General Geology and Natural Resources of Winnebago County, Wisconsin

Field Trip Guide Book • May 27, 2004

Photograph: Carl Guell Collection

Thomas S. Hooyer
University of Wisconsin–Extension
Wisconsin Geological and
Natural History Survey

Catherine Neiswender
University of Wisconsin–Extension
Winnebago County

UW Extension

Wisconsin Geological and Natural History Survey Open-File Report 2004-03

General Geology and Natural Resources of Winnebago County, Wisconsin

Field Trip Guide Book • May 27, 2004

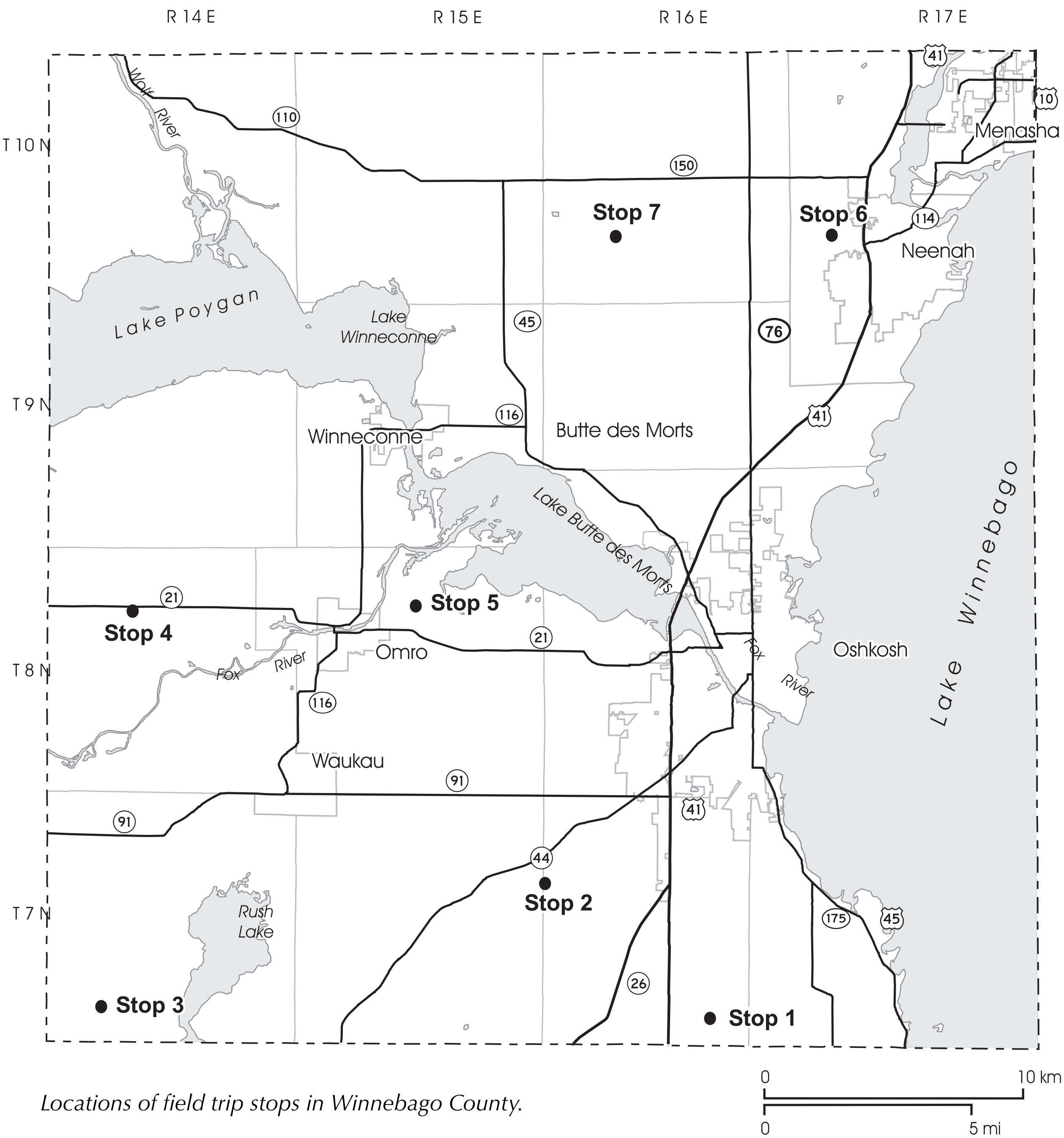
Thomas S. Hooyer
University of Wisconsin–Extension
Wisconsin Geological and Natural History Survey
3817 Mineral Point Road
Madison, Wisconsin 53705-5100
tel 608/263.4175
fax 608/262.8086
tshooyer@wisc.edu

Catherine Neiswender
University of Wisconsin–Extension
Winnebago County
625 E. County Road Y, Suite 600
Oshkosh, Wisconsin 54901-8131
tel 920/232.1970
fax 920/424.1277
CNeiswender@co.winnebago.wi.us

Wisconsin Geological and Natural History Survey
Open-File Report 2004-03

Contents

Figures



Locations of field trip stops in Winnebago County.

General Geology and Natural Resources of Winnebago County, Wisconsin

Field Trip Guide Book

Thomas S. Hooyer
Catherine Neiswender

Introduction

The state of Wisconsin experienced rapid population growth in the 1990s, especially in the Fox River lowland, which extends northward from Fond du Lac to Brown County in east-central Wisconsin. As a result of this population growth, many areas within the lowland are experiencing an increasing demand for natural resources, including crushed rock, sand and gravel, and groundwater. Geologists at the Wisconsin Geological and Natural History Survey (WGNHS) have undertaken an initiative to understand the geology of the Fox River lowland. As part of this project, they have recently completed preliminary geologic maps of Winnebago County, including the glacial deposits that cover the land surface, the elevation of the buried bedrock surface, and the bedrock geology.

Value of geologic mapping

An understanding of the extent and distribution of natural resources is important to local governing bodies as they proceed toward completing and implementing comprehensive (Smart Growth) plans as required under state law. Elements of the comprehensive plans that may be affected by the distribution of geologic resources include land use, natural resources, transportation, and economic development. For example, the bedrock formations are important for the nonmetallic minerals they provide: Sandstones are a resource for silica sand used in the foundry industry, and carbonate rocks (limestone/dolomite) are the primary source of construction aggregate in Winnebago County and the entire lower Fox River Valley region. In addition, sand and gravel resources in the county are limited, so mapping their distribution is important in the planning of future land use. Constructing rural housing developments near or on top of the few undeveloped potential sand and gravel deposits may not be in the best long-term interest of the citizens of Winnebago County.

Besides nonmetallic mineral resources, mapping the extent and distribution of surficial materials can help develop an understanding of stormwater infiltration and runoff to streams and rivers. Winnebago County has recognized the impact of such runoff on lakes and streams, and currently has an ordinance requiring erosion control and stormwater management at construction sites. A fundamental knowledge of the properties and composition of surficial materials will be helpful in effectively enforcing rules designed to protect streams and lakes—important natural resources of Winnebago County.

The geology of Winnebago County is also important in understanding the distribution of groundwater resources. The surficial materials and the bedrock layers are the principal aquifers that supply public and private water wells. The availability of groundwater and its quality are major concerns to county and local government due to the increasing number of rural homeowners dependent on private wells. In the past decade, more than 10,000 new water wells have been installed in the central Fox River lowland, placing additional demands on aquifers that contain a finite amount of water. As a result, availability and quality of groundwater have been affected in many locations. For example, in some aquifers, the water table has been lowered, allowing naturally occurring metals such as arsenic and other toxic heavy metals to be released into the groundwater by weathering of naturally occurring sulfide minerals.

These are only a few of the issues currently being discussed in Winnebago County. During this field trip, we will consider the importance of some geological resources to local and state officials.

