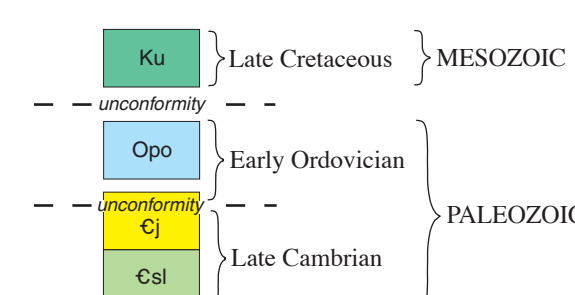


CORRELATION OF MAP UNITS



DESCRIPTION OF MAP UNITS

Ku Cretaceous rocks, undivided (Late Cretaceous)—A heterolithic assemblage of strata that lie above typical southeastern Minnesota Paleozoic bedrock (for example Mossler, 1987) and below typical till, sand, and gravel of Quaternary age. Includes variegated clay, sandstone, and conglomerate. Most sandstone is quartzose, light gray to pale brown, and fine- to medium-grained. It is cross-stratified or structureless, and differs from Paleozoic quartzose sandstone in that angular to subangular grains are common. Thin lenses of grayish-green to dark gray shale are interbedded in the sandstone and scattered clasts of kaolinite occur in some sandstone beds. Conglomerate clasts are composed of pebbles of Paleozoic chert and vein quartz, and typically occur as thin lenses where interstratified with quartzose sandstone.

Some local occurrences of variegated clay have been tentatively mapped as Cretaceous, others as part of the Onoeta Dolomite. The former includes small exposures of white, tan, and gray clay that locally is known to include pisolitic kaolinite (Humphrey, 1958; Parham, 1970). White and red clay is also locally mapped as Cretaceous in the subsurface where drilling records indicate they occur in a stratigraphic position and elevation that makes them unlikely to be an in situ residuum of the underlying bedrock. In contrast, occurrences of variegated clay mapped as Onoeta Dolomite are interpreted to be residuum of weathered Hagar City Member rock that is largely in situ, or to be displaced beds of Blue Earth Siltstone (see Onoeta Dolomite below).

Cretaceous sedimentary rocks unconformably overlie the Jordan Sandstone and Prairie du Chien Group dolomite, typically at elevations between 800 to 865 feet (244 to 264 meters) above sea level, and occur as scattered erosional remnants that are generally less than 30 feet (9 meters) thick. The mapped distribution of Cretaceous rocks on this quadrangle is much more speculative than for other map units; 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 confidently and consistently recognize these strata as distinct from quartz-rich Quaternary sandstone or from clay-rich, in situ residuum developed on bedrock.

Strata assigned to the Cretaceous on this and other quadrangles in the Mankato and outlying areas have not produced biostratigraphically useful fossils, and therefore their age can be confidently assessed only as younger than Early Ordovician and older than the Quaternary glacial deposits of this area. A Cretaceous age for this map unit is tentatively inferred largely on the basis of regional mapping relationships that place these deposits in a similar stratigraphic position (between Paleozoic and Quaternary strata) and in geographic proximity to reasonably well-dated Cretaceous quartzose sandstone and shale 15 to 20 miles (24 to 32 kilometers) to the west near Courtland, Minnesota. The Courtland sandstone and shale is an eastermost extension of a nearly continuous, large subcrop area of strata generally correlative with the Late Cretaceous Dakota Formation (Setterholm, 1990). Conglomerate in the Good Thunder quadrangle is in contrast more similar to the Ostrander conglomerate to the east, which is also considered to be Late Cretaceous in age (Sloan, 1964). The tenuous nature of assigning an age based on lithic correlations of patchy strata leave open the possibility that this "Cretaceous" map unit includes strata much older or younger than Cretaceous.

Cretaceous strata in the Mankato and outlying areas have not been consistently used for any economic purpose. Water potentially could be extracted locally in moderate quantities from friable sandstone, although no wells on this quadrangle are known to be constructed to draw water entirely from Cretaceous strata. At Courtland, Minnesota, deposits believed to be approximate age equivalents are mined for shale that is used as a raw material in the production of bricks and modeling clay.

