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COUNTY ATLAS SERIES
ATLAS C-39, PART A
Washington County
Plate 2—Bedrock Geology

BEDROCK GEOLOGY

By

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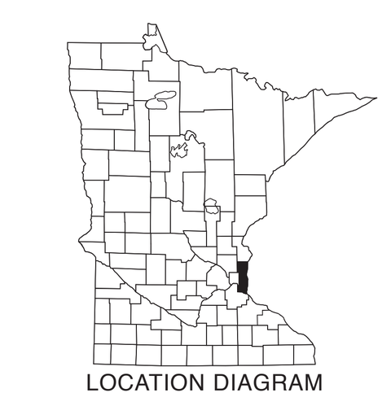
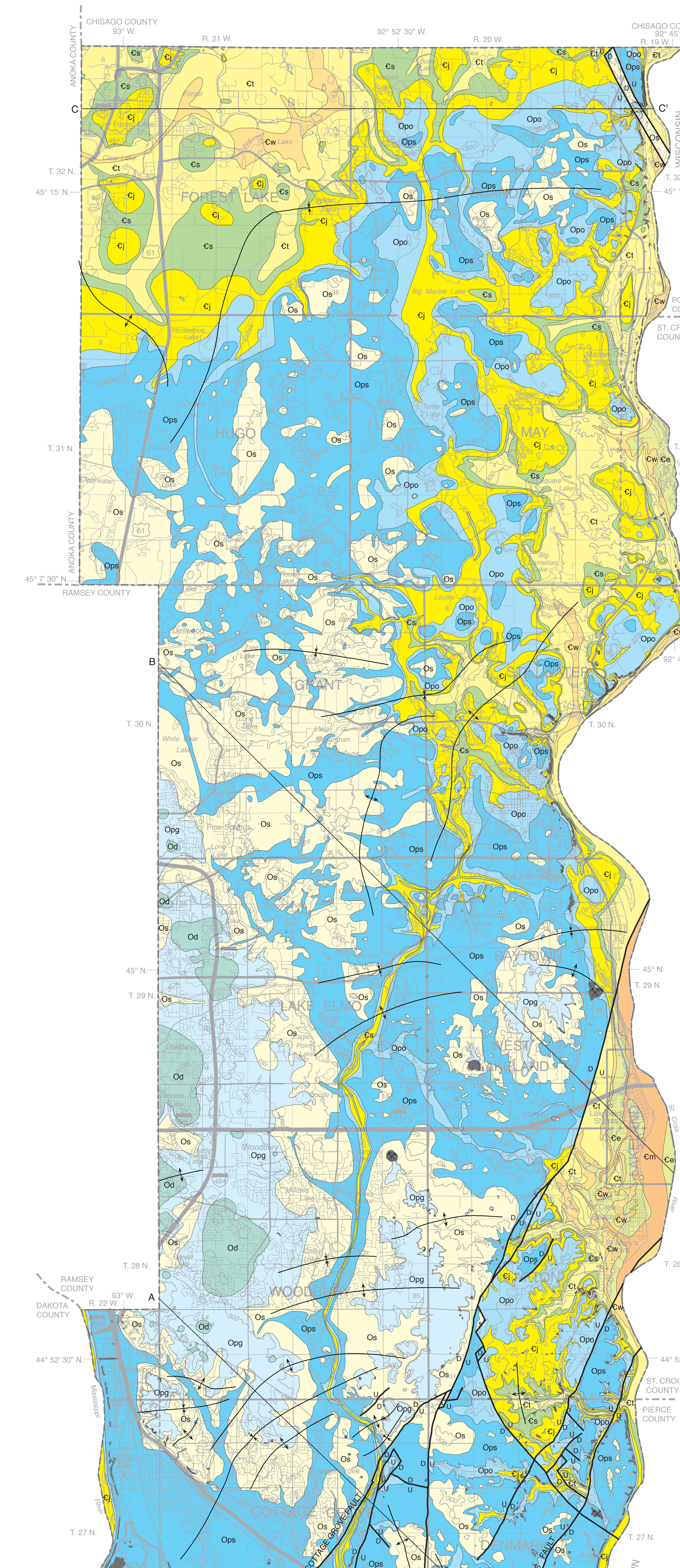
2016