Geology of Winnebago County

Glacial geology

Winnebago County is part of the Fox River lowland, which extends over parts of 13 counties in east-central Wisconsin. This lowland stretches from Green Bay to Portage and is defined by the Fox River, its tributaries, and associated drainage basins. The surficial geology of the lowland consists of landforms and sediment deposited from a glacier that most recently covered east-central Wisconsin approximately 21,000 years ago. This glacier, called the Green Bay Lobe, was part of the Laurentide Ice Sheet, which covered a large area of North America (fig. 1). This ice sheet was centered in northern Canada and extended eastward to the Atlantic Ocean, west to the Rocky Mountains, north to the Arctic Ocean, and southward into the upper Midwest. Six lobes of this ice mass extended into Wisconsin and covered a large part of the state. The Green Bay Lobe was the largest of these lobes and covered all east-central Wisconsin. The lobe terminated in the south near the Wisconsin/Illinois border and to the west by an area commonly referred to as the Central Sand Plain. To the east, the lobe abutted the Silurian Escarpment and the much larger Lake Michigan Lobe, which covered the Lake Michigan basin and extended southward into central Illinois.

The melting back of the Green Bay Lobe to the north resulted in the formation of a large lake in front of the ice margin and covered a vast area of the Fox River lowland. This lake was called glacial Lake Oshkosh and inundated most of Winnebago County. Red, clay-rich sediment was deposited within this lake. Glacial Lake Oshkosh initially drained southward into the lower Wisconsin River via an outlet located just north of Portage, Wisconsin (fig. 2a). With further retreat of the ice lobe, a series of lower outlets opened across the

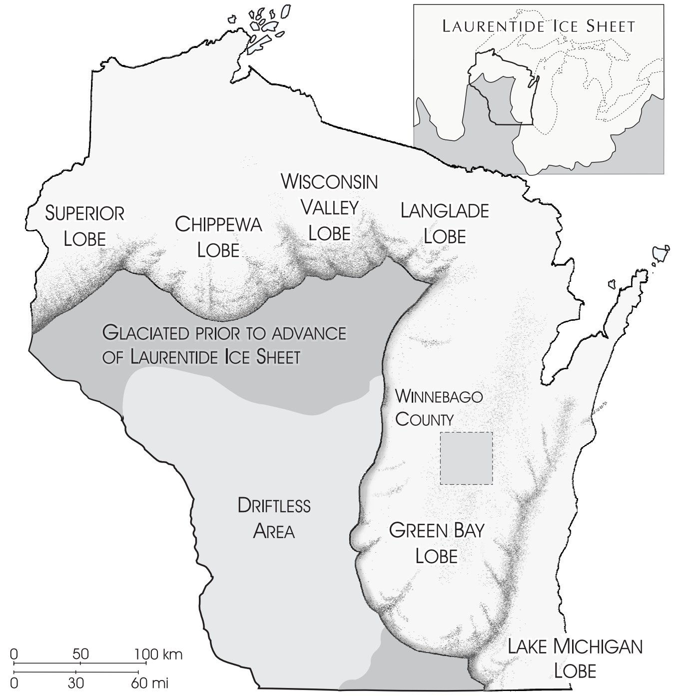
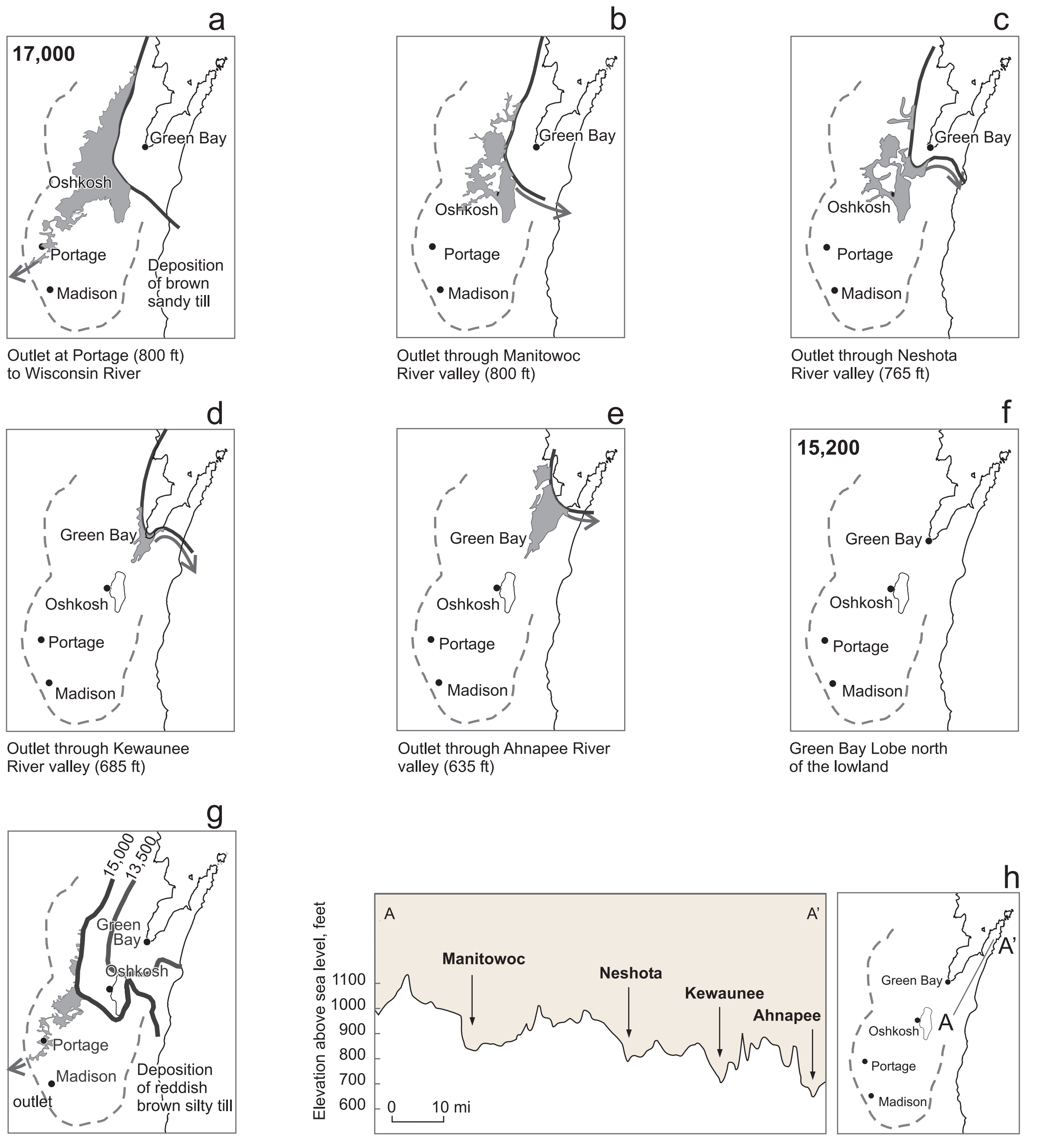


***Figure 1.** Location of Winnebago County in Wisconsin (**a**) in relation to the Laurentide Ice Sheet and its lobes (**b**) during the last part of the Wisconsin glaciation.*

Door Peninsula, lowering glacial Lake Oshkosh to the level of water in the Lake Michigan Basin (fig. 2b-h). Eventually, the Green Bay Lobe readvanced twice back into the Fox River lowland around 15,000 and 13,500 years ago (fig. 2g). During both readvances, glacial Lake Oshkosh was reactivated, depositing lake sediment over the landscape.