Opo Prairie du Chien Group: Onoeta Dolomite (Early Ordovician)—The Onoeta Dolomite consists of two members: the lower Blue Earth Siltstone dominated by fine-grained siliciclastic material, and an upper, largely dolostone unit called the Hagar City Member. The Blue Earth Siltstone is feldspathic and moderately glauconitic, laminated to thinly bedded, dolomitic, very fine-grained sandstone, siltstone, and shale. It is about 3 feet (1 meter) thick on average in outcrops to the north of this quadrangle, although it pinches and swells markedly. The Hagar City Member is predominantly tan to gray, thin- to thick-bedded dolostone. Fresh surfaces of dolostone commonly are gray to tan mottled with light gray or white at the centimeter scale. Meter-scale microbial mounds, chiefly thrombolites, are common. Near its base, the dolostone is sandy, variably glauconitic, and contains some shale stringers, reflecting a gradational contact with the underlying Blue Earth Siltstone. Large (up to meter-scale), solution-enlarged vertical joints and bedding-plane fractures are common, as are irregularly shaped, relatively small (centimeter scale) solution cavities.

The Onoeta Dolomite is as thick as 60 feet (18 meters), and occurs as erosional remnants in the eastern and northern parts of the quadrangle. Strata mapped as Onoeta Dolomite include clay or shale that lies directly on top of the Jordan Sandstone that we interpret to be a residuum of Onoeta Dolomite weathering and/or cavity fill derived from the underlying Blue Earth Siltstone and uppermost Jordan Sandstone. In exposures along the north bank of the Minnesota River (north of this map area in the Mankato West quadrangle: T. 108 N., R. 27 W., secs. 11 and 14) and nearby areas, joints and solution cavities are most commonly filled with a gray to white shale, siltstone, and quartzose sandstone. White, gray, and red siltstone and shale also cap the Hagar City Member locally in this area. This siliciclastic material appears in two areas: where it forms a cap on the Hagar City Member; and in some fractures and vugs, where it grades transitionally into indurated dolostone and thus represents at least in part the residuum from dissolved carbonate rock. Additionally, some vertical joints and vugs contain fill that can be physically traced to identical material in the underlying Blue Earth Siltstone and upper Jordan Sandstone beds. These pore-fillings originated as beds of Blue Earth Siltstone and sand from the Jordan Sandstone that was apparently displaced upward and "injected" into the cavities of the overlying Hagar City Member (Stauffer and Thiel, 1941; Humphrey, 1958; Stubblefield, 1971).

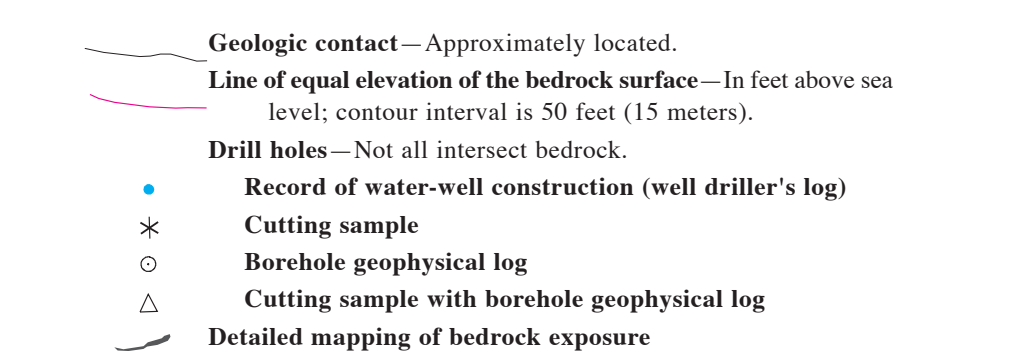
The Hagar City Member is widely used in the Mankato area as a crushed rock and dimension stone resource (Stubblefield, 1971). It is also important hydrogeologically. Open fractures and solution cavities likely serve as conduits in a karstic ground-water system. Alternatively, in areas where these cavities are absent or filled by fine-grained siliciclastic material, the lowermost few meters of the Hagar City Member may serve as a confining unit in combination with the low permeability Blue Earth Siltstone. As a result, ground water in the underlying Jordan Sandstone may at least locally be hydraulically separated from that in the upper part of the Hagar City Member of the Onoeta Dolomite.

