UNIVERSITY OF MINNESOTA
MINNESOTA GEOLOGICAL SURVEY
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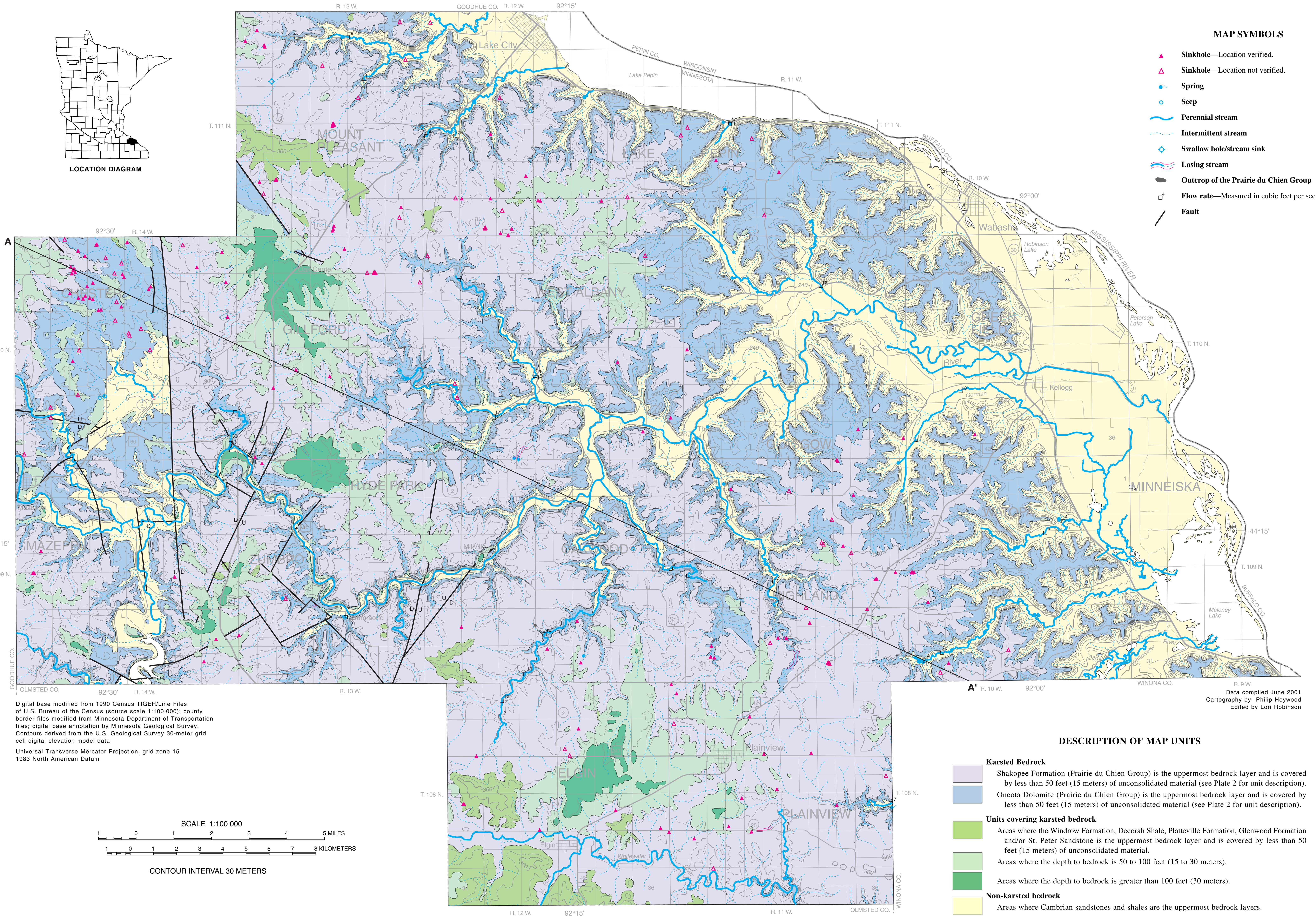
COUNTY ATLAS SERIES
ATLAS C-14, PART A
Plate 5—Karst Features