In Winnebago County, the lake covered a large part of the landscape (fig. 3), coating it with a layer of fine-grained lake sediment consisting primarily of clay and silt. With the first readvance of the ice sheet back into the Fox River lowland (fig. 4a), much of this lake sediment was reworked by the glacier and plastered onto upland areas of the county. Part of the readvancing lobe terminated in Winnebago County and formed a prominent ridge, called a moraine, which traverses the towns of Nekimi, Utica, and Rushford. This moraine is composed of reworked lake sediment called till, and it covers most upland areas in the county that



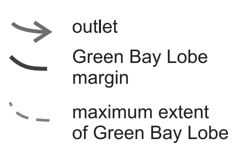


Figure 2. *About 20,000 to 15,200 years ago, the Green Bay Lobe receded, opening a sequence of lower outlets to the east (**a–f**). The lobe readvanced to the central part of the lowland twice, at about 15,000 and 13,500 years ago, resulting in reuse of the outlets (**g**). A profile of the land surface across the Door Peninsula shows the location and elevation of the eastern outlets of glacial Lake Oshkosh (**h**).*

were not covered subsequently by sediment deposited in glacial Lake Oshkosh.

Many small lakes formed in front of the ice lobe as it formed its terminal moraine. Several of these glacial lakes, including Cottonwood, Island, Gleason, and Bradley Lakes (fig. 4a), were located in Winnebago County. Silt and clay deposited in these lakes provide the substrate for the numerous wetlands in this part of the county. With the subsequent retreat of the lobe, the lakes drained into a lower and larger glacial Lake Oshkosh that once again covered a large part of the county (fig. 4b, c). Eventually, after one more minor advance of the Green Bay Lobe that only reached Neenah, the ice receded northward into Canada and glacial Lake Oshkosh ceased to exist. The final result of the glaciation in Winnebago County is that the landscape is coated mainly with silt and clay lake sediment. In many low-lying areas, wetlands formed because of this relatively impermeable substrate and the very low relief of the landscape. Today, many of these wetlands have been preserved and provide prime habitat for fish and wildlife.

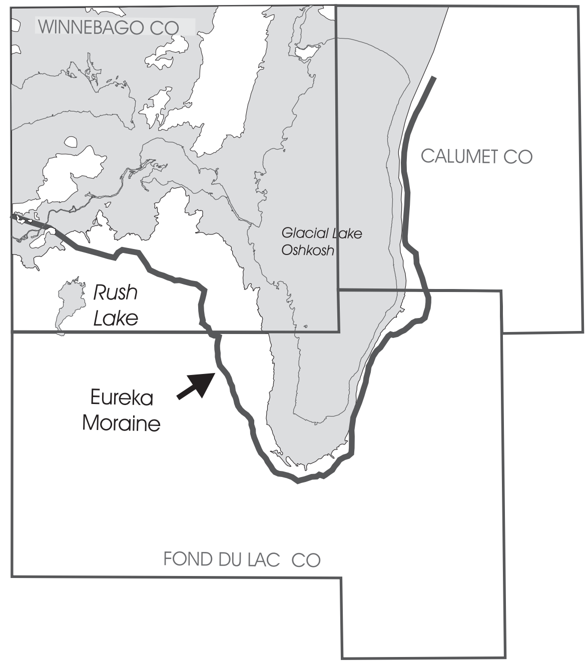


Figure 3. *Maximum extent of glacial Lake Oshkosh in Winnebago, Calumet, and Fond du Lac Counties.*

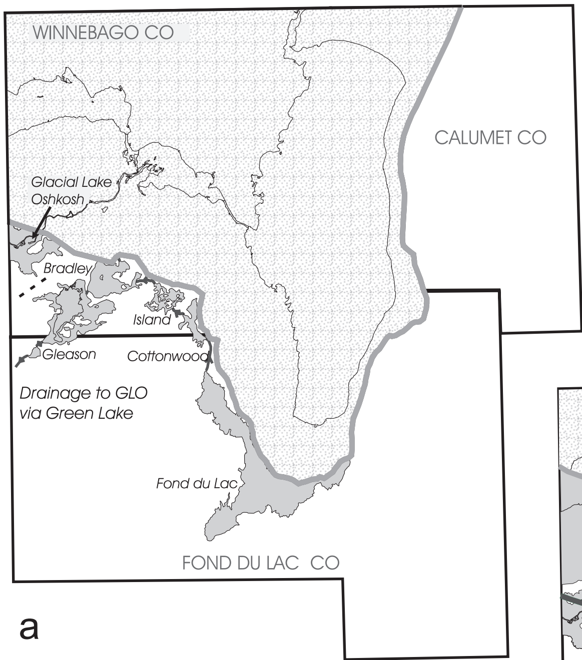
Bedrock geology

The bedrock, which lies immediately beneath the glacial deposits in Winnebago County, consists of layered sedimentary rocks, including sandstones and dolomites that formed 440 to 570 million years ago (fig. 5). Beneath these rock layers are much older Precambrian crystalline rocks that are as old as 1,750 million years; these rocks do not reach the surface in Winnebago County, but typical examples are the granites formerly quarried for building stone at Red Granite and Montello, and the rhyolite at Berlin.

The layered sedimentary rocks can be grouped into four major units that allow us to better understand their history and distribution. The four units include, from youngest to oldest, the Sinnipee Group, Ancell Group, Prairie du Chien Group, and the Cambrian sandstones. These rock strata dip gently (10 to 15 feet/mile) to the east (fig. 6) and extend under Lakes Winnebago and Michigan. The bedrock geologic map of Winnebago County shows that all four units are present at the bedrock surface (fig. 7).

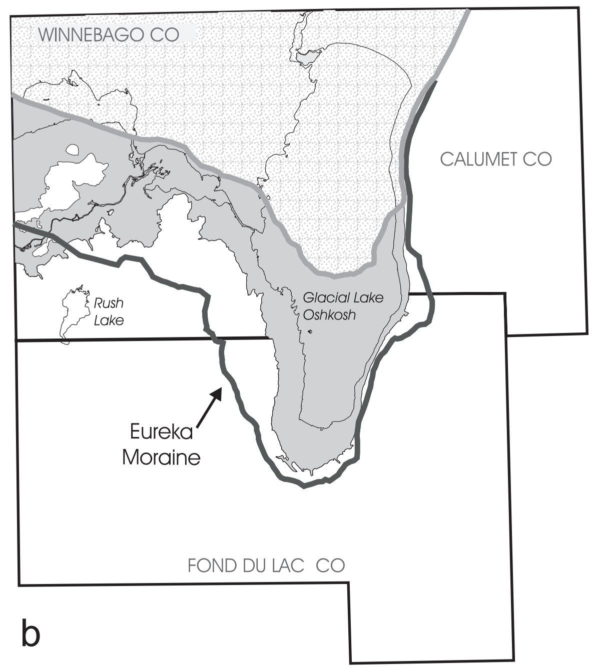
The oldest sedimentary rock unit in Winnebago County is the Upper Cambrian sandstone. It consists of many different rock formations, known mostly from samples collected by well drillers and studied at the WGNHS. These rocks are poorly exposed at the land surface, but form the bedrock surface beneath the glacial deposits in the northwestern part of the county. These sandstones are usually thick, saturated with water, and form the most productive deep aquifer in the county. They are the source rock for most municipal and high-capacity industrial wells.

