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Geology Field Trip Southwestern Dane County

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1971

Open-File Report 1971-06

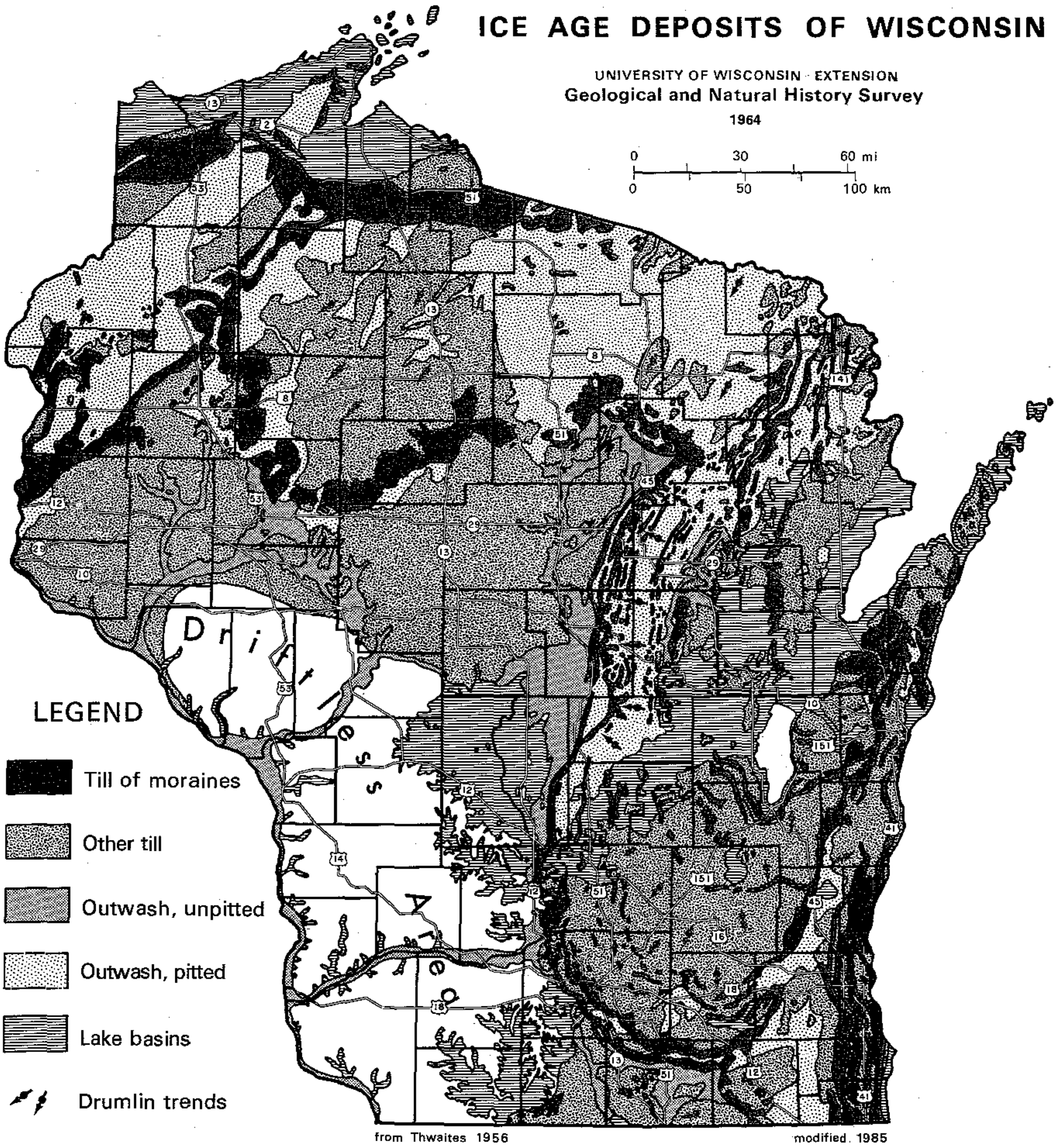
10 + vii p.

UNIVERSITY EXTENSION
The University of Wisconsin
Geological and Natural History Survey

GEOLOGY FIELD TRIP
SOUTHWESTERN DANE COUNTY

by
Meredith E. Ostrom

April 1, 1971


ICE AGE DEPOSITS OF WISCONSIN
UNIVERSITY OF WISCONSIN · EXTENSION
Geological and Natural History Survey
1964
0 30 60 mi
0 50 100 km
Driftless Area
LEGEND
Till of moraines
Other till
Outwash, unpitted
Outwash, pitted
Lake basins
Drumlin trends
from Thwaites 1956
modified 1985

SHORT HISTORY OF THE ICE AGE IN WISCONSIN

The Pleistocene Epoch or Ice Age began about 1,700,000 years ago which, in terms of geologic time, is not long ago. There were many separate glaciations during the Ice Age, each followed by a period when the ice sheets (except those on Greenland and Antarctica) melted away. The last major glacial episode is called the Wisconsin Glaciation, because it was first studied in detail in this state. It ended about 10,000 years ago.

