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BEDROCK GEOLOGY

By
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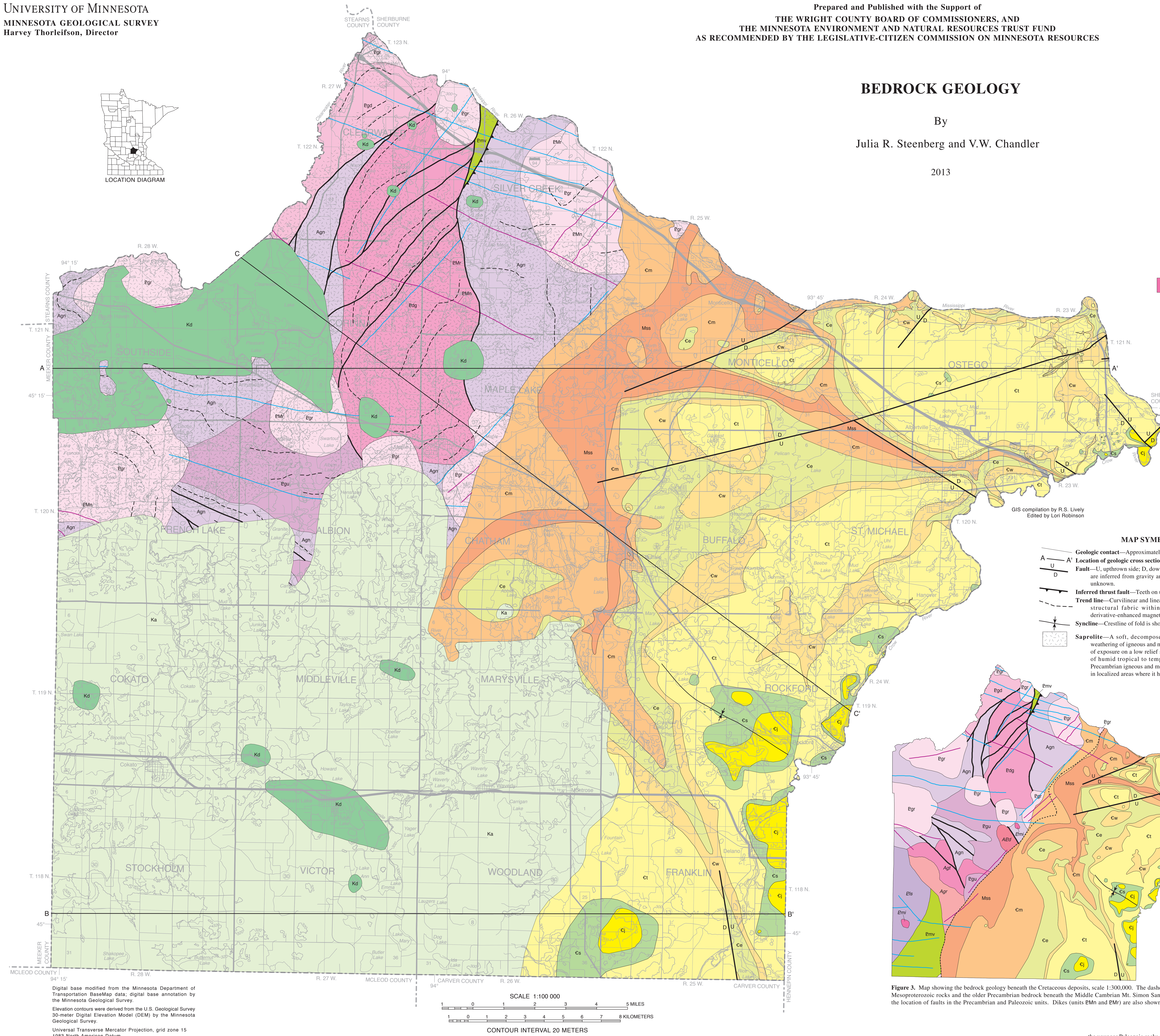
2013

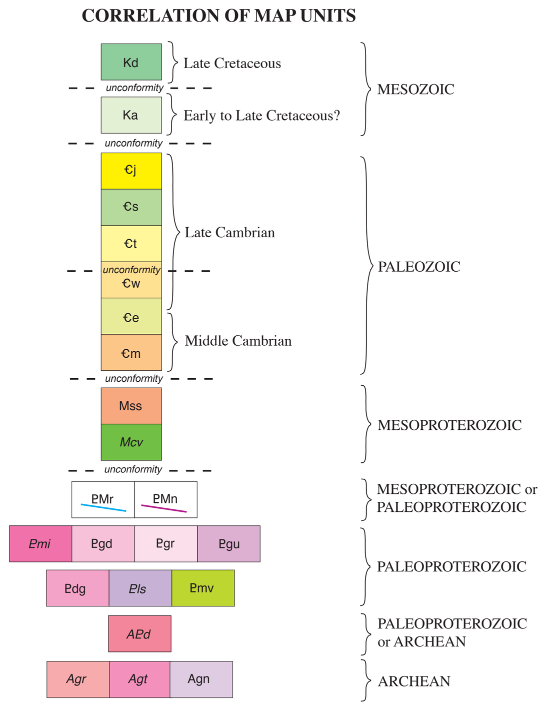


Digital base modified from the Minnesota Department of Transportation BaseMap data; digital base annotation by the Minnesota Geological Survey.

