, quartzose sandstone with white linguliform brachiopod shells. The lower portion of the formation is typically finer-grained and better sorted. Glauconite is present in the upper part of the formation and absent in the remainder. The formation is present throughout the subsurface of Blue Earth County and subcrops only in the extreme northwestern portion of the map area. The Wonewoc Sandstone ranges in thickness from 50 to 80 feet (15 to 24 meters). Contacts with formations above and below are conformable and transitional. A subtle unconformity is present in this formation (Runkel and others, 1998); however, it is not practical to subdivide the formation into two separate units on the basis of subsurface data.

**Ce** **Eau Claire Formation (Middle to Upper Cambrian)**—Variegated light green, feldspathic siltstone, shale, and fine-grained sandstone with subordinate light pink dolomite. Shale is dominantly green, white, and red. Sandstone is white to tan to pink and well-cemented with calcite. Glauconite and white to brown linguliform brachiopod shells are present throughout the formation and are most commonly associated with the dolostone beds. The Eau Claire Formation is 60 to 80 feet (18 to 24 meters) thick. This formation subcrops at the base of a buried bedrock valley in the extreme northwestern portion of the county. The contact with the Mt. Simon Sandstone is gradational and contains beds of medium- to coarse-grained Mt. Simon Sandstone interbedded within the very fine- to fine-grained sandstone of the Eau Claire Formation.

**Cm** **Mt. Simon Sandstone (Middle Cambrian)**—Fine- to coarse-grained, white to light gray to pale yellowish-brown, quartzose sandstone with thin interbeds of white and green feldspathic shale and siltstone. The sandstone is generally very friable to poorly cemented. Pebbles of vein quartz are present near its base and scattered white linguliform brachiopod shells are common in the upper one-third of the formation. The Mt. Simon Sandstone is 150 to 350 feet (46 to 107 meters) thick. It unconformably overlies the Mesoproterozoic Hinckley Sandstone throughout most of Blue Earth County and undivided Archean and Paleoproterozoic rocks near the western border of Blue Earth County.

### MESOPROTEROZOIC ROCKS

**Ehs** **Hinckley Sandstone, Fond du Lac Formation, and Solor Church Formation (shown only on cross sections)**

***Hinckley Sandstone and Fond du Lac Formation***—The Hinckley Sandstone is salmon-colored, very fine- to medium-grained, moderately to well sorted, quartzose sandstone, siltstone, and shale. Sandstone is variably cemented with quartz. Red-brown shale and siltstone are present in the lower part of the formation. The Fond du Lac Formation is reddish-orange to yellow-brown, feldspathic sandstone, siltstone, and shale. Sandstone is poorly sorted with grains that tend to be subrounded to angular (Morey, 1977; Boerboom, 2001). The combined thicknesses of the Fond du Lac Formation and Hinckley Sandstone are interpreted to be up to thousands of feet in the easternmost part of Blue Earth County based on the sparse number of wells that penetrate these units. However, the Hinckley Sandstone is discontinuous and represents only a small fraction of that thickness.

***Solar Church Formation***—Interbedded sandstone, siltstone, and shale. Sandstone and siltstone are generally red to pale reddish-brown and the shale is dark reddish-brown in color although dark to light greenish-gray shale beds occur at depth (Morey, 1977). Sandstone is poorly to moderately sorted with angular to subrounded grains. The rock is mineralogically immature and contains appreciable amounts of feldspar grains and volcanic rock fragments (Morey, 1977). It may be carbonate rich, especially in its upper part. The Solar Church Formation is thousands of feet thick like the Fond du Lac Formation. However, its thickness is extremely variable because of faulting of the Mesoproterozoic rocks.

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