Immediately above these Cambrian sandstones lies the dolomite of the Prairie du Chien Group. These rocks are exposed at the bedrock surface in a strip that extends from northeast to southwest across the central part of the county. In some places this dolomite is exposed at the land surface

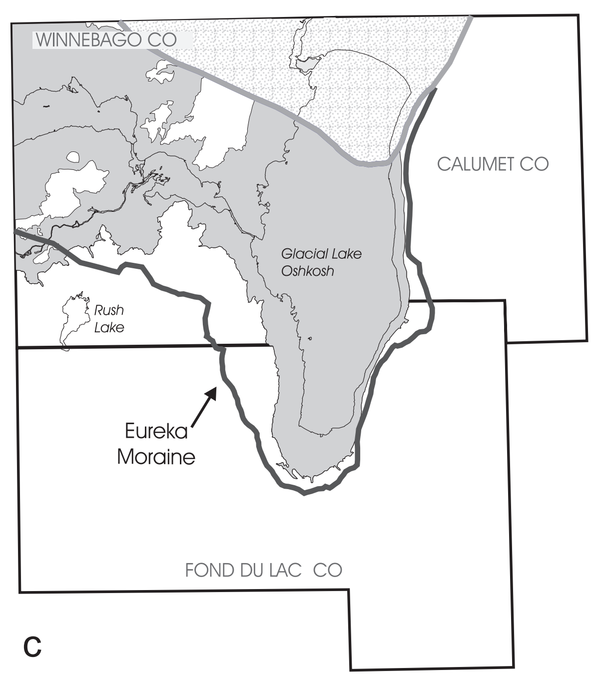


a

Figure 4. About 15,200 years ago, the Green Bay Lobe readvanced into the Fox River lowland, covering a large part of Winnebago County and northern Fond du Lac County (***a***). Numerous small lakes and a fairly prominent moraine formed in front of the ice margin. As the ice receded northward, these small lakes drained into glacial Lake Oshkosh (***b***). Continued recession of the ice margin northward resulted in the expansion of glacial Lake Oshkosh (***c***).