MAP SYMBOLS

- Sinkhole—Location verified.
- Sinkhole—Location not verified.
- Spring
- Seep
- Perennial stream
- Intermittent stream
- Swallow hole/stream sink
- Losing stream
- Outcrop of the Prairie du Chien Group
- Flow rate—Measured in cubic feet per second.
- Fault

Data compiled June 2001
Cartography by Philip Heywood
Edited by Lori Robinson

Digital base modified from 1990 Census TIGER/Line Files of U.S. Bureau of the Census (source scale 1:100,000); county border files modified from Minnesota Department of Transportation files; digital base annotation by Minnesota Geological Survey. Contours derived from the U.S. Geological Survey 30-meter grid cell digital elevation model data

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

SCALE 1:100 000

CONTOUR INTERVAL 30 METERS

DESCRIPTION OF MAP UNITS

Karsted Bedrock

Shakopee Formation (Prairie du Chien Group) is the uppermost bedrock layer and is covered by less than 50 feet (15 meters) of unconsolidated material (see Plate 2 for unit description).

Oneota Dolomite (Prairie du Chien Group) is the uppermost bedrock layer and is covered by less than 50 feet (15 meters) of unconsolidated material (see Plate 2 for unit description).

Units covering karsted bedrock

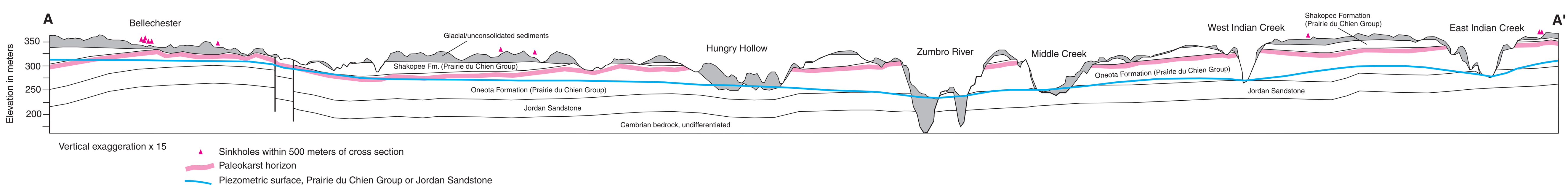
Areas where the Windrow Formation, Decorah Shale, Platteville Formation, Glenwood Formation and/or St. Peter Sandstone is the uppermost bedrock layer and is covered by less than 50 feet (15 meters) of unconsolidated material.

Areas where the depth to bedrock is 50 to 100 feet (15 to 30 meters).

Areas where the depth to bedrock is greater than 100 feet (30 meters).

Non-karsted bedrock

Areas where Cambrian sandstones and shales are the uppermost bedrock layers.



POSITION OF SINKHOLES ON THE LANDSCAPE

Figure 1. Preferential weathering and dissolution of Prairie du Chien Group bedrock in a quarry near Hammond (exposure height is 90 feet [27 meters]). As seen by the rust-colored stains in the rock and presence of vegetation, most water movement and weathering is focused along layers in the upper section of the bedrock and at the base of the soil zone. Distinct weathering is also visible along two vertical joints to the right of the crest of the hill (**A**). The joint to the right has a filled sinkhole at the top (**B**), and serves as a model of sinkhole occurrence elsewhere in the county. In this model, surface water runoff is diverted into the subsurface through a vertical joint in the bedrock of the wall before it reaches the valley bottom. These kinds of vertical openings are likely important ground-water pathways that contribute water to horizontal zones of high permeability, such as the one shown in Figure 3.

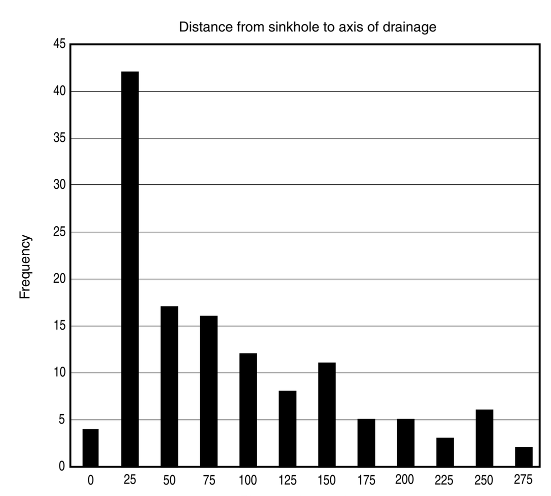


Figure 2. Histogram showing the distance of location-verified sinkholes to the nearest drainage axis. Most sinkholes occur near, but not always on the axis of drainage.