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

CORRELATION OF MAP UNITS



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.

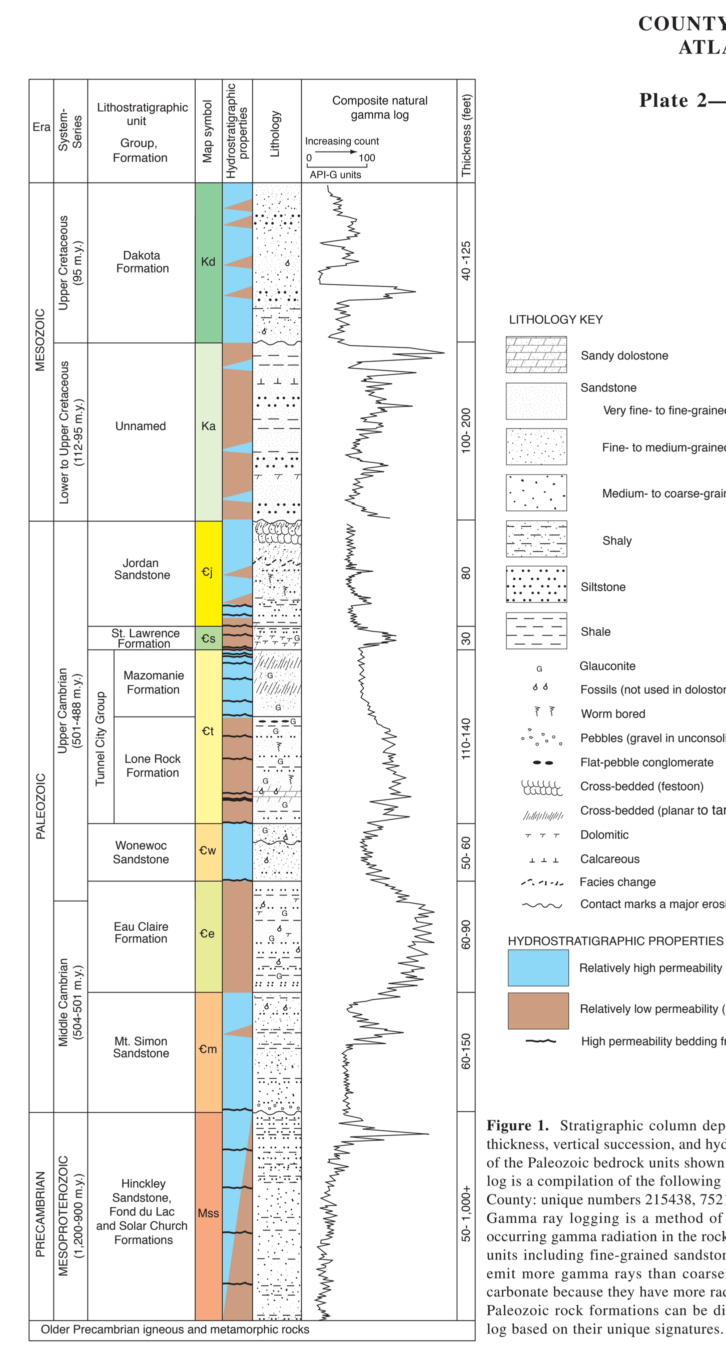


Figure 1. Stratigraphic column depicting the age, lithology, thickness, vertical succession, and hydrostratigraphic properties of the Paleozoic bedrock units shown on the map. The gamma log is a compilation of the following gamma logs from Wright County: unique numbers 215438, 752116, 757620, and 773224. Gamma ray logging is a method of measuring the naturally occurring gamma radiation in the rock units. The finer-grained units including fine-grained sandstone and siltstone typically emit more gamma rays than coarser-grained sandstone and carbonate because they have more radioactive potassium. The Paleozoic rock formations can be distinguished on a gamma log based on their unique signatures.

MAP SYMBOLS

Geologic contact—Approximately located.

Location of geologic cross section

Fault—U, upthrown side; D, downthrown side. Faults in Precambrian rocks are inferred from gravity and magnetic anomaly data; offset sense is unknown.