b



c

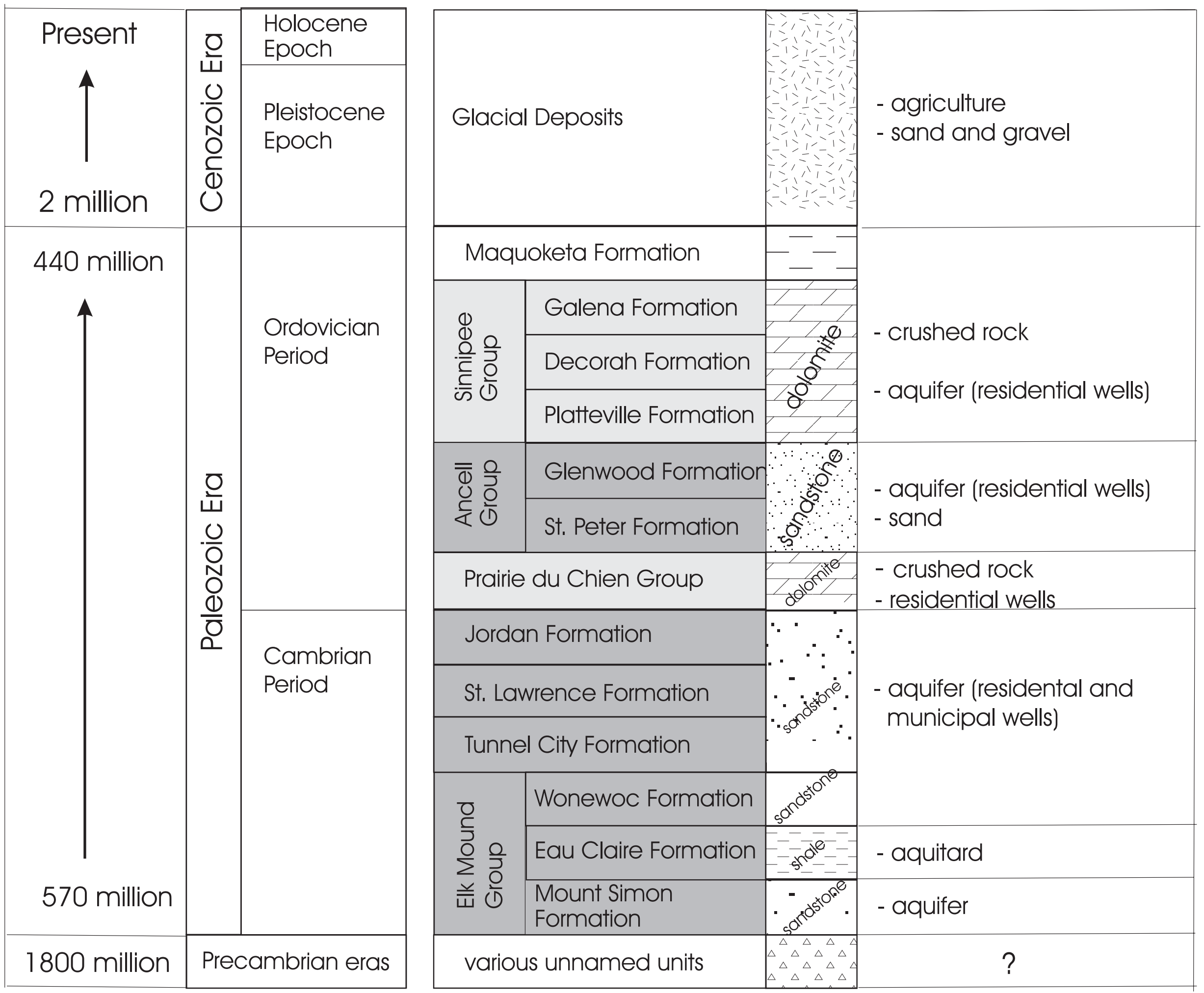


Figure 5. *Stratigraphic column of Winnebago County.*

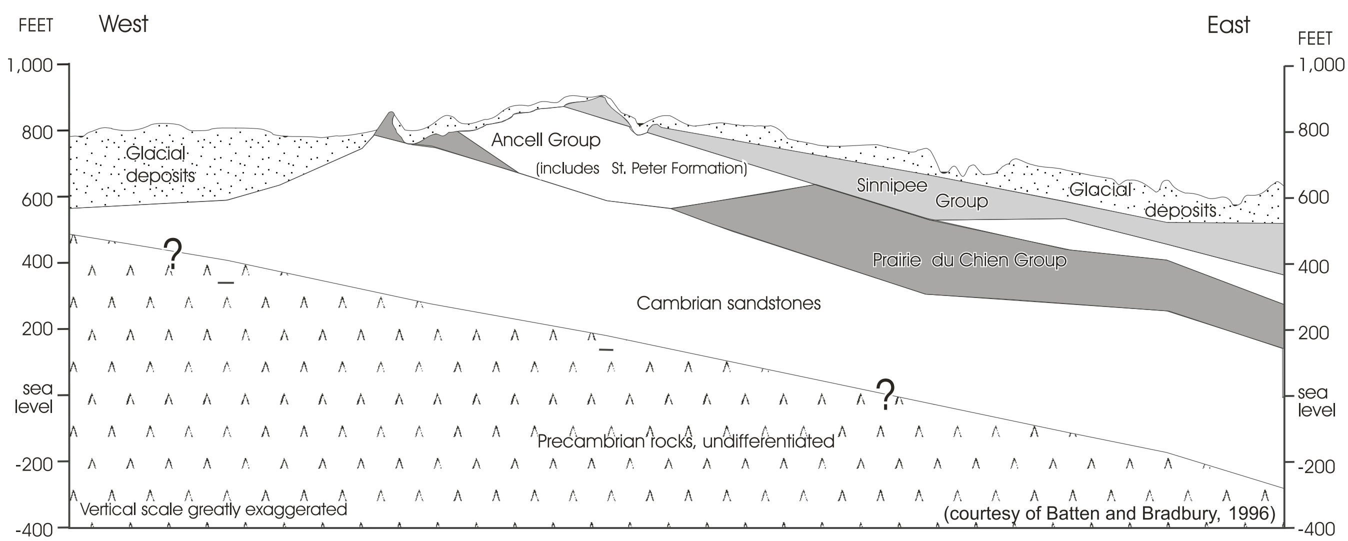


Figure 6. *Generalized geologic section across Winnebago County.*

0 1 2 3 4 5 MILES
0 1 2 3 4 5 KILOMETERS

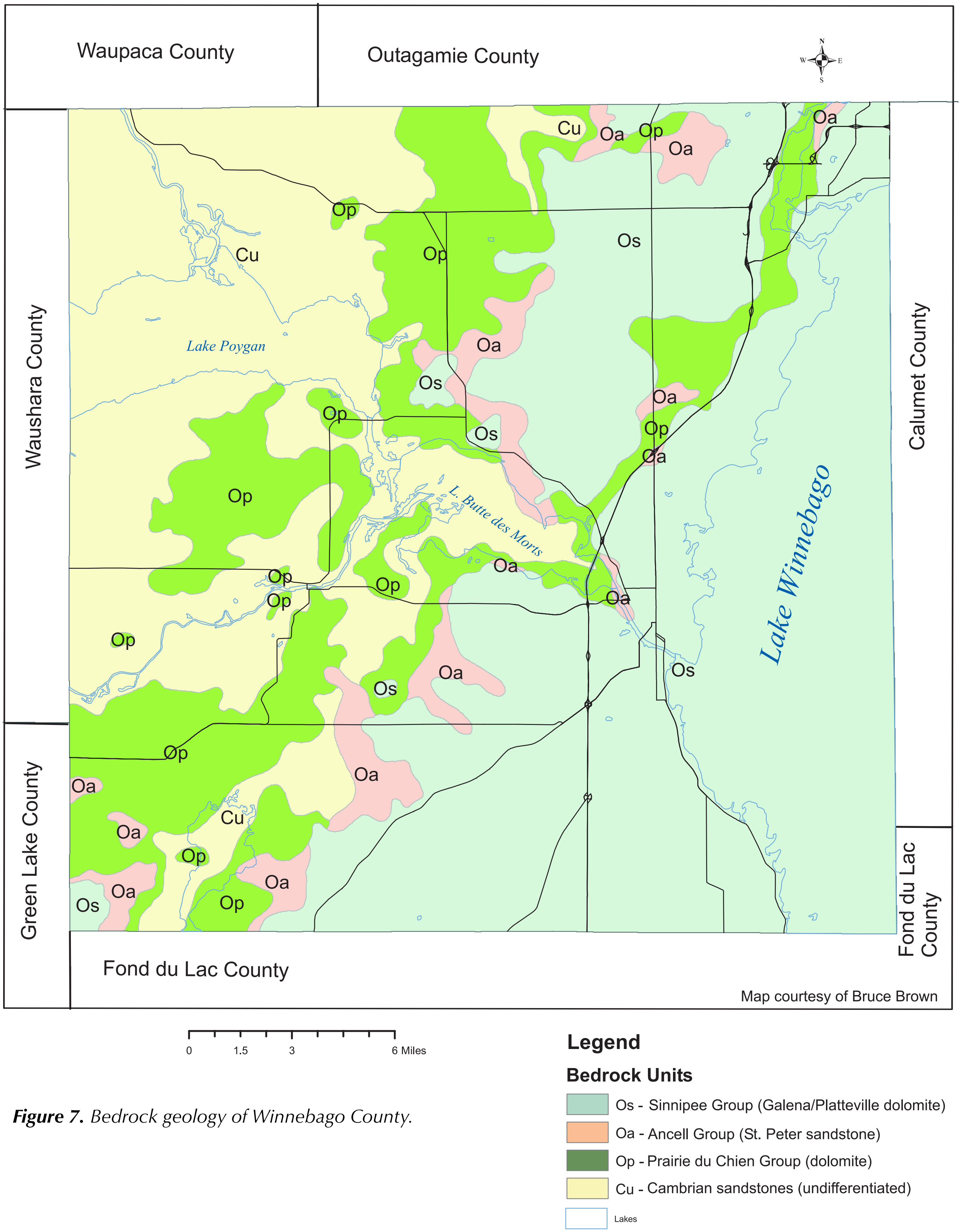


Figure 7. *Bedrock geology of Winnebago County.*

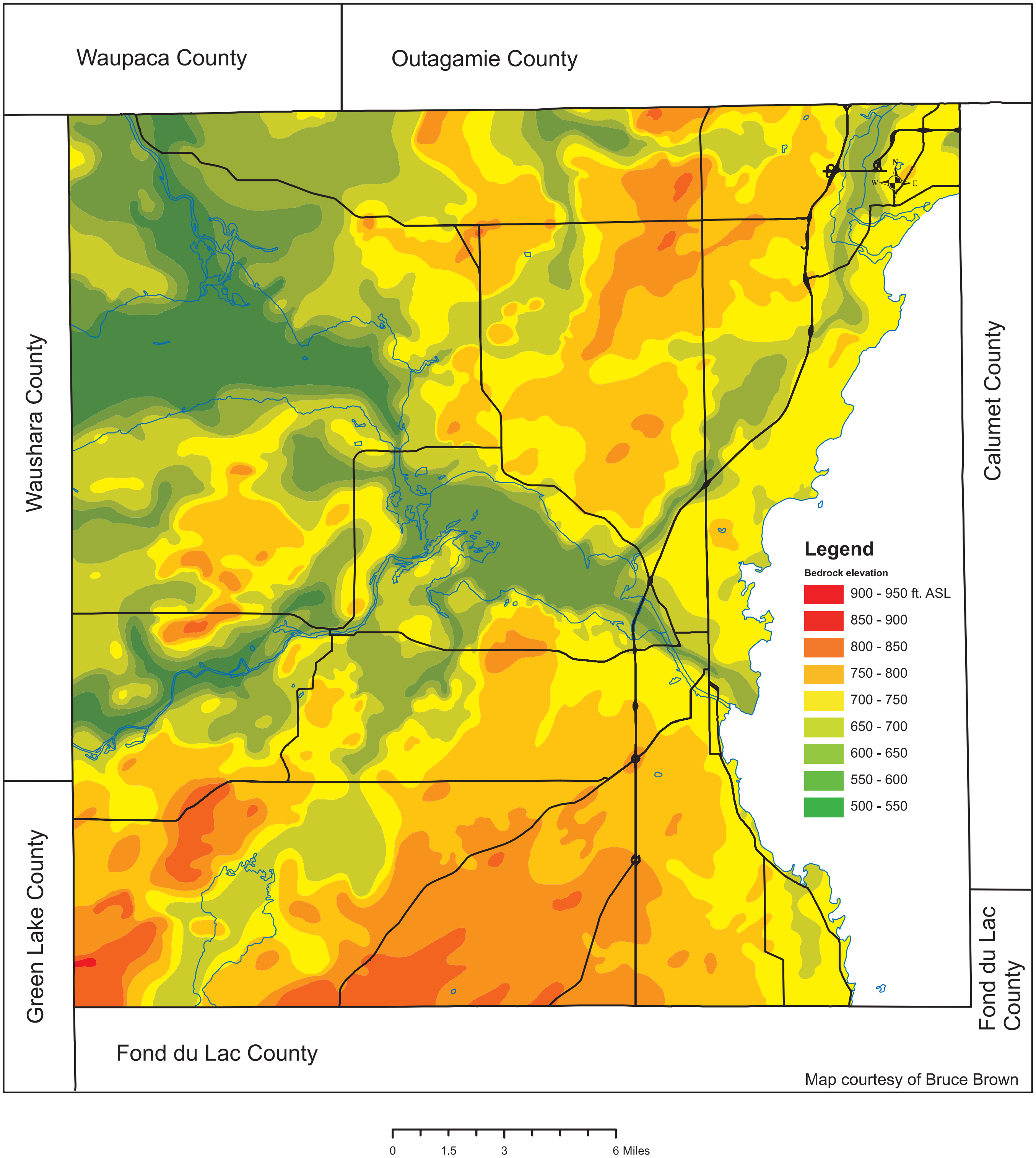


Figure 8. *Bedrock elevation of Winnebago County.*

and outcrops in a series of bluffs or escarpments. At many of these exposures, the rocks are quarried because they are a good source of high-quality aggregate for the construction industry.