PALEOKARST

Figure 3. Photograph of a quarry north of Plainview in south-central Wabasha County showing the paleokarst horizon near the contact of the Shakopee Formation and Oneota Dolomite. Some cavities are partly filled with dark, unconsolidated sediment (exposure height is 50 feet [15 meters]). Karstification of the Prairie du Chien Group has occurred repeatedly through time. Carbonate rocks were weathered and dissolved when the sea level dropped after deposition of the Oneota Dolomite, and again after deposition of the Shakopee Formation. The most weathered horizon is in a zone between zero and 70 feet (21 meters) below the Shakopee–Oneota contact. The zone is highly permeable, allowing for rapid movement of ground water. Many of the caves in Wabasha County are located in this horizon, and it is responsible for many of the county wells that blow and suck air. The openings of paleokarst features are commonly choked with sediments of unknown age, or are completely filled with lithified carbonate breccia and fine-grained sediment.

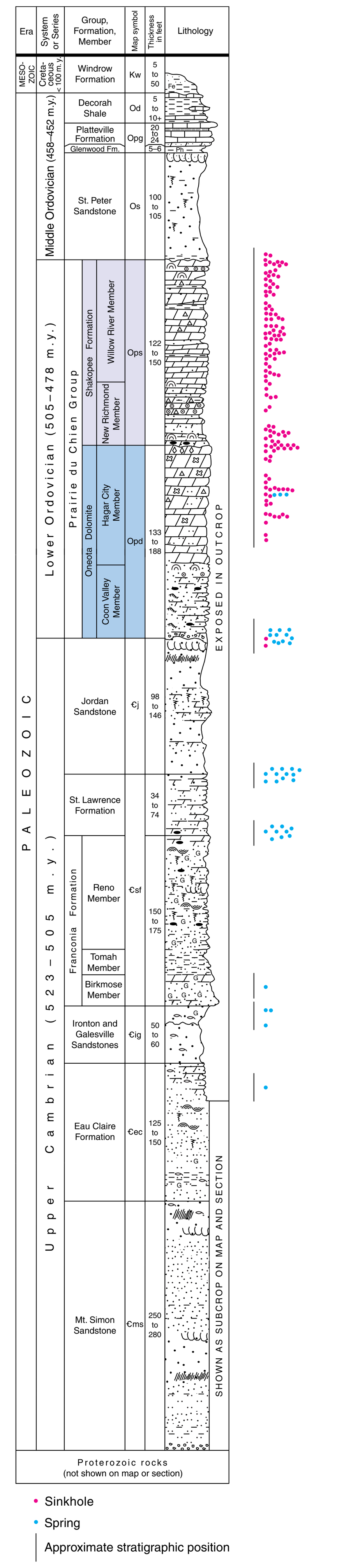


Figure 4. Stratigraphic column showing the position of springs relative to bedrock units in Wabasha County. Map units correspond to those on Plate 2, Bedrock Geology. Most springs occur below the Prairie du Chien Group, indicating that their source water comes from the karst-dominated uplands.

KARST FEATURES

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INTRODUCTION

Karst processes are responsible for the sinkholes, springs, caves, and other related features found in Wabasha County. Karstification occurs when the Prairie du Chien bedrock is slowly dissolved by acidic ground water. As precipitation enters the ground, carbon dioxide dissolves into the water and makes it mildly acidic. The acidic water moves through and enlarges existing cracks and fissures in the carbonate rock. Eventually, the water may emerge on the land surface as a spring after travelling through a system of interconnected bedrock conduits.

The dissolution of carbonate bedrock is a long process. Headstones made from limestone and marble measure long-term carbonate dissolution rates. These rates are typically less than one centimeter per 1,000 years (Buhmann and Dreybrodt, 1985). The carbonate rocks of the Prairie du Chien Group in Wabasha County are more than 450 million years old (see Plate 2, Bedrock Geology). They have been subjected to many different climates and water flow regimes. Each of these has left a dissolution imprint on the rocks, which continue to be modified or re-activated as drainage patterns change.