Cj Jordan Sandstone (Late Cambrian and Early Ordovician)—Dominantly light gray to tan sandstone that includes coarsening-upward sequences consisting of two interlayered facies, which are not separated on the map. They are medium- to coarse-grained, trough to planar cross-stratified, generally friable quartz sandstone; and very fine-grained, mottled or hummocky cross-stratified, feldspathic sandstone with lenses of siltstone and shale. Some exposures in the upper part of the Jordan Sandstone have extensive silica cementation. The Jordan Sandstone is from about 50 to nearly 100 feet (15 to 30 meters) thick where the entire unit is preserved. Its extensive distribution across flat subcrop areas may reflect the high degree of cementation of its uppermost beds, which served as a resistant cap that formed a non-buried, pre-Cretaceous plateau.

The Jordan Sandstone in this area likely contains a major unconformity. Beds of medium- to coarse-grained quartzose sandstone directly beneath the Blue Earth Siltstone are known to contain an Ordovician-age fauna (Powell, 1935) that is substantially younger than the age of the lower part of the Jordan Sandstone in this area (Stauffer and Thiel, 1941; Runkel and Miller, unpub. data). This Ordovician sandstone is equivalent to the lower part of the Coon Valley Member of the Onoeta Dolomite in southeastern Minnesota (Runkel and others, 1999). Powell (1935) and Stauffer and Thiel (1941) referred to this sandstone as the Kasota sandstone and it has in the past commonly been considered part of the Onoeta Dolomite. However, its lithic similarity to the Jordan Sandstone makes it impractical to map as a separate unit.

The Jordan Sandstone is locally an important source of potable water in this quadrangle. With the exception of areas where its uppermost beds are cemented by silica, the Jordan Sandstone has a high to very high porosity and permeability, serving as an excellent aquifer (Runkel and others, 2003). In addition, where it occurs as the uppermost bedrock, exposures have prominent joints with centimeter-scale apertures, indicating that ground-water flow through secondary pores in such settings may be of great importance. Finer-grained facies are of moderate to low porosity and permeability and may serve as local confining units. The Jordan Sandstone is also used in the Mankato area as a source of silica sand for industrial use in the oil industry.

MAP SYMBOLS



Csl St. Lawrence Formation (Late Cambrian)—Much of the St. Lawrence Formation is tan, white, or gray, hummocky cross-stratified, dolomite-cemented, very fine-grained sandstone and siltstone. Laminated green shale and pink to red, finely- to coarsely-crystalline dolostone occur as interbeds, the latter being particularly abundant in the lower one-half of the formation. Dolostone beds are commonly intraclastic, generally with centimeter-scale, angular to rounded clasts of very fine-grained sandstone. Glauconitic content in the dolostone increases toward the base of the formation, and the contact of the St. Lawrence Formation with the underlying Franconia Formation is transitional. "Contact strata" are characterized by 3 to 7 feet (1 to 2 meters) of glauconitic, intraclastic dolostone similar to St. Lawrence Formation strata above, interbedded with generally friable, glauconitic sandstone typical of the underlying Franconia Formation.

The St. Lawrence Formation is from 60 to 80 feet (18 to 24 meters) thick where it is unsected by erosion. It is covered by Quaternary glacial drift and alluvium and does not crop out on this quadrangle.

Dolostone beds commonly have solution features typical of karstic carbonate rock where the St. Lawrence Formation is exposed near Judson, Minnesota, northwest of the Good Thunder quadrangle. Bedding-plane exposures display an anastomosing network of centimeter-scale cavities that likely serve as ground-water conduits in saturated subsurface conditions (Runkel and others, 2003). The St. Lawrence Formation is used as a source of water for wells in this area, and yield is probably obtained largely through such features and through vertical fractures where the formation is at or close to the bedrock surface. However, in a vertical direction the St. Lawrence Formation as a unit probably serves as a hydraulic barrier separating the ground water in the Jordan Sandstone from that in the upper Franconia Formation.

The Franconia Formation and older Cambrian formations do not crop out on this quadrangle.