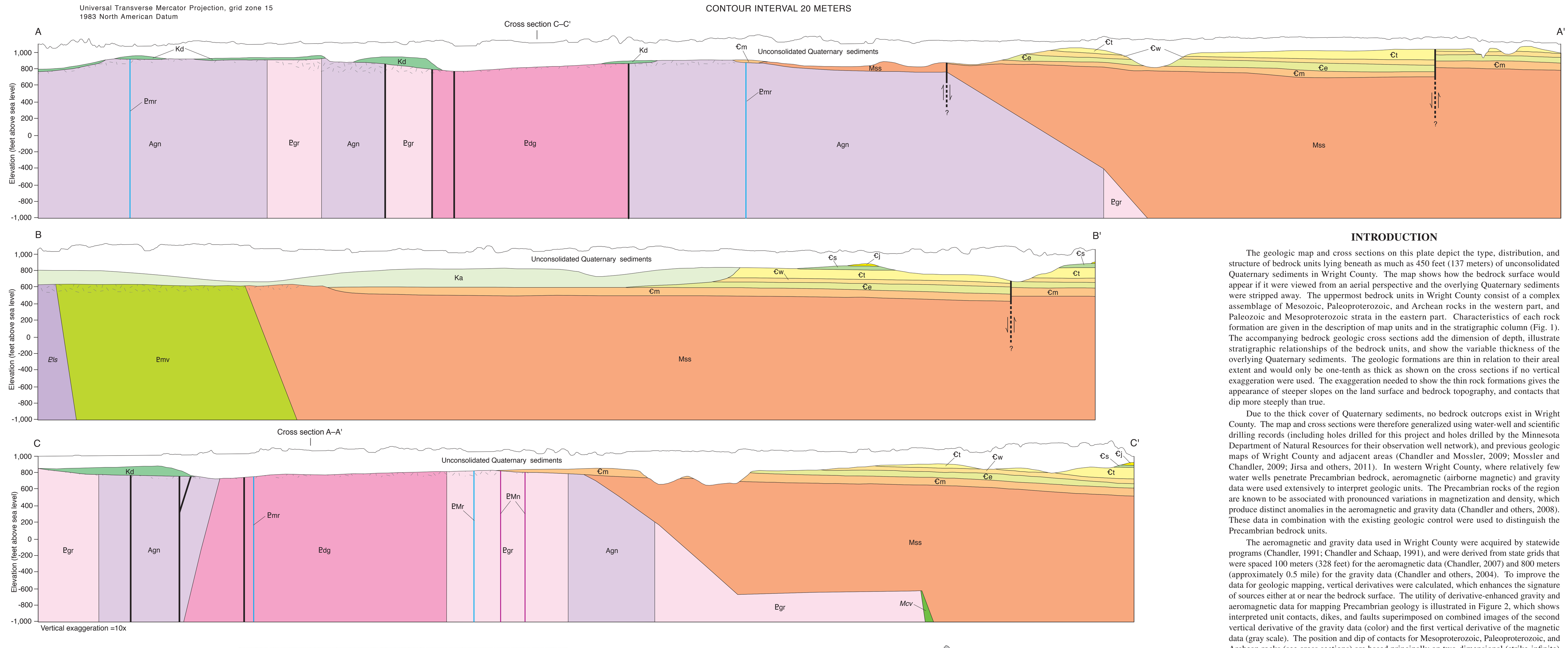
Inferred thrust fault—Teeth on upper plate.

Trend line—Curvilinear and linear trends of magnetic anomalies, reflecting structural fabric within Precambrian rocks. Inferred from derivative-enhanced magnetic data.

Syncline—Crestline of fold is shown.

Saprolite—A soft, decomposed rock derived primarily from in situ weathering of igneous and metamorphic rocks either from long periods of exposure on a low relief surface or intense weathering during times of humid tropical to temperate climate. Inferred to overlie all Precambrian igneous and metamorphic rocks in Wright County except in localized areas where it has been removed by subsequent erosion.

Figure 3. Map showing the bedrock geology beneath the Cretaceous deposits, scale 1:300,000. The dashed line indicates the contact between the Mesoproterozoic rocks and the older Precambrian bedrock beneath the Middle Cambrian Mt. Simon Sandstone. The thick black lines represent the location of faults in the Paleozoic and Precambrian units. Dikes (units ᵽMn and ᵽMr) are also shown.



INTRODUCTION

The geologic map and cross sections on this plate depict the type, distribution, and structure of bedrock units lying beneath as much as 450 feet (137 meters) of unconsolidated Quaternary sediments in Wright County. The map shows how the bedrock surface would appear if it were viewed from an aerial perspective and the overlying Quaternary sediments were stripped away. The uppermost bedrock units in Wright County consist of a complex assemblage of Mesozoic, Paleoproterozoic, and Archean rocks in the western part, and Paleozoic and Mesoproterozoic strata in the eastern part. Characteristics of each rock formation are given in the description of map units and in the stratigraphic column (Fig. 1). The accompanying bedrock geologic cross sections add the dimension of depth, illustrate stratigraphic relationships of the bedrock units, and show the variable thickness of the overlying Quaternary sediments. 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, and contacts that dip more steeply than true.

Due to the thick cover of Quaternary sediments, no bedrock outcrops exist in Wright County. The map and cross sections were therefore generalized using water-well and scientific drilling records (including holes drilled for this project and holes drilled by the Minnesota Department of Natural Resources for their observation well network), and previous geologic maps of Wright County and adjacent areas (Chandler and Mossler, 2009; Mossler and Chandler, 2009; Jirsa and others, 2011). In western Wright County, where relatively few water wells penetrate Precambrian bedrock, aeromagnetic (airborne magnetic) and gravity data were used extensively to interpret geologic units. The Precambrian rocks of the region are known to be associated with pronounced variations in magnetization and density, which produce distinct anomalies in the aeromagnetic and gravity data (Chandler and others, 2008). These data in combination with the existing geologic control were used to distinguish the Precambrian bedrock units.