The ice sheets were formed by the accumulation of snow that turned to ice and reached a thickness of two miles in some areas. The North American ice sheet formed in east-central Canada, spreading outward in every direction. The south edge of the advancing ice sheet had many tongues or lobes whose direction and rate of movement were controlled by the topography of the land surface over which they flowed and by the rates of ice accumulation in the different areas from which they were fed.

The ice sheet transported a great amount of rock and soil debris. Some of this debris, which is called till, was piled up at the margins of the ice lobes to form moraines. The pattern of moraines, in brown, shows the location of the major ice lobes in Wisconsin. One lobe advanced down the basin of Lake Michigan, another down Green Bay, and others down Lake Superior and over the northern peninsula of Michigan. The well-known Kettle Moraine was formed between the Lake Michigan and Green Bay Lobes. Drumlins are elongated mounds of debris that were molded by the ice passing over them; their orientations indicate the direction of ice movement. As the ice melted, the debris was reworked by melt-water rivers, and large amounts of sand and gravel were deposited to form outwash plains. Pits were formed in the outwash where buried blocks of ice melted, and many of these are now occupied by lakes.

The action of the ice profoundly modified the landscape, smoothing off the crests of hills and filling the valleys with till and outwash. In some places it changed the course of rivers forcing them to cut new channels such as that of the Wisconsin River at the Wisconsin Dells. Elsewhere it dammed valleys to create lakes such as those of the Madison area.

The Pleistocene glaciations were largely due to variations in the solar energy reaching the earth as a result of changes in its orbit and axial inclination. We are still in the Ice Age, and it is likely that glaciers will grow and again cover much of Wisconsin in future millennia.

More detailed information on Ice Age material in Wisconsin is given in the following publications.

Hadley, D.W., and Pelham, J.H., 1976, Glacial deposits of Wisconsin: Wisconsin Geological and Natural History Survey Map Series No. 10.

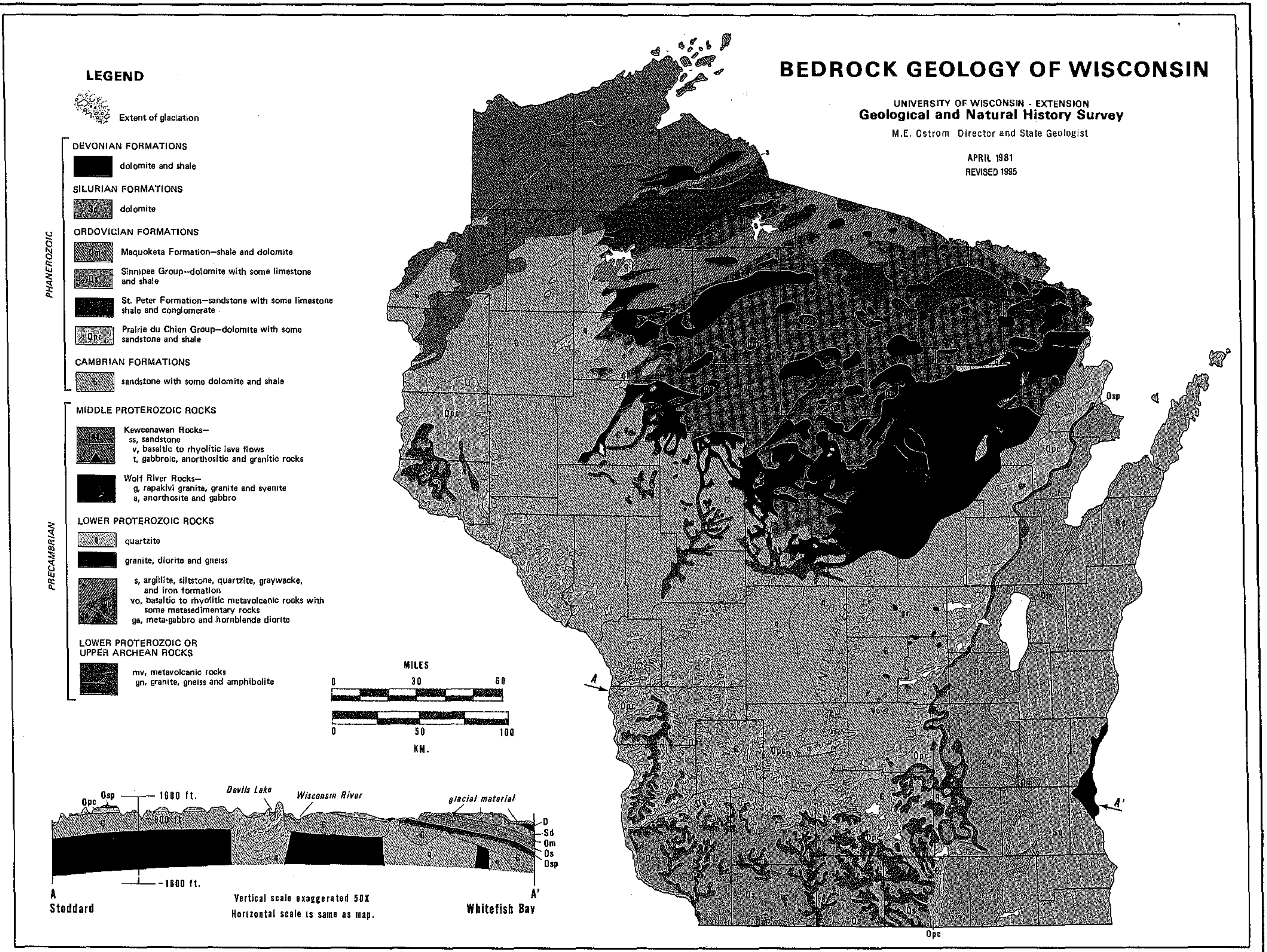
Mickelson, D.M., and others, 1984, Pleistocene stratigraphic units of Wisconsin: Wisconsin Geological and Natural History Survey Miscellaneous Paper 84-1, 15 p.