MAPPED FEATURES

Karst features mapped in Wabasha County illustrate drainage dominated by the presence of bedrock conduits. These features include sinkholes, stream sinks, losing streams, springs, seeps, and intermittent and perennial streams. Sinkhole locations, dimensions, and history were recorded where possible. This information came from field surveys, county records, landowners' descriptions, and aerial photographs. In an effort to understand the temporal nature of drainage patterns in the county, temperature, conductivity, and flow rates were recorded at selected springs and streams. In addition, one-time flow measurements were made along the headwaters of major drainages, and wet–dry conditions were recorded before, during, and after rainfall events and at different times of the year. Also, chemical and isotopic data were collected from selected springs.

Sinkholes are closed depressions in the land surface. They are a surface expression of subsurface drainage patterns. Sinkholes usually form near cracks, fissures, or conduits in the underlying bedrock. When water seeps into the ground, it preferentially moves toward these holes in the bedrock because they act as natural drains. As water flow converges toward the bedrock drain, it gains speed and becomes turbulent. The turbulent water erodes soil and sediments as it moves down into the bedrock. The sediment is preferentially removed near the contact of the bedrock with overlying deposits. If these deposits are not cohesive, they settle into the space created by the erosion of the sediment, and a depression forms on the surface. If the sediments are more cohesive, a void forms at the bedrock/sediment surface. That void grows until the overlying soil and sediment collapse into it. Once surface depressions form, they capture surface runoff and enhance the flow into the new sinkhole. Sinkholes provide a direct connection between surface runoff and the underlying ground water. This water bypasses the natural filtering capacity of the soil (Figs. 1 and 2). If the drain in the bottom of a sinkhole is obstructed, the sinkhole can temporarily hold water or fill completely with sediments. Excavations reveal many more filled and inactive sinkholes than active sinkholes.

Stream sinks, also known as swallow holes, are specific points where water drains from the land surface and directly enters into the bedrock. They commonly occur along the axes of intermittent streams. Like sinkholes, they provide a pathway for water to bypass the natural filtering capacity of the soil.

Losing streams are observed reaches over which stream flow is significantly reduced, without a clearly defined stream sink. Losing streams were mapped where shallow depth-to-bedrock conditions exist, indicating infiltration into bedrock conduits.

Springs are points where underground water emerges on the land surface. The stratigraphic positions of the springs were determined using the bedrock geology map (Plate 2).

Seeps, like springs, are places where underground water emerges at the land surface. They differ from springs in that a distinct emergence point cannot be located. Large clusters of phreatophytes typically characterize slopes near and downstream from seeps.

Intermittent streams carry water only after the heaviest precipitation. Most of the draws in Wabasha County are dry. In upland areas, the identification of intermittent streams is complicated by the presence of drainage tiles, which have altered the natural drainage characteristics of the landscape. U.S. Geological Survey 7.5-minute topographic maps for Wabasha County (see index to quadrangles on Plate 1, Data-Base Map) were used to identify most of the intermittent streams shown on the map because these maps pre-date many but not all tile installations. The purpose in mapping these features is to show areas that are dominated by subsurface drainage.

Perennial streams carry water all year. They typically have springs or seeps along their headwaters or, as with Trout Brook, Zumbro and Whitewater Rivers, originate outside of the county. Perennial streams are located in valley bottoms, and are the outlets for much of the water that infiltrates the intermittent stream-dominated uplands. The location of the headwaters of perennial streams shifts upstream and downstream, reflecting long-term variations in climate. Over the last decade, the headwaters for most streams have moved farther up their streambeds due to increased precipitation.

DRAINAGE HISTORY AND KARST DEVELOPMENT

The Prairie du Chien Group was deposited in a shallow sea that covered most of the central midcontinent. At times, the sea level dropped, exposing the carbonate rocks to weathering and dissolution. Because these processes took place a long time ago and under different drainage conditions, the term ***paleokarst*** is used to describe the relic caves and dissolution features left by these subaerial exposures. Figure 3 shows the typical paleokarst horizon in Wabasha County. The position of the paleokarst horizon relative to the land surface is shown in cross section A–A'. The horizon is characterized by a maze of conduits, many of which are filled with unconsolidated sediment (see Text Supplement). These conduits are a major component of subsurface drainage within the county and are a factor in sinkhole development.