The aeromagnetic and gravity data used in Wright County were acquired by statewide programs (Chandler, 1991; Chandler and Schaap, 1991), and were derived from state grids that were spaced 100 meters (328 feet) for the aeromagnetic data (Chandler, 2007) and 800 meters (approximately 0.5 mile) for the gravity data (Chandler and others, 2004). To improve the data for geologic mapping, vertical derivatives were calculated, which enhances the signature of sources either at or near the bedrock surface. The utility of derivative-enhanced gravity and aeromagnetic data for mapping Precambrian geology is illustrated in Figure 2, which shows interpreted unit contacts, dikes, and faults superimposed on combined images of the second vertical derivative of the gravity data (color) and the first vertical derivative of the magnetic data (gray scale). The position and dip of contacts for Mesoproterozoic, Paleoproterozoic, and Archean rocks (see cross sections) are based principally on two-dimensional (strike-infinite) modeling of gravity and magnetic data along profiles and the existing geologic control. Rock property data (Chandler and Lively, 2011) have been used to help constrain modeling, and where appropriate, end corrections have been applied to anomaly sources that terminate near the model profiles.

The oldest mapped Precambrian bedrock in Wright County consists of Paleoproterozoic and Archean rocks (see Fig. 3 for the full coverage of theses rocks beneath the younger Cretaceous deposits). The Paleoproterozoic rocks are associated with the Penokean (~1,850 Ma) and Yavapai (~1,780 Ma) orogenies. These two plate-convergent events were associated with extensive accretion and magmatism, through which a considerable amount of crustal material was added to the southeastern margin of an Archean craton represented by the ~2,700 Ma Superior Province (Holm and others, 2007). During the Penokean orogeny, northwest-verging thrusting of Archean and Paleoproterozoic rocks formed a series of terranes in which disparate slivers of rock were tectonically stacked and metamorphosed (Southwick and Morey, 1991; Schulz and Cannon, 2007). Within this framework, the Archean rocks that are inferred to occur in western Wright County (units Agn, *Agt*, and *Agr*) would most likely represent rocks of the Superior Province craton, and the metamorphosed Paleoproterozoic rocks and Archean gneissic rocks inferred in the southwestern and north-central parts of the county (units ᵽmv, ᵽdg, *ᵽls*, *Aᵽd*, Agn) would represent rocks that were accreted or emplaced during the Penokean orogeny. The Yavapai orogeny in east-central Minnesota was contemporaneous with extensive emplacement of granitoid intrusions, which are collectively referred to as the East-Central Minnesota Batholith (Holm and others, 2005), and the Paleoproterozoic intrusions inferred in the northwestern and north-central parts of Wright County (units *ᵽmi*, ᵽgd, ᵽgr, ᵽgu) are most likely related to this event.

The Mesoproterozoic rocks occur as a narrow band of subcrop that extends north from McLeod County into south-central Wright County, where it forms the bedrock surface between the younger Paleozoic rocks to the east and the older Precambrian rocks to the west (Fig. 3). The Mesoproterozoic rocks also locally form the bedrock surface in parts of northeastern Wright County, where erosion along paleo-valleys has cut through the Paleozoic strata. These rocks thicken eastwards beneath the Paleozoic formations from less than 100 feet (30 meters) to thousands of feet where they accumulated as part of the development of the Midcontinent Rift (see cross sections). The rift formed during a thermo-tectonic event 1,200 to 900 million years ago that involved extension of the earth's crust with concurrent faulting, volcanism, plutonism, and later deposition of a thick sequence of sedimentary rocks (Chandler and others, 1989). Collectively, these rocks form the Keweenawan Supergroup and Midcontinent Rift Intrusive Supersuite. The thick sequence of the Mesoproterozoic sedimentary rocks (unit Mss) is poorly known in Wright County, represented only by a few drill cuttings and gamma logs. Therefore, they cannot be assigned to particular formations, but likely correlate with parts of the Hinckley Sandstone, Fond du Lac, and Solor Church Formations.

The Paleozoic rocks are characterized by widespread layers of sandstone, siltstone, shale, and carbonate deposited in shallow seas during the Cambrian period of the Paleozoic era from about 500 to 488 Ma. Sandstone and siltstone dominate these formations—shale and carbonate occur only as relatively thin layers in these units. The geology of the Paleozoic rocks is based largely on descriptions from driller's logs, and where available, cuttings and geophysical logs from municipal and other deep wells. The distribution of the Paleozoic rock units is primarily influenced by the east to southeasterly regional dip of the Paleozoic bedrock reflected on the map by the progression of younger to older formations to the west and northwest and erosion within the paleo-valleys that expose older formations (Fig. 3).