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

GIS compilation by R.S. Lively
Edited by Lori Robinson

SCALE 1:100 000

CONTOUR INTERVAL 25 METERS

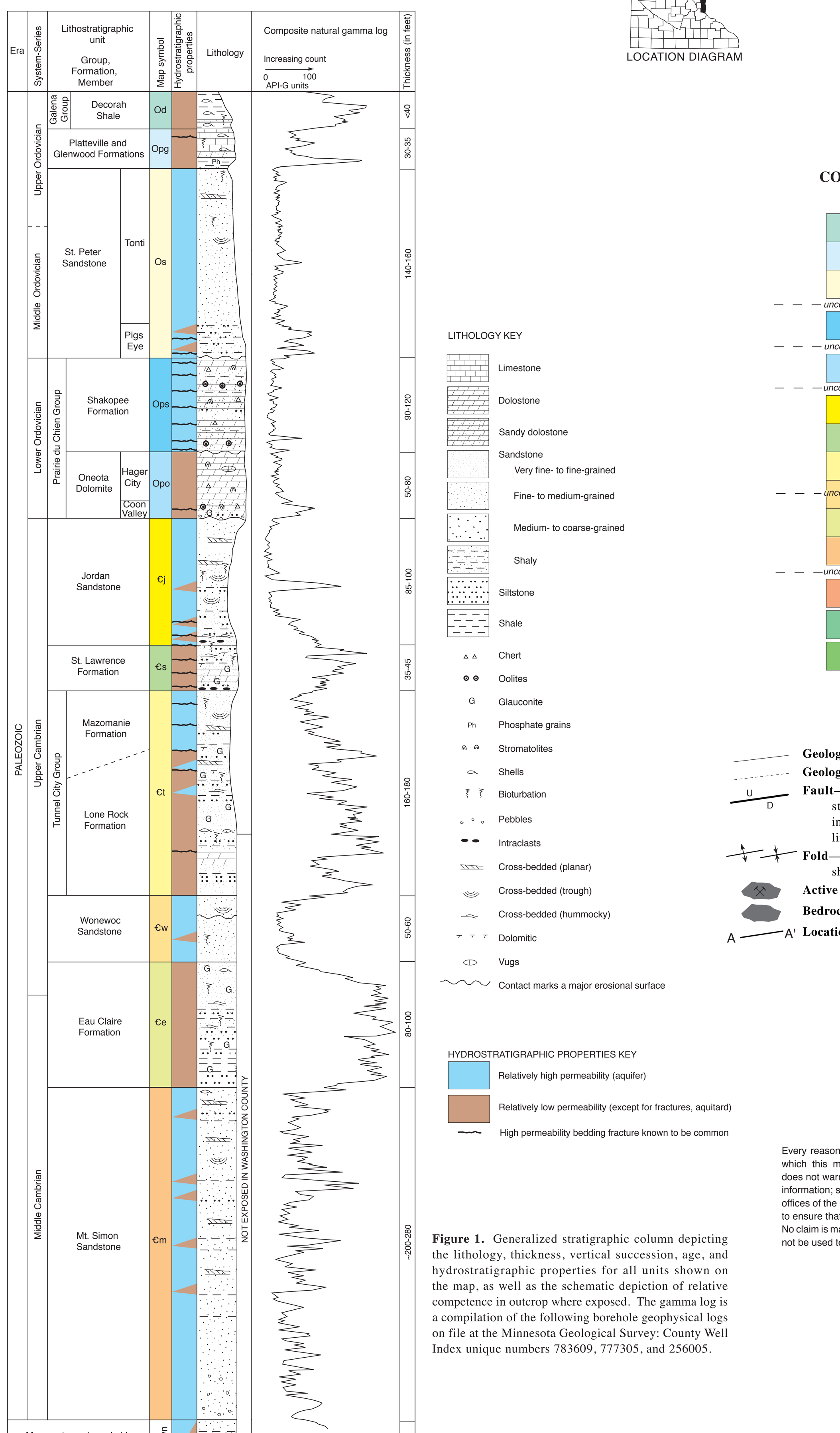
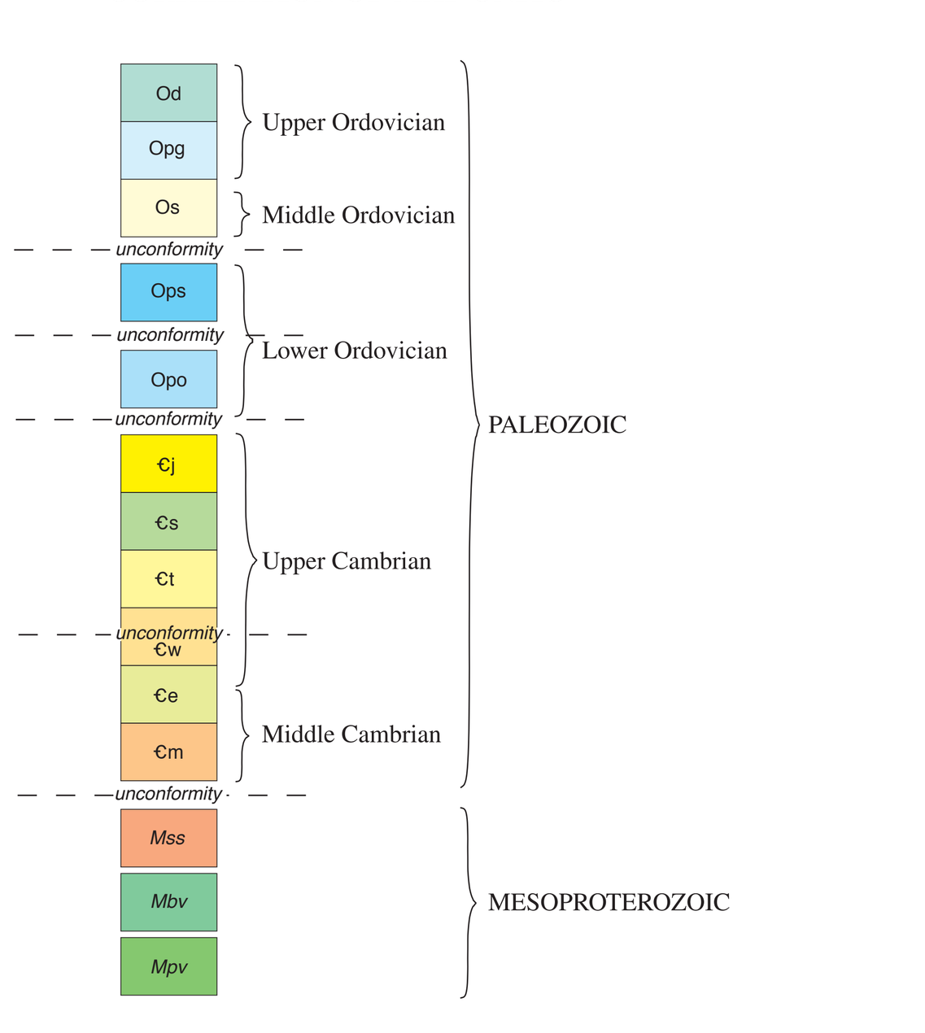


Figure 1. Generalized stratigraphic column depicting the lithology, thickness, vertical succession, age, and hydrostratigraphic properties for all units shown on the map, as well as the schematic depiction of relative competence in outcrop where exposed. The gamma log is a compilation of the following borehole geophysical logs on file at the Minnesota Geological Survey: County Well Index unique numbers 783609, 777305, and 256005.

CORRELATION OF MAP UNITS



MAP SYMBOLS

Geologic contact, approximatly located

Geologic contact, inferred

Fault—Faults are inferred from abrupt changes in the elevation of stratigraphic units from subsurface and outcrop data. Letters indicate relative vertical displacement: U—up, D—down. Dashed lines represent areas where it is inferred.