The Ancell Group, the third of four main units, consists mainly of sandstone of the St. Peter Formation. Where present it overlies the Prairie du Chien dolomite. This sandstone is also exposed at the bedrock surface in a narrow band that stretches from northeast to southwest across the county. A major geological break, or unconformity, occurs between the Prairie du Chien dolomite and the St. Peter sandstone. This unconformity is the result of a large river system draining into an ancient sea that eroded deep channels into the Prairie du Chien dolomite and subsequently filling them up with sand. Some of these channels were so deep that that in places the Prairie du Chien dolomite may have been completely eroded away, resulting in the St. Peter sandstone being directly deposited on top of the older Cambrian sandstone. In other cases, however, minimal erosion of the Prairie du Chien dolomite occurred, and no St. Peter sandstone is present. As a result, the younger Platteville dolomites may lie directly on top of the Prairie du Chien dolomite.

This irregular occurrence of St. Peter sandstone across the county is poorly understood because of the lack of good geologic information. This is frustrating for geologists and water managers alike because this sandstone, which has historically been an important aquifer, sometimes contains layers of naturally occurring sulfide minerals, including arsenic. It is from within this sandstone that many rural and suburban residential wells obtain their drinking water. As officials of many state and local governing bodies are aware, this is a significant problem that can pose serious health hazards throughout the region because the occurrence of arsenic in well water can vary widely over short distances and is difficult to predict.

The youngest bedrock rock unit in Winnebago County is the Sinnipee Group, which consists primarily of dolomite and is exposed at the bedrock surface in the eastern half of the county. As previously mentioned, these rocks either overlie the St. Peter sandstone or the Prairie du Chien dolomite. Similar to the Prairie du Chien dolomite, the Sinnipee Group occurs near the surface in many locations in the eastern half of the county, making it accessible for quarrying. The Platteville and Galena dolomites are the primary source of aggregate in the county. Their strength and durability make them ideal aggregate material for asphalt and concrete.

Depth to bedrock

The depth to the bedrock surface in Winnebago County is highly variable. It is the result of millions of years of river and stream erosion prior to glacial erosion and deposition. Prior to the most recent ice age (<2 million years ago), the landscape was probably similar to what we observe today in the Driftless Area of southwest Wisconsin: high broad plateaus dissected by deep continuous valleys. An evaluation of water well construction reports reveals a set of deeply incised valleys that cross Winnebago County (fig. 8). The deepest parts of these valleys are found along the axis of the Fox River, Lake Poygan, and the Wolf River. Some sections of these buried valleys are more than several hundred feet deep and are filled with thick sequences of glacial lake sediment.

Within some of the lake sediment sequences are layers of sand and gravel that provide a feasible source of water for domestic wells. Further investigation of the buried valleys may determine whether layers of sand and gravel within the buried valleys are sufficiently continuous to provide a source of groundwater for municipal water wells.

Stop 1. Eureka Moraine, Glacier Ridge Bison Farm Gravel Pit (owners: Mark and Michelle Schultz)

The Eureka moraine is a prominent ridge that cuts across southern Winnebago County. This moraine formed at the margin of the Green Bay Lobe when it stabilized at its maximum extent during the lobe's first readvance into Wisconsin around 15,000 years ago. From the study of modern glaciers, geologists know that many large streams carrying sand and gravel usually emerge from beneath the ice. This sand and gravel is usually deposited directly in front of the ice margin as the stream flows away from the ice lobe (fig. 9). Thick accumulations of sand and gravel can occur where the ice sheet stabilizes, forming a moraine.

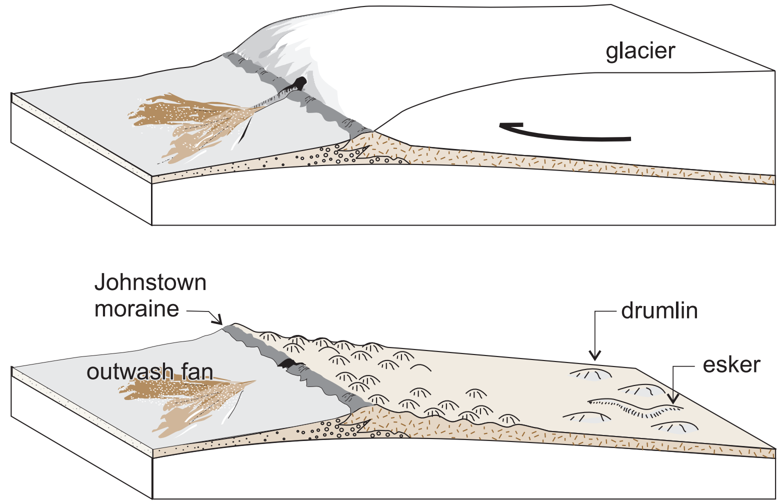


Figure 9. *Margin of the Green Bay Lobe forming the Eureka moraine and associated proglacial outwash fans (**a**). Many features such as drumlins and eskers that formed on the bed of the glacier (**b**) have been buried beneath lake sediment in Winnebago County.*

Such is the case at the Glacier Ridge Bison Farm where sand and gravel is currently being excavated at the crest of the moraine. Please note that in the main part of the pit up to ten feet of red glacial till (reworked lake sediment) overlies nearly 30 feet of sand and gravel. This sand and gravel was most likely deposited in a deep river channel that was emerging from the base of the ice lobe close to its margin. The extent of this old river channel is not obvious, but it appears to extend across the property and has apparently been mined for many decades.

A review of topographic maps and aerial photographs reveals that over the past 80 years numerous sand and gravel pits have been located in the ancient river channels associated with the Eureka moraine. Apparently, these deposits have supplied a significant amount of sand and gravel to the county. Currently only a few gravel pits are located along the moraine, but further exploration may reveal the potential for more deposits.

Stop 2. Eureka moraine, Radio Tower Hill

Radio Tower is located on top of the Eureka moraine and is an excellent location to view the surrounding landscape. As you look south, the landscape is dominated by a rolling topography consisting mainly of elongated hills called drumlins that were formed when the Green Bay Lobe was receding from its maximum extent, around 17,000 years ago. To the north of the Eureka moraine, the landscape is relatively flat and is dominated by red till and lake sediment deposited in glacial Lake Oshkosh.

The Eureka moraine is not only important because it marks the limit of the readvancing Green Bay Lobe and represents a potential resource of sand and gravel, but because it divides the region into two areas where the surface materials consist predominantly of sand to the south and fine-grained lake sediment consisting of silt and clay to the north. Representative grain-size analyses of these sediments show a dramatic increase in sand in the surface materials, from about 20 percent to 65 percent as we cross the moraine. This difference in grain size reflects the origin of the sediment. The sandy sediment to the south of the Eureka moraine was most likely eroded from the sandstone and dolomite that underlie large parts of the area covered by the Green Bay Lobe. On the other hand, the surface material north of the moraine is a product of fine-grained lake sediment deposited in glacial Lake Oshkosh, some of which has been reworked into glacial till.

Such a dramatic difference in sand content of surface materials will play a major factor in stormwater infiltration and runoff. The surface sediment south of the moraine is more permeable and likely to adsorb surface-water runoff. To the north of the moraine, however, the land surface is less permeable and runoff is more likely to occur.