The Cretaceous sedimentary rocks (Kd and Ka), which locally cover Precambrian and Paleozoic rocks in Wright County, consist of poorly lithified mudstone and sandstone. They were likely laid down continuously across the area, but are subsequently eroded to produce scattered erosional remnants. The mapped distribution of these units is much more speculative than for other units because of the presence of profound unconformities bounding these strata, and because information from drillers' logs and geophysical techniques are typically inadequate to consistently distinguish these strata from quartz-rich Quaternary sand, organic-rich Quaternary lake sediments, or saprolite on top of Precambrian rocks. The Late Cretaceous Dakota Formation (Kd) represent the easternmost extension of a large, nearly continuous subcrop area of strata generally correlative with the Dakota Formation (Setterholm, 1990). These rocks were likely deposited 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. This unit is lithically similar to well-dated mudstones, siltstones, and sandstones from Nicollet and Brown Counties to the south that contain a rich and diverse assemblage of palynomorphs with pollen taxa that are considered to be no older than Late Cretaceous (late Cenomanian) in age (Hu and others, 2008). The Early Cretaceous unit (Ka), which is formally known and mapped as the Phanerozoic undifferentiated unit (PMu) in adjacent counties (Chandler and Mossler, 2009; Mossler and Chandler, 2009). Although it has not yielded fossils in Wright County, gymnosperm pollens and dinoflagellate cysts extracted from lithologically similar strata from drill core in McLeod County to the south are indicative of a latest Albian to Cenomanian age (Early to Late Cretaceous; Ravn, unpub. data, 2009). The saprolite in Wright County consists of a white to greenish-gray or red kaolin-rich clay that generally grades downward into to less altered crystalline material with angular quartz, feldspar, and micaceous grains in a clayey matrix, then into hard, fresh Precambrian bedrock. Though the precise timing and nature of the weathering process that created the saprolite is unknown, it is present beneath Cretaceous sediments and the Middle Cambrian Mt. Simon Sandstone. Therefore, we know that saprolite development occurred on the same Precambrian surface at least twice, once prior to the deposition of the Mt. Simon Sandstone and again prior to the deposition of the Cretaceous strata.

The geologic structures in Wright County consist of faults and folds inferred from borehole data, additional constraints provided by patterns in aeromagnetic anomalies. The faults in eastern Wright County that have caused vertical displacement of Paleozoic and Mesoproterozoic strata on the order of 50 to 100 feet (15 to 30 meters), sufficient to juxtapose two different formations along the fault contact. Blocks of bedrock that have dropped down alongside faults preserve remnants of relatively young formations and uplifted blocks locally have brought older formations closer to the surface. These faults are interpreted to represent reactivation of Precambrian structures related to the Mesoproterozoic Midcontinent Rift. The structural contours of the top of the Precambrian rocks depicted in Figure 4, where not shaded, are based on the elevation of the stratigraphic top of the Mesoproterozoic rocks. These contours depict the range in vertical displacement along each of these inferred faults based on the offset seen in the Paleozoic and Mesozoic rocks from borehole data.

Very little can be inferred regarding the sense of displacement of the Precambrian faults in western Wright County. These faults, which are wholly based on gravity and magnetic data, are interpreted to strike predominantly to the northeast and northwest (Fig. 2), and model studies for constructing the cross sections indicate that most faults are essentially vertical, although some in the north-central part of the county may dip steeply eastwards. A generally northwest-directed convergence has been envisioned for Paleoproterozoic tectonism in this part of North America (Holm and others, 2007), so the faults inferred in western Wright County could have originated as thrust or strike-slip faults. No information exists regarding possible Phanerozoic reactivation, except that in areas of Cretaceous rocks overlying some of these faults, indicating there has been no activity since the Cretaceous period.

HYDROSTRATIGRAPHIC PROPERTIES

Stratified (layered) sedimentary bedrock is a significant source of ground water in Wright County. This map and associated products, such as the bedrock Digital Elevation Models, provide a three-dimensional depiction of the rock properties that control flow in these water-bearing layers. Such rock properties are called hydrostratigraphic properties. The hydrostratigraphic properties shown in the stratigraphic column (Fig. 1) distinguish layers that have relatively high permeability (easily transmits water), versus layers that have lower permeability (relatively more difficult to transmit water). The high permeability layers are potential aquifers that are able to store and yield water in usable quantities in most places. The low permeability layers are potential aquitards that retard fluid flow, generally separating the aquifer layers from one another in many places.

In Wright County, most aquifers are layers dominated by relatively coarse-grained sandstone such as the Wonewoc Sandstone. Aquitards are composed mostly of finer-grained sandstone, siltstone, and shale with a much lower permeability, such as the Eau Claire Formation. However, layers designated as aquifers can locally contain low permeability strata that serve as internal aquitards including parts of the upper Mt. Simon and the lower Jordan Sandstones. Conversely, aquitards that have very low permeability in a vertical direction commonly contain horizontal fractures that are conductive enough to yield large quantities of water; the St. Lawrence Formation is an example. Horizontal as well as vertical fractures are more common when bedrock layers are at or near the bedrock surface (unconfined by overlying strata). As a result, aquitards in such conditions may be especially conductive and have a diminished ability to retard water flow to underlying aquifers. This generalized characterization for Wright County is based on hydrogeologic reports by Runkel and others (2003, 2006a, b), Tipping and others (2006), and unpublished borehole and core data collected by the Minnesota Geological Survey in the general Twin Cities Metropolitan area. The relatively hard Precambrian "crystalline" bedrock locally supplies water to domestic wells in northwestern Wright County, derived largely from water-bearing fractures.

Hydrogeologic data and interpretations by the Minnesota Department of Natural Resources as part B of the Wright County atlas may result in modifications to the hydrostratigraphic characterization presented here. Furthermore, the well construction regulations of the Minnesota Department of Health may not correspond precisely in designation of aquifers and aquitards.