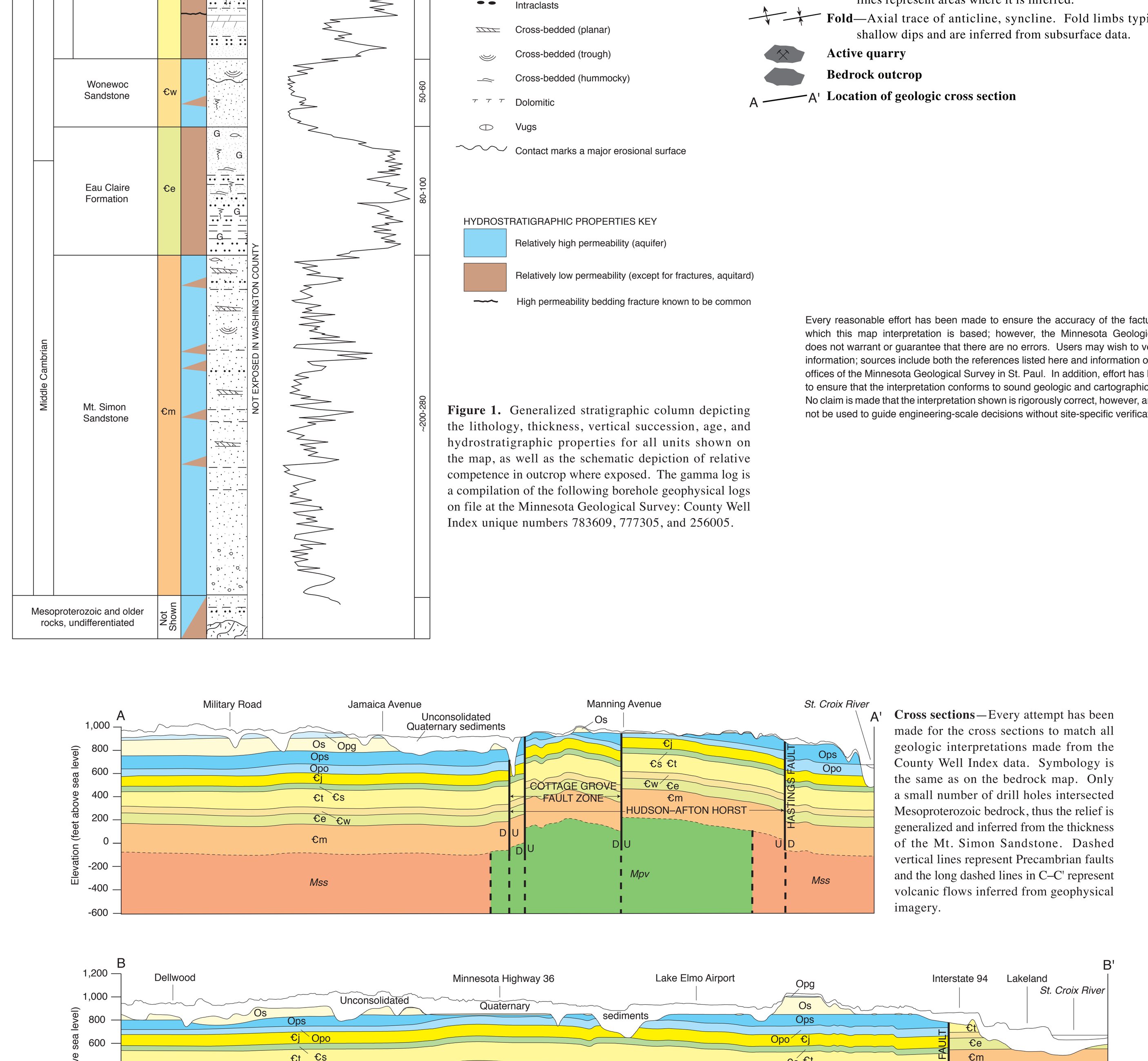
Fold—Axial trace of anticline, syncline. Fold limbs typically have shallow dips and are inferred from subsurface data.

Active quarry

Bedrock outcrop

Location of geologic cross section

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.



Cross sections—Every attempt has been made for the cross sections to match all geologic interpretations made from the County Well Index data. Symbology is the same as on the bedrock map. Only a small number of drill holes intersected Mesoproterozoic bedrock, thus the relief is generalized and inferred from the thickness of the Mt. Simon Sandstone. Dashed vertical lines represent Precambrian faults and the long dashed lines in C–C' represent volcanic flows inferred from geophysical imagery.

INTRODUCTION

The geologic map, cross sections, and stratigraphic column on this plate depict the type, distribution, and structure of the bedrock units in Washington County that are either exposed at the land surface or lie directly beneath unconsolidated Quaternary glacial sediments of variable thickness (see cross sections and Plates 3, 4, and 5, *Surficial Geology, Quaternary Stratigraphy, Depth to Bedrock,* and *Bedrock Topography*). The map shows how the bedrock surface would appear if it was viewed from an aerial perspective and the overlying Quaternary sediments were stripped away. The bedrock units near the land surface in Washington County consist of sedimentary rocks of Paleozoic age that form distinguishable and mappable layers designated as formations. These units are commonly exposed along the Mississippi and St. Croix River bluffs, within rock quarries, and along roadcuts within the county. Several of the Paleozoic bedrock formations are major reservoirs for water supply in Washington County and also provide a source of crushed carbonate rock and silica sand.

Characteristics of each formation are given in the stratigraphic column (Fig. 1) and in the description of map units. The accompanying bedrock geologic cross sections add the dimension of depth and illustrate the stratigraphic, structural, and topographic relationships of the bedrock units, as well as the variable thickness of the overlying Quaternary sediments. Surfaces representative of the elevation of the tops of the mapped formations are also available as Digital Elevation Models (DEMs) for use in GIS programs. The geologic formations are thin in relation to their aerial extent, and would only be one-tenth as thick as shown on the cross sections if no vertical exaggeration were used. The exaggeration necessary to show the thin rock formations gives the appearance of steeper slopes on bedrock unit contacts, the land surface, and bedrock topography. Most of the Paleozoic units shown on this plate, with the exception of the Mt. Simon and Wonewoc Sandstones and Eau Claire Formation, can be seen at the land surface in places in Washington County. The sedimentary rocks differ in their resistance to weathering and erosion, as indicated by the weathering profile on the lithology column of Figure 1. The units that cover the largest areas of the map are the most resistant to weathering and generally form plateaus composed of carbonate rock (limestone and dolostone). The soft sandstone and shale formations are more easily eroded and commonly occur on bedrock plateau or valley walls.

Production of the map and associated products relied on several data sources, including outcrops, water-well and scientific drilling records from the County Well Index, rock core, drill cutting samples, borehole geophysical logs, seismic soundings, geophysical images, and previously published geologic maps of Washington and adjacent counties (Mossler and Bloomgren, 1990; Mossler and Tipping, 2000; Mossler, 2005a, b, 2006a, b, c, d, 2013; Anderson, 2009). This map supersedes the previous bedrock geology map of Washington County (Mossler and Bloomgren, 1990). Significant improvements and modifications were made to the previous map based on additional water-well records, drill cuttings, borehole geophysics, and refined geophysical images. The Prairie du Chien Group is separated into the Oneota Dolomite and Shakopee Formation and the St. Lawrence Formation is mapped separately from the Tunnel City Group (previously the Franconia Formation). Faults and folds in the southeastern part of the county were mapped to reflect significant offset in the Paleozoic formations. This provides detail of the subsurface geologic conditions, which has implications for modeling groundwater flow. The different data sources and their irregular distribution and density can be seen on Plate 1, *Data-Base Map*, and these should be considered when assessing the reliability of the map at any particular location. Areas with a high density of bedrock control points are more likely to have an accurate interpretation of the bedrock geology, whereas those areas with widely spaced control points may be less reliable and inappropriate for site-specific needs. During production of this map, the records of over 14,000 located water wells existed within Washington County in the County Well Index and nearly 10,000 of those reached Paleozoic bedrock. Geologic interpretations of subsurface material described by drillers or gathered from other data sources were made by the authors and are represented in the County Well Index records. Every reasonable effort has been made for the geologic interpretations in the County Well Index to correspond to the map.