Stop 3. NorRok Materials Quarry (owner: Tim Trapp); A.F. Gelhar Company Quarry (owner: Jim Gelhar)

The NorRok and Gelhar Quarries are located immediately adjacent to each other in the southwest corner of Winnebago County. The quarries, when viewed together, provide an excellent example of how the Platteville dolomite (Sinnipee Group) overlies the highly irregular St. Peter sandstone.

The walls of the Gelhar Quarry expose approximately 60 feet of St. Peter sandstone. This rock, as you will observe, consists of sand grains that are weakly cemented together. As a result, the sand is easy to mine and is commonly used in the foundry industries as molding sand. Close inspection of the quarry walls shows structure in the rock, indicating that the sand was initially deposited in a deep river channel cut down into the older Prairie du Chien dolomite (not visible). From the dimensions of the quarry it is not easy to determine the shape or direction of the filled channel as it crosses the landscape.

Immediately adjacent to this pit is the NorRok Materials Quarry where the younger Platteville dolomite is actively being mined and crushed for the construction industry. In the southern part of this quarry near the scale house, the dolomite lies on top of the St. Peter sandstone. However, as we move immediately northward, the sandstone pinches out beneath the younger dolomite and ceases to exist, showing the lateral discontinuity of the formation. The thin, 1- to 2-foot sand seam observed in the face of the dolomite quarry may be the sandstone that separates the Platteville dolomite from the much older Prairie du Chien dolomite.

In many other areas of the county such as the towns of Omro, Algoma, and Clayton, the St. Peter sandstone is buried deeply beneath younger rocks and is saturated with water, making an excellent aquifer for domestic wells. As residential development has increased in these areas over the past decade, many new wells have tapped into this sandstone aquifer. This increased demand for water has lowered the water table in places, allowing oxygen to enter the aquifer, resulting in chemical reactions (oxidation) that release certain heavy metals including arsenic, cadmium, chromium, nickel, and iron. Even without the process of oxidation, the presence of sulfide minerals may result in low levels of arsenic in groundwater wells (on the order of 5 to 30 parts per billion). For example, based on previous well water sampling in the Town of Clayton, one of every four wells is likely to have unacceptable water quality due to the presence of heavy metals.

Stop 4. Allen Quarry (owners: Michaels Materials)

The Allen Quarry, located off Highway 21 near the intersection of County Highway K, is an excellent place to view a 40-foot high section of Prairie du Chien dolomite overlain by 10 feet of red glacial till. Close inspection of the dolomite reveals a set of horizontal cracks (bedding planes) and a set of vertical cracks (fractures). The dolomite is continuous across the quarry, providing Michaels Materials with a good supply.

The Prairie du Chien dolomite, a dominant source of crushed rock in southwestern Winnebago County, forms many of the broad upland areas in the towns of Nepeuskun, Rushford, and Poygan. The western edge of many of these upland areas represents the westernmost extent of dolomite in the county.

A review of the bedrock surface elevation map (fig. 8) reveals that many of these upland areas are dissected by broad valleys where the dolomite has been eroded away, exposing the older Cambrian sandstone at the bedrock surface (fig. 6). These bedrock valleys are filled predominantly with lake sediment, although layers of sand and gravel may be present. As a result, these buried bedrock valleys may be a source of groundwater for domestic water wells.

At the top of this quarry the dolomite is covered by red till. Because we are within the margin of the Eureka moraine, most of this material is reworked lake sediment from glacial Lake Oshkosh. These deposits usually contain less than 20 percent sand, making them relatively impermeable to the infiltration of stormwater.

Stop 5. Lunch (Review of lake sediments from glacial Lake Oshkosh)

The WGNHS has drilled nine deep boreholes in the Fox River lowland to characterize the type of sediment present in buried bedrock valleys. These valleys dissect Winnebago County and have been filled in with glacial sediment deposited during the most recent glaciation. These glacial sediments most likely consist of lake sediment that is clay and silt. However, some of the sediment may contain layers of sand and gravel that could be a groundwater resource.

Although the WGNHS has not yet drilled any boreholes in the buried valleys in Winnebago County, several boreholes are located immediately to the west in Waushara County. Several of these boreholes show saturated sand layers that range between 40 and 60 feet in thickness. More drilling will be needed to determine whether these sand layers extend into the buried valleys in Winnebago County and whether they contain adequate groundwater resources for municipal wells.

The majority of the sediment in the nine boreholes contains thick sequences of lake sediment. Several boxes of this lake sediment, displayed for examination, reveal numerous small layers of silt and clay. One silt layer and one clay layer, usually called a couplet, represent one year of deposition. Counting these couplets shows that glacial Lake Oshkosh existed for more than 1,000 years during its most extensive phase.

Old organic material consisting of lake plants and tree branches is also buried in the clay and silt couplets, allowing us to perform radiocarbon analyses to determine the age of glacial Lake Oshkosh. The history of the lake is now fairly well known (fig. 2), including the distribution of lake sediment in the Fox River lowland.

The distribution of such fine-grained lake sediment over the landscape explains the poor infiltration and the problems with soil erosion in Winnebago County. Such erosion has significant impact on surface-water bodies, including the lakes. Winnebago County has realized the impact of this runoff and has an ordinance requiring erosion control and stormwater management at construction sites. Educating the public on the impact of the soil erosion on surface-water bodies could also help improve their quality.

Stop 6. Ben Carrie Quarry (owners: Michaels Materials)

The Ben Carrie Quarry, owned and operated by Michaels Materials, is located in the Town of Menasha just west of Neenah. The quarry is an excellent place to observe the relationships between the St. Peter sandstone and the Platteville and Prairie du Chien dolomites.

In the northeastern end of the quarry, approximately 20 feet of fractured Platteville dolomite overlies 15 feet of yellow St Peter sandstone. Examination of the quarry wall shows that the sandstone pinches out laterally to the north. As we observed at Stop 1, this is not surprising given the irregular occurrence of the St. Peter sandstone across Winnebago County. Where the sandstone pinches out in the quarry wall, the Platteville dolomite overlies the Prairie du Chien dolomite. A walk along the quarry walls shows that the dolomite from these two units is very similar, although there are slight differences that help geologists identify them independently. Some of these differences include the mechanical properties of the rock as well as the presence of shale layers.

The St. Peter sandstone is especially interesting at this stop because it shows the presence of naturally occurring sulfide minerals. These sulfide minerals, when exposed to the oxygen in the air, oxidize and turn parts of the rock red and yellow. A result of this oxidation process is that heavy metals such as arsenic, chromium, and nickel can be released to the environment.

In many areas of Winnebago County, the St. Peter sandstone is buried deep below the land surface. As a result, the sandstone can be fully saturated, thereby providing a good source of groundwater for residential water wells. Due to the rapid development of many new housing developments in the county, the demand for water from the St. Peter sandstone has increased dramatically over the last decade.

Stop 7. Emerald Valley Development, Town of Clayton

The Emerald Valley Development, which covers approximately 100 acres, is a rural subdivision approved by the Town of Clayton. The development, located 5 miles west of Neenah, is amidst many other housing developments in the area. Given that public water and sewer will not be extended to the site, dwellings in the development will most likely have to rely on septic systems for wastewater disposal and individual wells for water supply. This gives rise to several questions.

1. Is there a potential source of sand and gravel or crushed rock at the site or in the surrounding neighborhood?

The development is located on an upland area where approximately 15 feet of red till overlies 75 feet of Platteville dolomite. The elevation of this upland area drops off 1 mile to the east onto a lower plain that is covered with glacial Lake Oshkosh sediment. This drop in elevation, or escarpment, is where the Platteville dolomite terminates and comes near the land surface. This escarpment trends north to south, crosses the Town of Clayton, and provides good access for companies mining dolomite. Although there appear to be no quarries along this escarpment in the Town of Clayton, it is a source of dolomite as determined by the location of other quarries located in Outagamie County.

Closer inspection of the surrounding landscape shows that there is a hill located immediately west of the development. This hill most likely consists of Platteville dolomite and would probably be an excellent source of crushed rock.