DESCRIPTION OF MAP UNITS

MESOZOIC ROCKS

Kd **Dakota Formation (Upper Cretaceous)**—Interbedded sandstone, siltstone, and mudstone. Sandstone is quartzose and white to light gray to brown or orange in color. It is generally friable with minor iron oxide and calcite cement. Sand grains are fine- to coarse-grained and subangular to subrounded. Mudstone is dark gray to brown, non-calcareous, with light brown to white silty laminations. Black lignite plant fragments and well-cemented siderite concretions have been found in drill cuttings and core in the sandstone, siltstone, and mudstone. Nearly whole shells of articulated calcareous bivalves have also been found in dark organic-rich clay from drill core. The formation is 40 to 125 feet (12 to 38 meters) thick and disconformably overlies the undifferentiated unit (Ka), saprolite, and Precambrian crystalline rock at elevations between 730 and 840 feet (223 and 256 meters) above sea level.

Ka **Undifferentiated (Lower to Upper Cretaceous?)**—Red-brown to pale olive mudstone and siltstone with interbedded yellow-gray, very fine- to medium-grained sandstone. Generally friable but does contain local iron-rich concretions, intergranular carbonate cement, or pyrite mineralization. Faint horizontal laminations and layering are recorded in some beds, others are very uniform and massive, and some are convoluted by soft sediment deformation. The unit is as thick as 200 feet (61 meters) in southwest Wright County. It unconformably overlies saprolite and the Late Cambrian and Precambrian formations at elevations between 530 and 670 feet (162 to 204 meters) above sea level.

PALEOZOIC ROCKS

Ꞓj **Jordan Sandstone (Upper Cambrian)**—Dominantly tan to light gray, fine- to coarse-grained sandstone characterized by coarsening-upward sequences consisting of two interlayered facies (Runkel, 1994), which are not separated on the map. They are medium- to coarse-grained, cross-stratified, generally friable, quartz sandstone; and a very fine-grained, commonly bioturbated, feldspathic sandstone with lenses of siltstone and shale. The fine-grained facies is best developed in the basal 30 feet (9 meters). The Jordan Sandstone reaches a maximum eroded thickness of 90 feet (27 meters) in Wright County and is present only in the easternmost part of the county.

Ꞓs **St. Lawrence Formation (Upper Cambrian)**—Dominantly tan, white to light gray, very fine- to fine-grained quartzose sandstone with interbedded pale yellowish-green feldspathic siltstone and light green shale. Light pink to gray dolomite cement as well as dark green to black glauconite grains occur in the lower portion. The formation is 20 to 35 feet (6 to 10 meters) thick where uneroded. It occurs in the easternmost part of the map area. The upper contact with the Jordan Sandstone is conformable and gradational. The gradational nature of the contact can make selecting a precise contact between these formations problematic even in borehole cuttings samples and natural gamma logs.

Ꞓt **Tunnel City Group (Upper Cambrian)**—Formerly referred to as the Franconia Formation (Mossler, 2008). It is 115 to 130 feet (35 to 40 meters) thick where it has not been eroded and is divided into two formations not shown separately on the map: the Mazomanie Formation and the Lone Rock Formation. The Mazomanie Formation is dominantly white to yellowish-gray, fine- to medium-grained, cross-stratified, friable, quartz sandstone with minor amounts of glauconite. The Mazomanie Formation is present in the upper 40 feet (12 meters) of the Tunnel City Group and is mostly restricted to the northeastern part of the map area. The Lone Rock Formation underlies the Mazomanie Formation and intertongues with it in Wright County. It is a very fine-to fine-grained, glauconite-rich, feldspathic sandstone and siltstone interbedded with very thin, greenish-gray shale partings. Thin to medium beds of pink, orange, and dark red dolostone are present in the lower third of the formation. These beds also contain minor amounts of white linguliform brachiopod shells. The contact between the Tunnel City Group and the overlying St. Lawrence Formation is conformable but fairly distinct between the fine- to medium-grained quartzose sandstone of the Mazomanie Formation and the silty sandstone and shale of the St. Lawrence Formation.

Ꞓw **Wonewoc Sandstone (Upper Cambrian)**—Formerly referred to as the Ironton-Galesville Sandstone (Mossler, 2008). It is white, light gray to yellowish in color, quartzose, and generally friable with little cement. Grains are fine- to coarse-grained, moderately- to well-rounded. The lower part of the formation is the finest-grained and better sorted; the upper part is coarsest-grained and more poorly sorted with a larger range of grain sizes. Minor amounts of siltstone and green to blue shale beds are interbedded throughout the formation, but are more common near the base. Green to black glauconite grains occur in the upper part of the formation and white to tan linguliform brachiopod shells occur throughout the formation. The Wonewoc Sandstone is about 50 feet (15 meters) thick where it is not eroded. The contact between the Wonewoc Sandstone and the Tunnel City Group is conformable and distinct. A regional unconformity is present within the Wonewoc Sandstone (Runkel and others, 1998), though it is not possible to distinguish it through examination of borehole cuttings samples or geophysical logs.

Ꞓe **Eau Claire Formation (Middle to Upper Cambrian)**—Yellowish-gray to grayish-purple, fine- to very fine-grained, feldspathic sandstone, siltstone, and shale. White and brown linguliform brachiopod shells are common throughout the formation. Some beds are slightly glauconitic. The Eau Claire Formation has a maximum thickness of 70 feet (21 meters). The contact between the Eau Claire Formation and the overlying Wonewoc Sandstone is conformable and distinct.