Paleozoic bedrock lies on top of a thick sequence of Mesoproterozoic (approximately 1,100 million years, or Ma, ago) rocks of the Keweenawan Supergroup, associated with the Midcontinent Rift (see cross sections and Fig. 2). These rocks include sandstone, siltstone, and shale of the Hinckley Sandstone, Solor Church and Fond du Lac Formations (unit *Mss*), and volcanic rocks composed mostly of basalt including the Powder Mill (unit *Mpv*) and North Branch (unit *Mbv*) volcanic sequences. Due to their deep burial and limited subsurface data, the distribution of these individual units is less certain than the Paleozoic units. Therefore, the contact between the top of these units and the overlying base of Mt. Simon Sandstone is dashed in cross sections. No new mapping of these units was done for this project; instead a recent compilation map of the Precambrian bedrock geology of Minnesota is depicted (Fig. 2; Jirsa and others, 2012).

The Paleozoic rocks of Washington County are characterized by relatively thin, widespread layers of sandstone, shale, and carbonate deposited in shallow seas during the Cambrian and Ordovician Periods of the Paleozoic Era, from about 500 to 450 million years ago. The older Cambrian-age formations are dominated by siliciclastic sedimentary rock including sandstone and siltstone with minor shale, such as the Jordan Sandstone and Mazomanie Formation (Tunnel City Group). Carbonate rock occurs only as relatively thin layers within these units. Ordovician-age formations, in contrast, are dominated by thicker units of carbonate rock with less sandstone and shale, such as the Prairie du Chien Group and the Platteville Formation. Where carbonate rock and silica-rich (quartzose) sandstone exist near the land surface (or within 50 feet [15 meters]), they are considered a valuable geologic resource. Carbonate rock products are crushed, sorted, and used as construction material for roads and buildings, and in concrete operations. The silica-rich sandstone is texturally mature and well-rounded, which makes it a sought after resource in the oil industry. It also has a wide variety of other uses including glassmaking, foundry operations, ceramics, filtration, and agriculture. However, viability of extraction is dependent on many other factors, including detailed geologic conditions at individual sites, proximity to bulk transportation, current land ownership and use, market prices, regulatory requirements, and many others. Figure 3 depicts where carbonate or quartzose sandrock is within 50 feet (15 meters) of the land surface and highlights the active quarry operations at the time this map was created.

Across most of Washington County, bedrock units are slightly tilted (less than 1°) southwest towards the central Twin Cities metropolitan area, as part of the eastern margin of a shallow structural depression known as the Twin Cities basin. As a result, progressively younger bedrock formations subcrop from eastern to western Washington County. This general trend is locally interrupted by deep valleys that incise older formations, and by faults and folds. A fault is recognized where changes in the elevation of a bedrock contact occur within a very short distance, generally elevation changes of 50 feet (15 meters) or more within a distance of 1,000 feet (305 meters). A fold is inferred where these elevation changes indicate more gradual slopes. The stratigraphic top of the Jordan Sandstone was contoured at 25-foot (15-meter) intervals to show the inferred location of faults and folds in Washington County (Fig. 4). The top of the Jordan Sandstone was selected to portray these structures because it is a well-recognized and distinct contact, has numerous control points including outcrops that expose the contact, and has water wells that penetrate it. Displacement along faults in Washington County is on the order of 25 to 300 feet (8 to 91 meters), which is sufficient in places to juxtapose several different formations along the fault contact (see cross sections and Fig. 4). Bedrock that has dropped alongside a fault preserves relatively younger formations (shown with a D on the map) at the surface and bedrock that has been uplifted brings older formations closer to the surface (shown with a U on the map). Most faults trend in the northeast direction but several trend northwest.

Several of the faults observed in Paleozoic strata are subparallel to faults in the underlying Mesoproterozoic Midcontinent Rift rocks, as inferred from geophysical imagery, and are therefore interpreted to represent reactivation of these older structures (Fig. 2). The aeromagnetic and gravity data show where a great thickness of dense and magnetic basalts have been brought near the surface in an inverted graben known as the Hudson–Afton horst (Sims and Zeitz, 1967; Cannon and others, 2001). Paleozoic rocks overlying the Hudson–Afton horst in Washington County are also uplifted relative to the rocks on either side, although the displacement is of a lesser magnitude than that in the underlying Mesoproterozoic bedrock (Fig. 4). Lower Ordovician Prairie du Chien Group rocks thin (less than 50 feet [15 meters]) within the uplifted horst and thicken along either side (less than 300 feet [91 meters]), suggesting displacement was occurring during Early to Middle Ordovician time (see cross section A–A' and Fig. 5).

HYDROSTRATIGRAPHY

The Paleozoic bedrock formations contain significant sources of groundwater, which provide the majority of the water supply for Washington County. This map and associated products, such as the bedrock unit DEMs, 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 classification, shown by brown and blue colors on the hydrostratigraphic column of Figure 1, distinguishes layers that are dominated by relatively high permeability (easily transmitting water) material, versus layers dominated by lower permeability (relatively more difficult to transmit water) material. This generalized characterization for Washington County is based on hydrogeologic reports by Runkel (1996), Paillet and others (2000), Runkel and others (2003, 2006a, b, 2014a, b), Tipping and others (2006), Anderson and others (2011), Luhmann and others (2011), Green and others (2012), and unpublished borehole and core data collected by the Minnesota Geological Survey. The high permeability layers are potential aquifers, able to yield economic quantities of water in most places. The low permeability layers are potential aquitards that retard vertical flow, hydraulically separating the aquifer layers from one another in many places, and protecting water resources in the underlying layers from surface contamination. Fractures parallel to bedding that have been demonstrated to have high permeability are likely to be present, at least locally, in all formations in Washington County, but are placed on the column where the hydrogeologic reports cited above indicate they are most common. The locations of springs in Washington County most commonly occur within the lower Jordan Sandstone, St. Lawrence Formation, and upper Tunnel City Group, where high permeability bedding fractures are known to be common. The hydrogeologic properties of the Mesoproterozoic bedrock are poorly understood. It does not supply water to Washington County at least in part because sufficient water resources are available at shallower depths in the Paleozoic rocks.

In Washington County, most aquifers are layers dominated by relatively coarse-grained sandstone, such as within the upper part of the Jordan Sandstone, in which water can be fairly easily transmitted in both horizontal and vertical directions through the pore spaces between sand grains, as well as through fractures. Other aquifers, such as the upper part of the Prairie du Chien Group, are composed mostly of carbonate rock in which water is transmitted through a relatively dense network of fractures and solution cavities. However, layers designated as aquifers can locally contain low permeability strata that serve as small, internal aquitards including parts of the upper Mt. Simon Sandstone and the lower Jordan Sandstone.