Goebel, J.E., and others, 1983, Quaternary geologic map of the Minneapolis 4° x 6° Quadrangle, United States: U.S. Geological Survey Map I-1420(NL-15).

Farrand, W.R., and others, 1984, Quaternary geologic map of the Lake Superior 4° x 6° Quadrangle, United States and Canada: U.S. Geological Survey Map I-1420(NL-16).

Lineback, J.A., and others, 1983, Quaternary geologic map of the Chicago 4° x 6° Quadrangle, United States: U.S. Geological Survey Map I-1420(NK-16).

Revised November 1984


BEDROCK GEOLOGY OF WISCONSIN
UNIVERSITY OF WISCONSIN - EXTENSION
Geological and Natural History Survey
M.E. Ostrom Director and State Geologist
APRIL 1981
REVISED 1995
LEGEND
Extent of glaciation
PHANEROZOIC
DEVONIAN FORMATIONS
dolomite and shale
SILURIAN FORMATIONS
Sd dolomite
ORDOVICIAN FORMATIONS
Om Maquoketa Formation—shale and dolomite
Os Sinnipee Group—dolomite with some limestone and shale
St. Peter Formation—sandstone with some limestone shale and conglomerate
Opc Prairie du Chien Group—dolomite with some sandstone and shale
CAMBRIAN FORMATIONS
sandstone with some dolomite and shale
PRECAMBRIAN
MIDDLE PROTEROZOIC ROCKS
Keweenawan Rocks—
ss, sandstone
v, basaltic to rhyolitic lava flows
t, gabbroic, anorthositic and granitic rocks
Wolf River Rocks—
g, rapakivi granite, granite and syenite
a, anorthosite and gabbro
LOWER PROTEROZOIC ROCKS
quartzite
granite, diorite and gneiss
s, argillite, siltstone, quartzite, graywacke, and iron formation
vo, basaltic to rhyolitic metavolcanic rocks with some metasedimentary rocks
ga, meta-gabbro and hornblende diorite
LOWER PROTEROZOIC OR UPPER ARCHEAN ROCKS
mv, metavolcanic rocks
gn, granite, gneiss and amphibolite
MILES
0 30 60
0 50 100
KM.
UNGLACIATED
Osp
Opc
Os
Sd
Om
A
A'
Opc
Osp
1600 ft.
800 ft.
Devils Lake
Wisconsin River
glacial material
D
Sd
Om
Os
Osp
-1600 ft.
A
Stoddard
Vertical scale exaggerated 50X
Horizontal scale is same as map.
A'
Whitefish Bay

GEOLOGIC HISTORY OF WISCONSIN'S BEDROCK

Introduction

The bedrock geologic record in Wisconsin is divided into two major divisions of time: the Precambrian, older than 600 million years, and the Paleozoic, younger than 600 million years. The Precambrian rocks are at the bottom and consist predominantly of crystalline rocks. They are overlain by Paleozoic rocks which consist of relatively flat-lying, in some cases fossil-bearing, sedimentary rocks.