Ꞓm **Mt. Simon Sandstone (Middle Cambrian)**—Dominantly white to pale yellowish-gray to orange-pink, medium- to coarse-grained, quartz sandstone. Quartz grains are frosted and well rounded. Interbeds of grayish-green shale, pale olive dolomitic siltstone, and very fine-grained feldspathic sandstone are common, particularly in the upper half of the formation. Linguliform brachiopods are also common in the upper one-third of the formation. The basal part has more very coarse-grained sandstone and it is commonly conglomeratic at the base with pebbles of polycrystalline quartz that are generally white to tan in color. The formation is generally very friable and poorly cemented with pyrite and calcite cement present locally. The Mt. Simon Sandstone is about 60 to 150 feet (18 to 34 meters) thick where it has not been eroded. The contact with the overlying Eau Claire Formation is conformable and transitional. Shale and dolomitic siltstone of the Eau Claire Formation are commonly interbedded with the coarser-grained, quartzose Mt. Simon Sandstone. In Wright County the Mt. Simon Sandstone unconformably overlies part of the Mesoproterozoic rocks (unit Mss) and older Precambrian units at elevations between 250 and 850 feet (76 and 259 meters) above sea level (see Fig. 4 and cross sections).

MESOPROTEROZOIC ROCKS

Keweenawan Supergroup and Midcontinent Rift Intrusive Supersuite

Mss **Sandstone, siltstone, and minor shale**—Sedimentary rocks consisting largely of sandstone, with minor amounts of siltstone and shale. The sandstone is salmon colored, quartz-rich, very fine- to medium-grained, and moderately- to well-sorted with variable quartz cement. Reddish-brown siltstone and shale occur mainly in the lower part of the unit as thin beds. These rocks are poorly known in Wright County, represented only by a handful of borehole cuttings samples and gamma logs. Therefore they cannot be confidently assigned to individual formations, but likely correlate with parts of the Hinckley Sandstone, Fond du Lac, and Solor Church Formations. Geophysical modeling implies that this unit is more than 0.9 mile (1.5 kilometers) thick in the easternmost part of the map area beneath the Paleozoic rocks, and thins to less than 100 feet (30 meters) to the west at the edge of the Paleozoic rocks.

Mcv **Chengwatana Volcanic group** (shown only on cross section C–C')—Volcanic rocks, mainly basalt flows. Restricted to areas beneath the Hinckley Sandstone, Fond du Lac, and Solor Church Formations (unit Mss). The distribution of this unit is inferred from modeling of gravity and magnetic data.

PALEOPROTEROZOIC OR MESOPROTEROZOIC ROCKS

Aeromagnetic anomalies inferred to be diabasic dikes. Dike widths are inferred to be generally less than 328 feet (100 meters) based on exposures elsewhere (Boerboom and others, 1995).

ᵽMn **Dike inferred from positive magnetic anomalies**—Mostly northeast-trending, a few northwest- to west-trending. Positive magnetic anomaly signatures in derivative-enhanced magnetic data imply normal magnetic polarity. Magnetic data imply that the northeast-trending dikes are more abundant to the east, toward the Midcontinent Rift, and they may therefore be related to this Mesoproterozoic feature.

ᵽMr **Dike inferred from negative magnetic anomalies**—Mostly west-northwest- to west-trending, a few are northeast-trending. Negative anomaly signatures in derivative-enhanced magnetic data imply reversed magnetic polarity. These dikes most likely correlate with similarly described dikes in east-central Minnesota, including the ᵽd dikes described by Jirsa and others (2003) and some of the ᵽd dikes described by Boerboom and others (1995).

PALEOPROTEROZOIC ROCKS

Rocks associated with the 1,720 to 1,800 Ma Yavapai Orogeny

ᵽmi **Plug-like to dike-like pluton of mafic to ultramafic rock** (shown on Fig. 3)—Composed of serpentinized peridotite, pyroxenite, hornblendite, and hornblende- and mica-bearing diorite and gabbro. Most likely correlated with units ᵽgpu of Boerboom and others (1995) and ᵽp of Jirsa and others (2003) in east-central Minnesota. Plutons of this type are typically associated with small, irregular-to circular magnetic highs. These plutons may be of Yavapai Orogeny affinity (Geon 1,700), although their ages are poorly constrained.

ᵽgu **Granitic rock, undifferentiated**—Largely inferred from gravity and magnetic data. Most commonly associated with subdued magnetic anomaly signatures and intermediate to slightly positive gravity signatures.

ᵽgr **Granite**—Reddish, variably porphyritic, massive; may be most closely related to the St. Cloud Red (~1,779 Ma) and Foley (~1,774, 1,779 Ma) granites (Jirsa and others, 2011). Most commonly associated with a moderate to subdued magnetic anomaly signature and negative gravity signature.

ᵽgd **Gray granodiorite to granite intrusion**—May reflect the eastern extension of the Reformatory Granodiorite (1,783 Ma) from Stearns County to the north. Rock is characterized by a positive magnetic signature and a slightly positive gravity signature (Jirsa and others, 2011).