SOURCES USED TO COMPILE THE GEOLOGIC MAP

The Good Thunder bedrock geologic map was compiled from several sources. The authors mapped and described bedrock outcrops. Theses by Humphrey (1958), Austin (1971), and Stubblefield (1971) provided additional descriptions for some outcrops on the quadrangle or outcrops of the same stratigraphic unit in adjacent quadrangles to the north. Most of the area is overlain by thick Quaternary glacial deposits or by thick Holocene alluvium. Outcrops are found only along deeply incised stream valleys or on bedrock terraces. Therefore, mapping for most of the area relied principally on subsurface information derived from water wells and other borings. Drillers' logs for water wells and monitoring wells provided much of the data. Well cutting sample sets and geophysical logs are available for some of these borholes.

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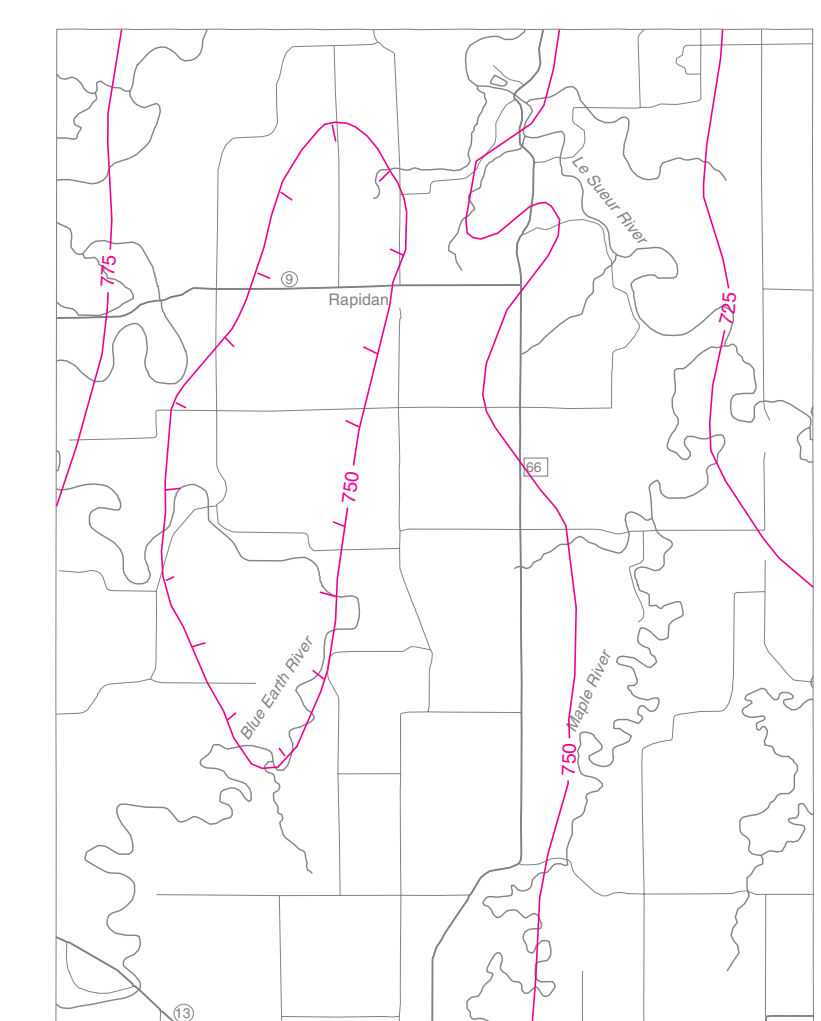
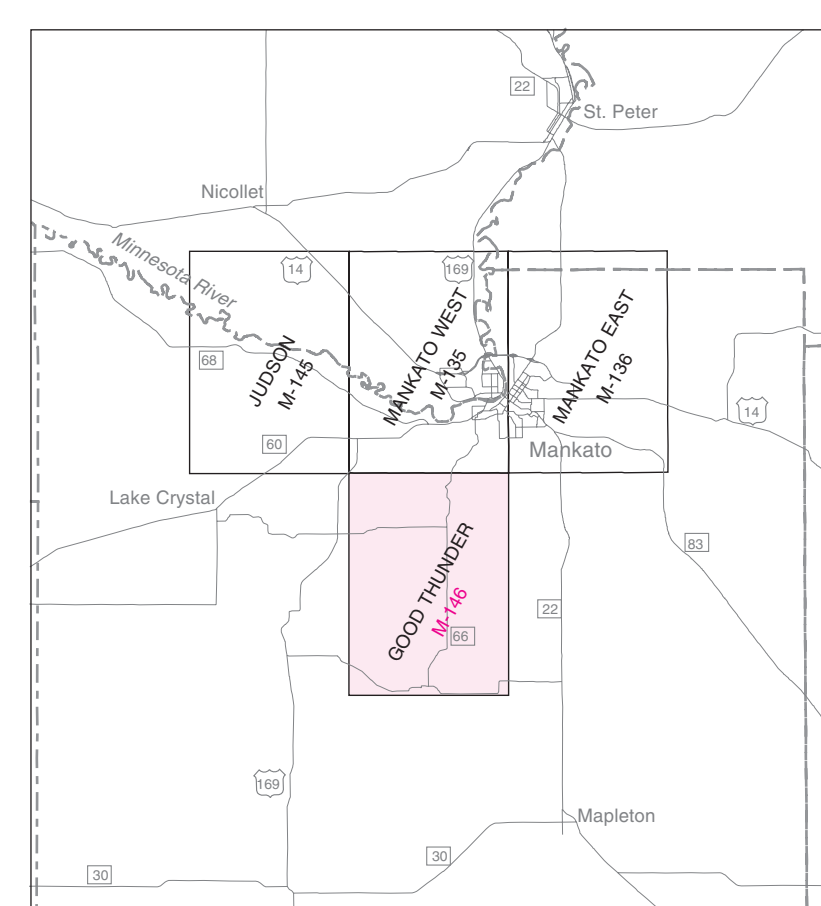