Most layers designated as aquitards in the county have a much lower permeability in the vertical direction than do aquifers. Examples in Washington County include the lower Jordan Sandstone, St. Lawrence, and Eau Claire Formations, whose rocks are composed mostly of very fine-grained sandstone and shale with small, poorly connected pore spaces. Carbonate rock with relatively sparse fractures, such as the lower part of the Prairie du Chien Group (Oneota Dolomite), are also aquitards. However, layers designated as aquitards with very low permeability in the vertical direction may locally contain horizontal fractures that are conductive enough to yield large quantities of water, including the St. Lawrence Formation.

Horizontal and vertical fractures are more common where bedrock layers are at or near the bedrock surface. As a result, aquitards in such conditions are likely to have higher permeability compared with more deeply buried portions of the same formation, and may have a diminished ability to retard water flow to underlying aquifers. There is no precise boundary between shallow and deep conditions of burial, but in most areas of southeastern Minnesota about 50 feet (15 meters) of depth below the bedrock surface is considered a best approximation (Runkel and others, 2006a).

In addition to this hydrostratigraphic classification, the Minnesota Department of Natural Resources, as Part B of the Washington County atlas, will conduct a thorough hydrogeologic study of the groundwater flow system, aquifer capacity, and aquifer sensitivity, which may result in modifications to this classification. Furthermore, designations of aquifers versus aquitards made here may not correspond precisely with those made for regulatory purposes by the Minnesota Department of Health.

DESCRIPTION OF MAP UNITS

Od **Decorah Shale (Upper Ordovician)**—Dominantly grayish-green shale interbedded with thin beds of fossiliferous limestone. Fossiliferous, yellowish-brown limestone beds are most common at the base of the Decorah Shale, and are recognized as the basal Carimona Member (Mossler, 2008). The Decorah Shale is present as erosional remnants capping Platteville mesas in the southwestern part of the county. Though no exposures exist in the county, water well logs indicate the Decorah Shale has a maximum preserved thickness of 40 feet (12 meters).

Opg **Platteville and Glenwood Formations (Upper Ordovician)**—The Platteville Formation is generally tan to gray, fossiliferous limestone and dolostone. The underlying Glenwood Formation is dominantly a green-gray, sandy shale. The Platteville Formation is the dominant uppermost bedrock unit across a large expanse of the southwestern part of the county. The combined thickness of the formations is 30 to 35 feet (9 to 11 meters).

Platteville Formation—The Platteville Formation is 25 to 30 feet (8 to 9 meters) thick. It is composed of tan to gray limestone and dolostone. It is commonly burrowed, mottled, and fossiliferous. It contains fine- to coarse-grained quartz sand and phosphate grains in the lowermost 2 feet (0.6 meter).

Glenwood Formation—The principal rock type of the Glenwood Formation is a grayish-green to brownish-gray, calcareous, sandy, and phosphatic shale. The Glenwood Formation is 3 to 7 feet (1 to 2 meters) thick.

Os **St. Peter Sandstone (Middle to Lower Ordovician)**—The upper 100 to 140 feet (30 to 43 meters) of the St. Peter Sandstone is mostly a white to tan, fine- to medium-grained, friable quartzose sandstone. Bedding and structures are generally absent. It is exposed in patchy outcrops in the southern half of the county where glacial sediments are thin. The lowermost 10 to 40 feet (3 to 12 meters), referred to as the Pigs Eye Member, includes white to gray feldspathic shale and siltstone interbedded with coarser-grained sandstone similar to that of the Tonti Member. The Pigs Eye Member is not exposed in Washington County. The thickness of the St. Peter Sandstone varies from about 130 to 160 feet (40 to 49 meters). The basal contact of the formation with the underlying Shakopee Formation (unit Ops) is a major erosional unconformity (Smith and others, 1993).

Prairie du Chien Group (Lower Ordovician)—Dominated by dolostone interlayered with lesser amounts of quartz sandstone. Outcrops are exposed along the tops of bluffs of the Mississippi and St. Croix River valleys; small patchy outcrops are also present in southeastern Washington County where the Quaternary sediments are thin. The Prairie du Chien Group is a significant source of rock aggregate in this part of the county. The Prairie du Chien Group is formally divided into two formations: the Shakopee Formation and underlying Oneota Dolomite. Geophysical logs and drill cuttings in the northern part of the county and within parts of the Hudson–Afton horst that span the St. Peter through the Jordan Sandstones are lacking and water well records are typically inadequate to distinguish the Oneota Dolomite from the Shakopee Formation and St. Peter Sandstone from the sandy upper Shakopee Formation. Therefore, the mapped distribution of these units is more speculative in these areas. The thickness of the Prairie du Chien Group beneath the St. Peter Sandstone varies greatly across Washington County, from less than 50 to nearly 300 feet (15 to 91 meters; Fig. 5). This is interpreted to be due to several factors, including syndepositional faulting along the Hudson–Afton horst, and erosion of the Shakopee Formation prior to deposition of the St. Peter Sandstone. This erosional surface is the unconformity that marks the contact between the Shakopee Formation and overlying St. Peter Sandstone.

Ops ***Shakopee Formation (Lower Ordovician)***—A heterolithic unit composed mainly of light brown, thin- to medium-bedded dolostone, sandy dolostone, sandstone, and shale. It contains oolites, intraclasts, fossilized microbial mounds, chert nodules, quartz sandstone, and green-gray shale partings. Thickness of the Shakopee Formation beneath the St. Peter Sandstone is quite variable within the area of the Hudson–Afton horst, ranging from almost absent to nearly 200 feet (61 meters) thick. It appears to be thickest in the most southeast part of the county, east of the Hastings fault, where it is nearly 200 feet (61 meters) thick. On the opposite side of the horst, on the west side of the Cottage Grove fault, it reaches thicknesses of 115 feet (35 meters) and appears to progressively thin towards the northwest. Based on a limited amount of drill cuttings and geophysical data within the Hudson–Afton horst, it appears that the Shakopee Formation thins to less than 50 feet (15 meters) and may even be absent beneath the St. Peter Sandstone at several locations (see cross section A–A').

Opo ***Oneota Dolomite (Lower Ordovician)***—Predominantly a yellowish-gray to light brown, medium- to thick-bedded dolostone that generally lacks sedimentary features such as oolites and quartz sand characteristic of the Shakopee Formation, except in its lowermost part. The formation contains two members, the Hager City and the Coon Valley, but they are not mapped separately. The basal Coon Valley Member is a heterolithic unit composed of thinly bedded dolostone, sandy dolostone, and beds of fine- to coarse-grained, poorly sorted quartz sandstone. Thickness of the Coon Valley Member is quite variable, it is locally absent to 30 feet (9 meters) thick. There appears to be a slight trend in its thickness along the Hudson–Afton horst whereby it is thickest on the down dropped sides of the faults (20 to 30 feet [6 to 9 meters]) and thinner between the faults (10 to 15 feet [3 to 5 meters]). It also appears to be thin to absent towards the western edge of the county and within the central and northern parts of the county. The Hager City Member is primarily very finely crystalline dolostone, with microbial textures. Its thickness also shows a similar trend to the Coon Valley Member in being thicker along the down-dropped sides of the Hastings and Cottage Grove faults (50 to 70 feet [15 to 21 meters]) and thinner between them (40 to 50 feet [12 to 15 meters]).