2. Are the surface materials (soils) suitable for the development of septic systems?

A review of the preliminary geologic maps and the soil survey for Winnebago County shows that this site is covered by reworked lake sediment (till), consisting mainly of clay and silt. The surface sediment, therefore, is likely to be unsuitable for traditional below-grade septic systems due to poor infiltration of water. Apparently, percolation tests on the soils confirm this finding, making mound septic systems the most viable alternative for wastewater disposal.

3. Is surface-water runoff during development of the site a potential concern?

The presence of a relatively impermeable clay-rich soil at the site makes surface-water runoff a potential problem at the site if not managed correctly. A review of topographic maps shows that the development is located on a rolling upland area away from any major lakes or streams. Two small swales cut across the site, draining any surface-water runoff to the ditches located along the roadway. These ditches eventually drain the water westward to the Arrowhead River, which flows into Lake Winneconne.

4. Will numerous septic systems potentially impact groundwater resources at this site?

A review of water well records show that there is approximately 10 feet of till over 75 feet of Platteville dolomite before reaching the St. Peter sandstone. It appears that many of the residential wells use groundwater from the sandstone as their primary water supply. Further review of the well records shows that groundwater is first detected around 40 to 50 feet below the ground surface. Given this information, there appears to be a relatively small chance that contaminants from septic systems would have an impact upon the groundwater beneath the site due to the relatively low-permeability of the surface sediment and the depth to groundwater.

Please be aware that when an aquifer is close to the ground surface, there is always a chance that contaminated surface water could have an impact upon shallow groundwater resources. As observed in the Ben Carrie Quarry (Stop 6), the Platteville dolomite contains many vertical fractures that may allow contaminants to reach the groundwater more quickly than expected.

5. Assuming no public water supply, are there sufficient shallow groundwater resources to supply individual domestic water wells?

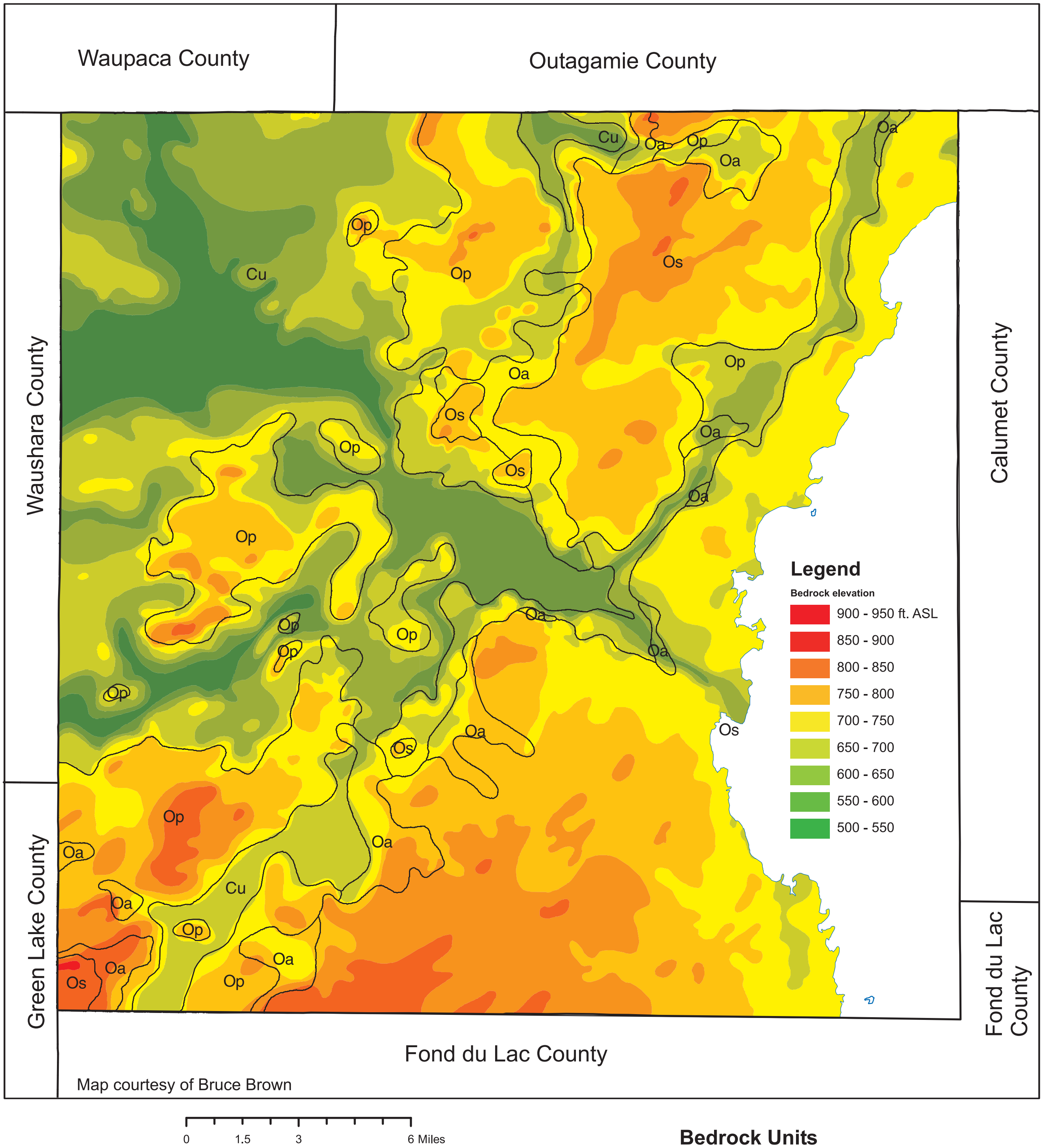
Again, the review of water well records in the area shows that the St. Peter sandstone as a primary aquifer supplying groundwater to many water wells. Water-level data on these records indicate that the sandstone is fully saturated when the wells were initially installed. Without monitoring many of these wells, it is not possible to determine whether the water levels have fallen due to increased use of the groundwater. Although there is likely sufficient quantity of groundwater, in this area the St. Peter aquifer does not reliably supply groundwater that meets state and federal drinking-water guidelines.

6. Assuming water levels will fall with increased use of the St. Peter sandstone aquifer, are sulfide minerals present in the rock that could lead to contamination of the groundwater?

There is sufficient evidence in the Town of Clayton that many wells located in the St. Peter sandstone have been contaminated with elevated levels of arsenic. Therefore, we can conclude that naturally occurring sulfide minerals are present in the St. Peter sandstone. The increase in use of this sandstone aquifer has probably lowered water levels, allowing oxidation of the sulfide minerals to occur. In many cases, this has resulted in contamination of the groundwater. Even without the process of oxidation, the presence of sulfide minerals in the sandstone may result in low levels of arsenic in groundwater wells (on the order of 5 to 30 parts per billion). Based on previous well water sampling in the Town of Clayton, one of every four wells is likely to have unacceptable water quality.

7. Given that many wells in the St. Peter Sandstone have been impacted with arsenic and other metals, are there deeper aquifers that could supply better quality water?

The water well records reveal that the formations beneath the St. Peter sandstone include the dolomite of the Prairie du Chien Group and the Cambrian sandstones, both potentially containing abundant groundwater. Given that these potential aquifers are much deeper, the additional drilling costs to install the wells might be substantial and would increase the cost of site development by several thousand dollars.



Supplemental figure to the Field Trip Guide Book

Bedrock geology superimposed on the bedrock elevation

Bedrock Units

Os - Sinnipee Group (Galena/Platteville dolomite)

Oa - Ancell Group (St. Peter sandstone)

Op - Prairie du Chien Group (dolomite)

Cu - Cambrian sandstones (undifferentiated)