Rocks associated with the 1,830 to 1,880 Ma Penokean Orogeny

ᵽdg **Granodiorite to gabbroic rock, variably foliated and deformed**—May be coeval with the syn- to late-Penokean Bradbury Creek (~1,877 to 1,857 Ma) and Philbrook (~1,854 Ma) intrusions (Jirsa and others, 2011).

ᵽmv **Metamorphosed volcanic rock**—Interlayered and variably deformed volcanic, volcaniclastic, sedimentary, and hypabyssal intrusive rocks. Inferred from subdued gravity and magnetic signatures, regional geologic context, and modeling of gravity and magnetic data.

ᵽls **Little Falls Formation** (shown only on cross section B–B' and Fig. 3)—Schist and slate of graywacke-mudstone protolith. Based on subdued gravity and magnetic signatures, regional geologic context, and modeling of gravity and magnetic data.

PALEOPROTEROZOIC OR ARCHEAN ROCKS

Aᵽd **Dioritic to granodioritic intrusion of uncertain age** (shown only on Fig. 3)—Based on moderately positive gravity and magnetic signatures and regional geologic context.

ARCHEAN ROCKS

Agr **Granitic intrusion** (shown only on Fig. 3)—Based on subdued gravity and magnetic signatures and regional geologic context.

Agt **Foliated to gneissic intrusive tonalite, granodiorite, and diorite** (shown only on Fig. 3)—Based on gravity and magnetic signature and regional geologic context. Defined by a low-to-moderate gravity signature with magnetic foliation apparent from aeromagnetic maps.

Agn **Granitic to granodioritic orthogneiss**—Based on scattered geologic control, gravity and magnetic signatures, and regional geologic context. Age dates from a drill core of rocks with similar geophysical attributes in Sherburne County to the north range from 3,180 to 2,800 Ma (Van Schmus and others, 2007). May also include equivalents of the 2,700 Ma McGrath Gneiss (Jirsa and others, 2011). Characterized by a moderately complex magnetic signature and a generally positive gravity signature. May locally include variably deformed and metamorphosed Paleoproterozoic rocks.

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A.C. Runkel (Minnesota Geological Survey) compiled information on the hydrostratigraphic properties of the rock units.

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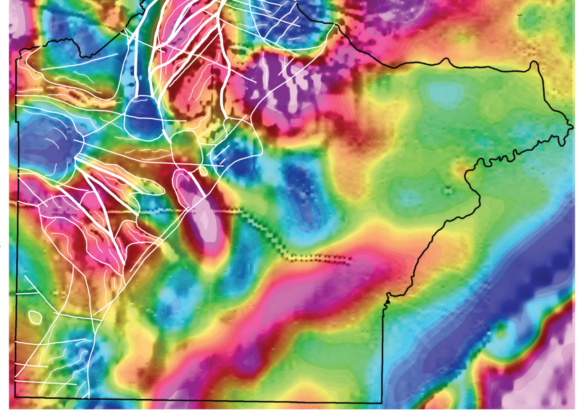

Figure 2. Superimposed geophysical images of first vertical derivative magnetic anomaly data (gray scale) and second vertical derivative gravity data (color) for the Wright County area. The range of first vertical derivative magnetic values is approximately -200 (black) to 200 (white) nanoTeslas/km, and the range of second vertical derivative gravity values is approximately -0.25 (blue) to 0.25 (magenta) milligals/km^2. Geologic contacts and dikes are shown by medium weight white lines, faults are shown by heavy white lines, and trend lines are shown as thin white lines. The anomaly pattern also shows that some Paleoproterozoic features can be traced for several miles to the southeast, beneath the thickening cover of relatively non-magnetic Mesoproterozoic sedimentary rocks. The broad gravity and magnetic high that curves through the southeastern part of Wright County has been interpreted to be caused by Midcontinent Rift lavas, lying about 6,600 feet (2 kilometers) beneath the surface (Chandler, 2009). The sharp, linear magnetic high extending east–west and southeast–northwest across the south-central part of Wright County is caused by a power transmission line.

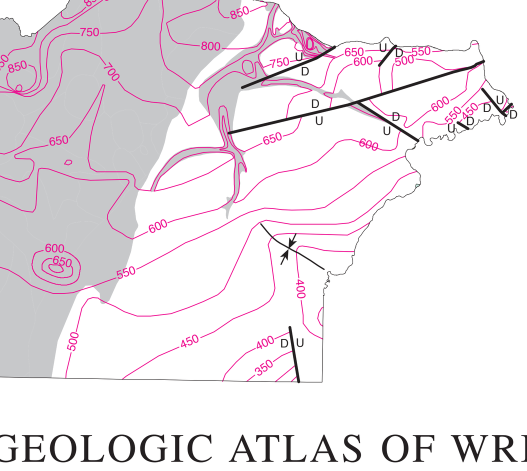

Figure 4. Elevation of the Precambrian bedrock surface; scale 1:500,000. Contour interval is 50 feet (15 meters). In eastern Wright County where the map is not shaded, the contours are based on the stratigraphic top of the Mesoproterozoic rocks (unit Mss). Because of the scarcity of data, contours are inferred from vertical projection of other formation contacts where available. The faults and fold (with arrows) shown on this figure represent the structures found in the Paleozoic and Mesozoic units. Areas where the Precambrian rocks exist as uppermost bedrock and have been partially eroded are shaded.