€j **Jordan Sandstone (Upper Cambrian)**—Dominantly white to yellow, very fine- to coarse-grained, friable quartz sandstone characterized by coarsening-upward sequences consisting of two interlayered facies (Runkel, 1994). They are medium- to coarse-grained, cross-stratified, generally friable, quartz sandstone; and very fine-grained, commonly bioturbated, feldspathic sandstone with lenses of siltstone and shale. The major part of the very fine-grained facies forms a regionally continuous interval that gradationally overlies the St. Lawrence Formation (unit €s), although there are lithologically similar intervals intercalated with the medium- to coarse-grained facies at higher stratigraphic intervals. An unconformity, locally marked by thin beds of quartz pebble conglomerate and silcrete-cemented sandstone clasts (Runkel and others, 1999, 2007), separates the Jordan Sandstone from the overlying Oneota Dolomite. The Jordan Sandstone is exposed along the Mississippi and St. Croix River bluffs and ranges in thickness from 80 to 100 feet (24 to 29 meters). In the northernmost part of the county near Scandia, it appears to thin to 65 to 70 feet (20 to 21 meters) thick.

€s **St. Lawrence Formation (Upper Cambrian)**—The St. Lawrence Formation is principally light gray to yellowish-gray and pale yellowish-green, dolomitic, feldspathic siltstone with interbedded, very fine-grained sandstone and shale. Lenses and layers of light gray, finely crystalline, sandy dolostone occur locally, especially in the lowermost few feet of the formation (Runkel and others, 2006a). The formation is 35 to 45 feet (8 to 12 meters) thick. The upper contact with the Jordan Sandstone is conformable and gradational. The gradational nature of the contact in well cuttings and on natural gamma logs can make selecting a precise contact between these formations difficult.

€t **Tunnel City Group (Upper Cambrian)**—The Tunnel City Group, formerly named the Franconia Formation (Berg, 1954), varies from about 160 to 180 feet (49 to 55 meters) in thickness across Washington County. It is formally divided into two formations: the Mazomanie and the Lone Rock Formations (Mossler, 2008). The Mazomanie Formation is dominantly white to yellowish-gray, fine- to medium-grained, cross-stratified, generally friable, quartz sandstone. Glauconitic grains typically are rare to absent and never exceed 5 percent (Berg, 1954). Some beds contain brown, intergranular dolomite cement. *Skolithos* burrows and sandstone intraclasts are common along discrete horizons. The Lone Rock Formation underlies the Mazomanie Formation and intertongues with it. It consists of pale yellowish-green, very fine- to fine-grained glauconitic, feldspathic sandstone and siltstone, with thin, greenish-gray shale partings. Thin beds with dolomitic intraclasts are common. In northeastern Washington County, individual tongues of Mazomanie Formation are as thick as 50 feet (15 meters), and the Mazomanie Formation as a whole can reach thicknesses of 100 feet (30 meters). The Mazomanie Formation thins to the south, where it is progressively replaced laterally by the Lone Rock Formation. As a result, in southern Washington County the Mazomanie Formation is less than 25 feet (8 meters) thick to absent. The upper contact of the Tunnel City Group with the St. Lawrence Formation is conformable. The contact is fairly sharp and the contrast between the siltstone and shale of the St. Lawrence Formation, and underlying fine- to medium-grained, quartzose sandstone in the Mazomanie Formation of the Tunnel City Group, is distinct and typically marked by an intraclastic conglomerate.

€w **Wonewoc Sandstone (Upper Cambrian)**—This sandstone unit, formerly referred to as the Ironton-Galesville Sandstone, is composed mostly of fine- to coarse-grained, moderately to well sorted, light gray, cross-stratified, quartz sandstone (Mossler, 2008). White, brown, and black linguliform brachiopod shells are locally abundant. The upper part is the coarsest-grained; the lower part is finer-grained, better sorted, and progressively finer-grained toward its base. The very fine-grained sandstone in the lower part is feldspathic. The thickness of the formation is 45 to 75 feet (14 to 23 meters). The Wonewoc Sandstone is conformable with overlying and underlying formations; however, there is a subtle unconformity marked by a pebbly sandstone layer within the formation (Runkel and others, 1998).

€e **Eau Claire Formation (Middle to Upper Cambrian)**—The formation is composed of yellowish-gray to pale olive-gray, fine- to very fine-grained, feldspathic sandstone, siltstone, and shale. White and brown linguliform brachiopod shells are common. The formation ranges from 80 to 100 feet (24 to 30 meters) in thickness. The contact with the Mt. Simon Sandstone is conformable.

€m **Mt. Simon Sandstone (Middle Cambrian)**—The Mt. Simon Sandstone is pale yellowish-brown to grayish-orange-pink to light gray, medium- to coarse-grained, quartz sandstone. Interbeds of shale, siltstone, and very fine-grained feldspathic sandstone are common, particularly in its upper half (Mossler, 1992). Inarticulate brachiopod shells are locally common in the upper one-third of the formation. Thin beds of quartz-pebble conglomerate occur at several stratigraphic positions, and are especially abundant near the base of the formation. The Mt. Simon Sandstone unconformably overlies Mesoproterozoic rocks. Based on a limited number of full penetrations of the formation, it appears to have a maximum thickness of about 280 feet (85 meters).

MESOPROTEROZOIC

Keweenawan Supergroup

Mss **Sandstone, siltstone, and local conglomerate (shown on cross sections and Fig. 2)**—Includes the Hinckley Sandstone and Fond du Lac (youngest detrital zircons ~1,000 Ma) and Solor Church Formations; deposited in eolian, fluvial, and lacustrine environments.

Mbv **North Branch volcanic sequence (shown on cross section C–C' and Fig. 2)**—Part of the St. Croix horst.

Mpv **Powder Mill volcanic sequence (~1,099 Ma; shown on cross sections and Fig. 2)**—Part of the St. Croix horst.