Sinkholes

Cross section A–A' shows the position of the paleokarst zone relative to the land surface. In Chester Township in western Wabasha County, the paleokarst zone and the water table converge. The greatest number of sinkholes per township occur here. When sediment-choked bedrock conduits are periodically flushed out by heavy precipitation, the overlying soil can collapse. The Bellechester wastewater stabilization pond treatment facility in Chester Township was the site of a lagoon failure in 1992 due to sinkhole collapse (Alexander and others, 1993).

In addition to the cluster in Chester Township, sinkholes commonly are found along the crests of drainage divides, such as along the southern borders of Mount Pleasant and Lake Townships in northern Wabasha County, and through Elgin, Plainview, and Highland Townships in southern Wabasha County. The location of 136 sinkholes have been verified, and the location of 60 mapped sinkholes have not been verified.

Sinkholes may be present near the contact of the St. Peter Sandstone and Prairie du Chien Group. The sinkholes may be the result of enhanced ground-water flow near this contact. The St. Peter Sandstone is present in plateaus within the county, preserved from erosion by the overlying resistant limestone of the Platteville Formation (Fig. 4). Below the Platteville Formation, the less permeable shale of the Glenwood Formation causes water moving through the Platteville Formation to run out the edges of the mesa, similar to water running off of a roof. This area of focused recharge also appears to move enough sediment to cause the formation of sinkholes. Examples of this type can be seen in T. 111 N., R. 13 W., secs. 21, 29, and 30, and T. 108 N., R. 12 W., sec. 19.

The most significant physical factor that controls the formation of sinkholes may be the depth to the bedrock surface. With few exceptions, sinkholes do not form where the depth to bedrock is greater than 50 feet (15 meters). Because ground-water recharge is not focused in these areas, the rate of sediment removal through bedrock cracks and solution cavities is not great enough to propagate a void on the land surface. The depth-to-bedrock intervals (see Description of Map Units) of 50 to 100 feet (15 to 30 meters) and greater than 100 feet (30 meters) are taken from Plate 4 (Depth to Bedrock) and have been included as map units to show the relationship of depth to bedrock and sinkhole occurrence.

Springs

Forty-nine springs have been mapped in Wabasha County. Figure 4 shows the stratigraphic position of most of these springs, which typically are found where there is a change in rock properties. This commonly, but not always, corresponds to lithostratigraphic or rock-name boundaries. Most of the springs are lower in the stratigraphic section at the base of bluffs, and are either gravity-driven or, under artesian conditions, boils. Springs in the Prairie du Chien Group are rare. Commonly, streambeds change from flow rates near zero to several tens of gallons per minute over a reach of the stream as the paleokarst zone within the Prairie du Chien Group and the streambed converge. Examples of this can be seen in the headwaters of the southern branch of Spring Creek (T. 110 N., R. 13 W., sec. 23) and in the headwaters of Cold Brook Creek (T. 110 N., R. 14 W., sec. 25).

The springs of Wabasha County are similar to other springs in southeastern Minnesota because they typically are composed of older ground water mixed with water that recently entered the subsurface. The subsurface residence times of spring water can range from hours to days, thus reflecting the vulnerability of these springs to surface-water contamination. Short residence times are evidenced by increased spring-water turbidity after heavy rains. Residence times measured using tritium data for four springs in Wabasha County show that the spring water entered the ground within the last 40 years.

KARST DATA MANAGEMENT

With the exception of a few large, tree-lined sinkholes that have remained features on the landscape, many sinkholes in Wabasha County are temporary. To understand and in turn predict their occurrence, it is essential to have accurate records of the location, dimensions, activity, and treatment of sinkholes. An attempt was made to map the karst features in each township; however, sinkholes, stream sinks, or losing streams exist that do not appear on this map. Future occurrences of these karst features should be tracked consistently. To accomplish this, a karst-feature data base has been created by the University of Minnesota Department of Geology and Geophysics, and the Minnesota Geological Survey that can be used by Wabasha County to track the locations and history of karst features. This data base is accessible at the Minnesota Geological Survey.

ACKNOWLEDGMENTS

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