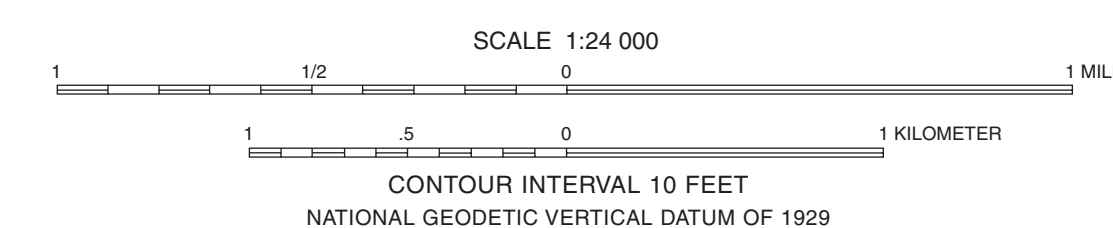
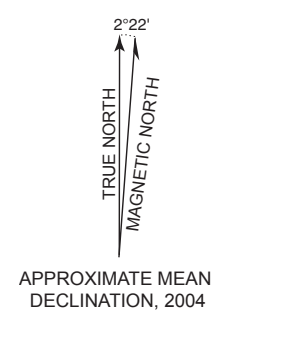
Figure 1. Map of the Good Thunder quadrangle contoured at the top of the St. Lawrence Formation showing geologic structure; scale 1:100,000. Contour interval for the top of the St. Lawrence Formation is 25 feet (8 meters).



INDEX TO BEDROCK STATEMAP QUADRANGLES IN THE MANKATO AREA IN THE MISCELLANEOUS MAP SERIES
Good Thunder (M-146)
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Mankato East (M-136)
Mankato West (M-135)

Base from U.S. Geological Survey Good Thunder 1:24,000 quadrangle, 1974.
Universal Transverse Mercator grid, zone 15
1983 North American Datum

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. The views and conclusions contained in this document are those of the authors and should not be interpreted as necessarily representing the official policies, either expressed or implied, of the U.S. Government. This map is submitted for publication with the understanding that the U.S. Government is authorized to reproduce and distribute reprints for governmental use. Supported by the U.S. Geological Survey, National Cooperative Geologic Mapping Program, under assistance Award No. G3HQAG0071.



BEDROCK GEOLOGY OF THE GOOD THUNDER QUADRANGLE,
BLUE EARTH COUNTY, MINNESOTA

by
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2004