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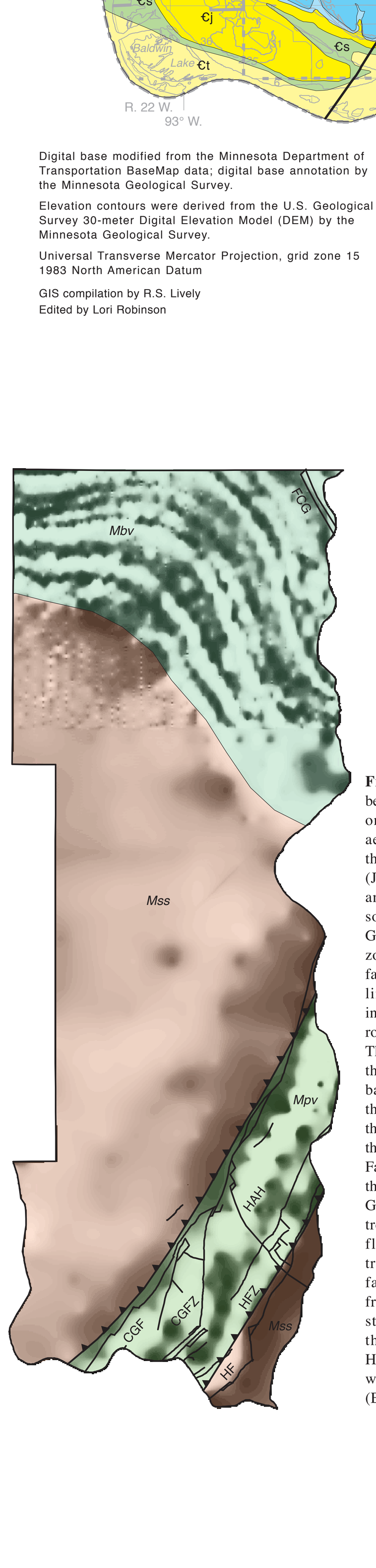

Figure 2. Faults that displace Paleozoic bedrock in Washington County superimposed on a map of the first vertical derivative aeromagnetic data (Chandler, 1991) and the underlying Mesoproterozoic rock units (Jirsa and others, 2012). Paleozoic faults and fault zones where they cluster in the southern part of the map (CGF—Cottage Grove fault, CGFZ—Cottage Grove fault zone, HF—Hastings fault, HFZ—Hastings fault zone) are subparallel to strong, abrupt, linearly extensive contrasts in magnetic intensity in the underlying Mesoproterozoic rocks associated with the Midcontinent Rift. The aeromagnetic data display where a great thickness of magnetic Mesoproterozoic rift basalts (unit *Mpv*) have been brought near the surface in an inverted graben known as the Hudson–Afton horst (HAH), bounded by thrust faults, shown by black lines with teeth. Faults in the northeastern corner of the county that bound what is known as the Falls Creek Graben (FCG) are subparallel to foliation trends of underlying Mesoproterozoic lava flows (unit *Mbv*). Due to their similar trends and close proximity, all Paleozoic faults are interpreted to have originated from reactivation of deep Mesoproterozoic structures. Abrupt thickness changes in the Prairie du Chien Group across the Hudson–Afton horst indicate that faults were reactivated during Early Paleozoic (Early to Middle Ordovician) time.

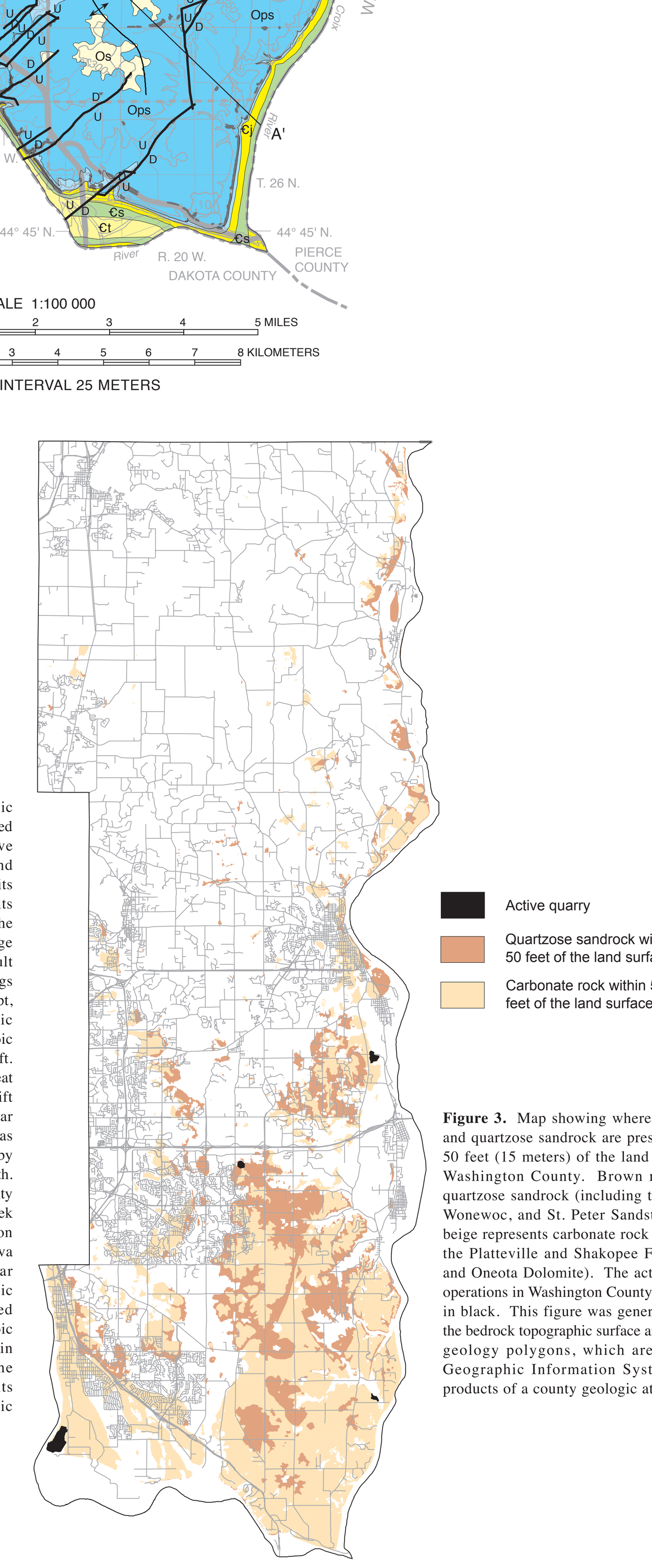

Figure 3. Map showing where carbonate and quartzose sandrock are present within 50 feet (15 meters) of the land surface in Washington County. Brown represents quartzose sandrock (including the Jordan, Wonewoc, and St. Peter Sandstones) and beige represents carbonate rock (including the Platteville and Shakopee Formations and Oneota Dolomite). The active quarry operations in Washington County are shown in black. This figure was generated using the bedrock topographic surface and bedrock geology polygons, which are standard Geographic Information System (GIS) products of a county geologic atlas.

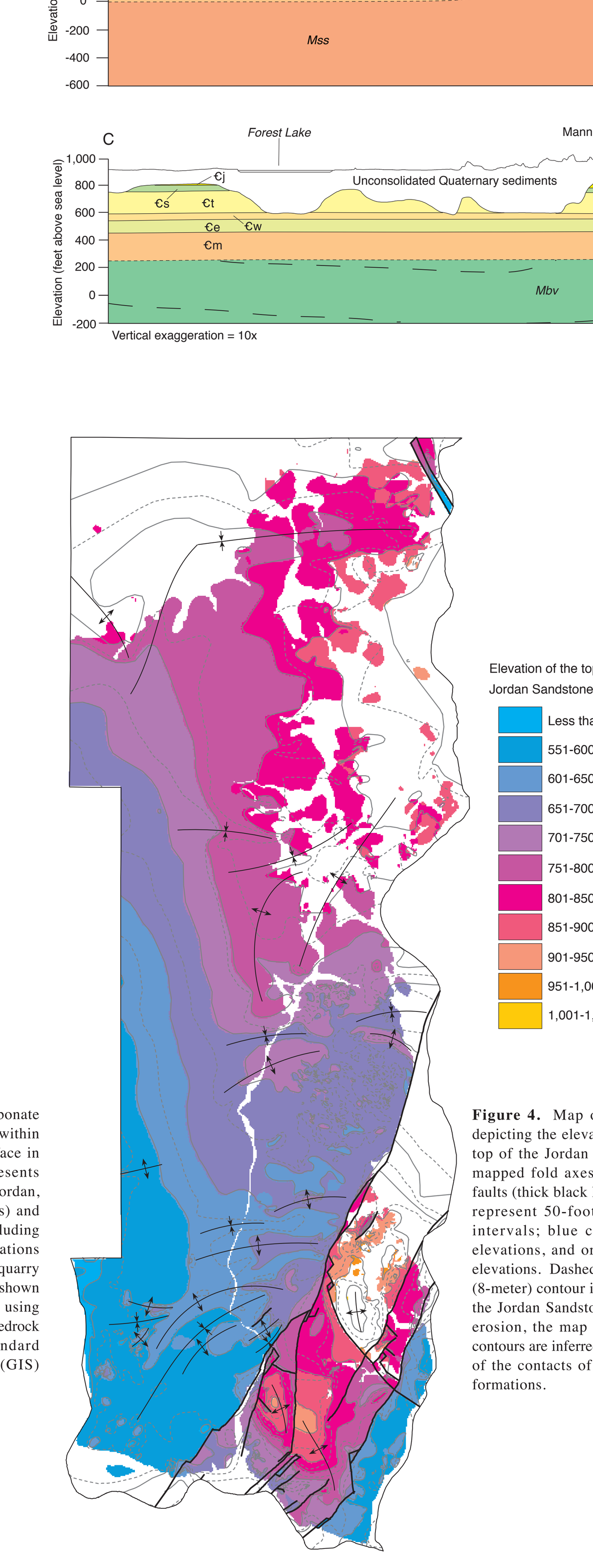

Figure 4. Map of Washington County depicting the elevation of the stratigraphic top of the Jordan Sandstone showing the mapped fold axes (thin black lines) and faults (thick black lines). Colored intervals represent 50-foot (15-meter) elevation intervals; blue colors represent lower elevations, and orange represents higher elevations. Dashed lines depict the 25-foot (8-meter) contour intervals. In areas where the Jordan Sandstone is absent because of erosion, the map is not colored, and the contours are inferred from vertical projection of the contacts of stratigraphically lower formations.

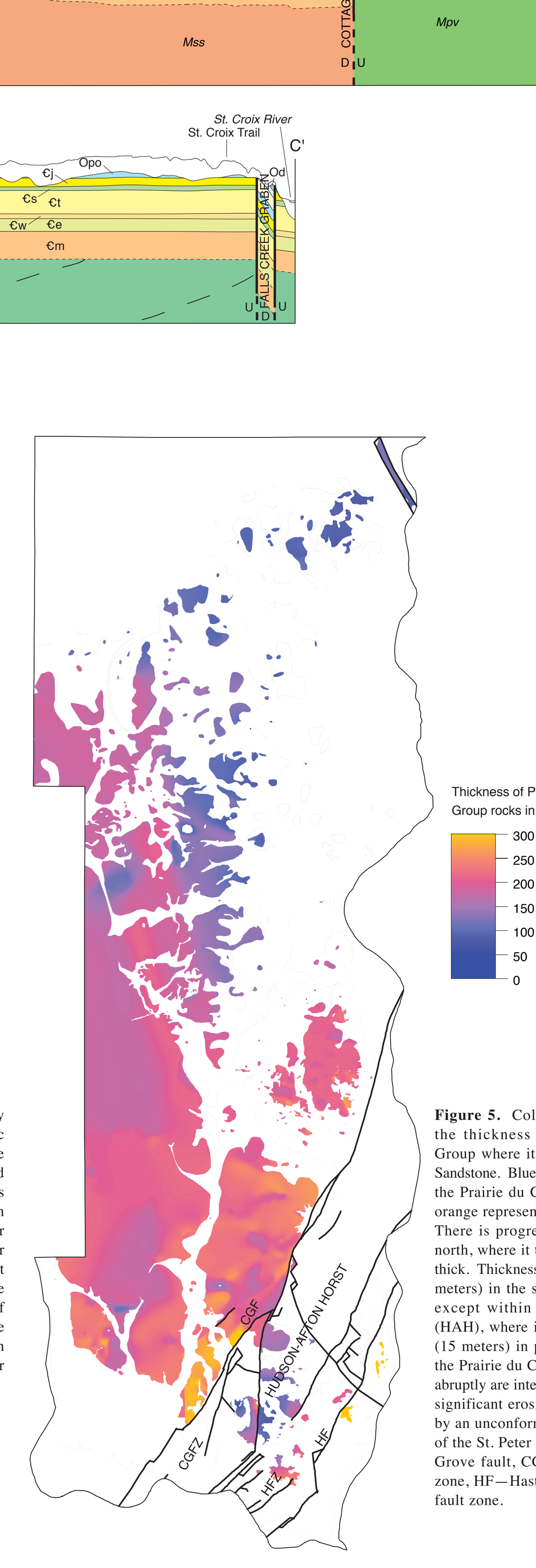

Figure 5. Color shaded map indicating the thickness of the Prairie du Chien Group where it exists below the St. Peter Sandstone. Blue colors represent areas where the Prairie du Chien Group is thinner and orange represents areas where it is thicker. There is progressive thinning toward the north, where it thins to 50 feet (15 meters) thick. Thicknesses reach nearly 300 feet (91 meters) in the southern part of the county except within the Hudson–Afton horst (HAH), where it thins to less than 50 feet (15 meters) in places. Small areas where the Prairie du Chien Group appears to thin abruptly are interpreted to represent areas of significant erosion during a hiatus marked by an unconformity prior to the deposition of the St. Peter Sandstone. CGF—Cottage Grove fault, CGFZ—Cottage Grove fault zone, HF—Hastings fault, HFZ—Hastings fault zone.