Precambrian rocks form the bedrock beneath the glacial deposits in northern Wisconsin and occur beneath the Paleozoic rocks in the south (see the last paragraph and the cross-section on the reverse side). Paleozoic rocks may once have covered northern Wisconsin, but if they did, they have been removed by erosion. Glacial deposits, including clay and sand and gravel, cover bedrock in the northern and eastern three-fifths of the state.

In areas covered by glacial deposits, surface outcrops are so sparse that details of the bedrock geology are obscured. In such areas the only clues to the underlying rocks are obtained from rock cuttings and cores obtained from drill holes and from geophysical surveys which disclose magnetic and gravity variations.

Precambrian Eon

The Precambrian is divided into two eras, the older Archean and the younger Proterozoic. Each is subdivided into three periods--Early, Middle, and Late.

Archean

Rocks older than 2,500 million years are termed Archean. The oldest Archean rocks are gneisses (gn), or banded rocks. These are more than 2,800 million years old and are in Wood County. Similar old ages have been determined for rocks south of Hurley, where recognizable volcanic rocks (mv) have been intruded by 2,700 million year old granite (gn). All of these rocks have been extensively deformed, and in many areas they are so highly altered that their original nature and origin are extremely difficult to interpret. Because of this difficulty, both the older gneisses and some younger (Proterozoic) gneissic and crystalline rocks are combined on this geologic map.

Proterozoic

There are four principal groups of rocks in the Proterozoic. The oldest are around 1,800 to 1,900 million years old. These Early Proterozoic rocks consist of sedimentary (s) rocks including slates, graywacke and iron formation, and volcanic (vo) rocks. The sedimentary rocks dominate in the north, with volcanic rocks becoming more abundant in central Wisconsin. These layered rocks were intruded by gabbros (ga), diorities, and granites (gr) about the same time that they were being folded and deformed.

Quartz-rich Early Proterozoic sedimentary rocks (q) occur as erosional remnants, or outliers, on the older Proterozoic rocks; they were deformed about 1,700 million years ago. The Barron Quartzite in the Blue Hills of Rusk and Barron counties, the Baraboo Quartzite in Sauk and Columbia counties, and Rib Mountain Quartzite in Marathon County are some of the major remaining areas of once widespread blankets of sandstone.

The oldest Middle Proterozoic rocks include the granites, syenites, and anorthosites (g, a) of the Wolf River complex. This extensive body of related granitic rocks was intruded into Lower Proterozoic volcanic and sedimentary rocks around 1,500 million years ago.

The youngest Proterozoic rocks in Wisconsin are about 1,100 million years old and are called Keweenawan rocks. At the time of their formation a major rift or fracture zone split the continent from Lake Superior south through Minnesota and into southern Kansas. Keweenawan rocks can be divided into two groups: an older sequence of igneous rocks including lavas (v) and gabbros (t); and a younger sequence of sandstone (ss). These rocks occur in northwestern Wisconsin. In central Wisconsin diabase dikes were also emplaced at this time.

At the close of the Precambrian, most of Wisconsin had been eroded to a rather flat plain upon which stood hills of more resistant rocks such as the quartzites in the Baraboo bluffs.

Phanerozoic Eon

The Phanerozoic is divided into three eras. They are from the oldest to the youngest: the Paleozoic (old life), Mesozoic (middle life), and Cenozoic (most recent life). The Paleozoic is represented by a thick sequence of sandstones, shales and dolomites (dolomite is similar to limestone); the Mesozoic, possibly by gravels; and the Cenozoic, only by glacier-related deposits.

In the Paleozoic Era the sea advanced over and retreated from the land several times. The Paleozoic Era began with the Cambrian Period (Є) during which Wisconsin was submerged at least twice beneath the sea. Sediments eroded by waves along the shoreline and by rivers draining the land were deposited in the sea to form sandstone and shale. These same processes continued into the Ordovician Period (Opc, Osp, Os, Om) during which Wisconsin was submerged at least three more times. Animals and plants living in the sea deposited layers and reefs of calcium carbonate which are now dolomite. Deposits that built up in the sea when the land was submerged were partially or completely eroded during the times when the land was elevated above sea level. At the close of the Ordovician Period, and in the succeeding Silurian (Sd) and Devonian (D), Wisconsin is believed to have remained submerged. There are no rocks of the Paleozoic Era younger than Devonian in Wisconsin. Whether material was deposited and subsequently removed by erosion, or was never deposited, is open to speculation.

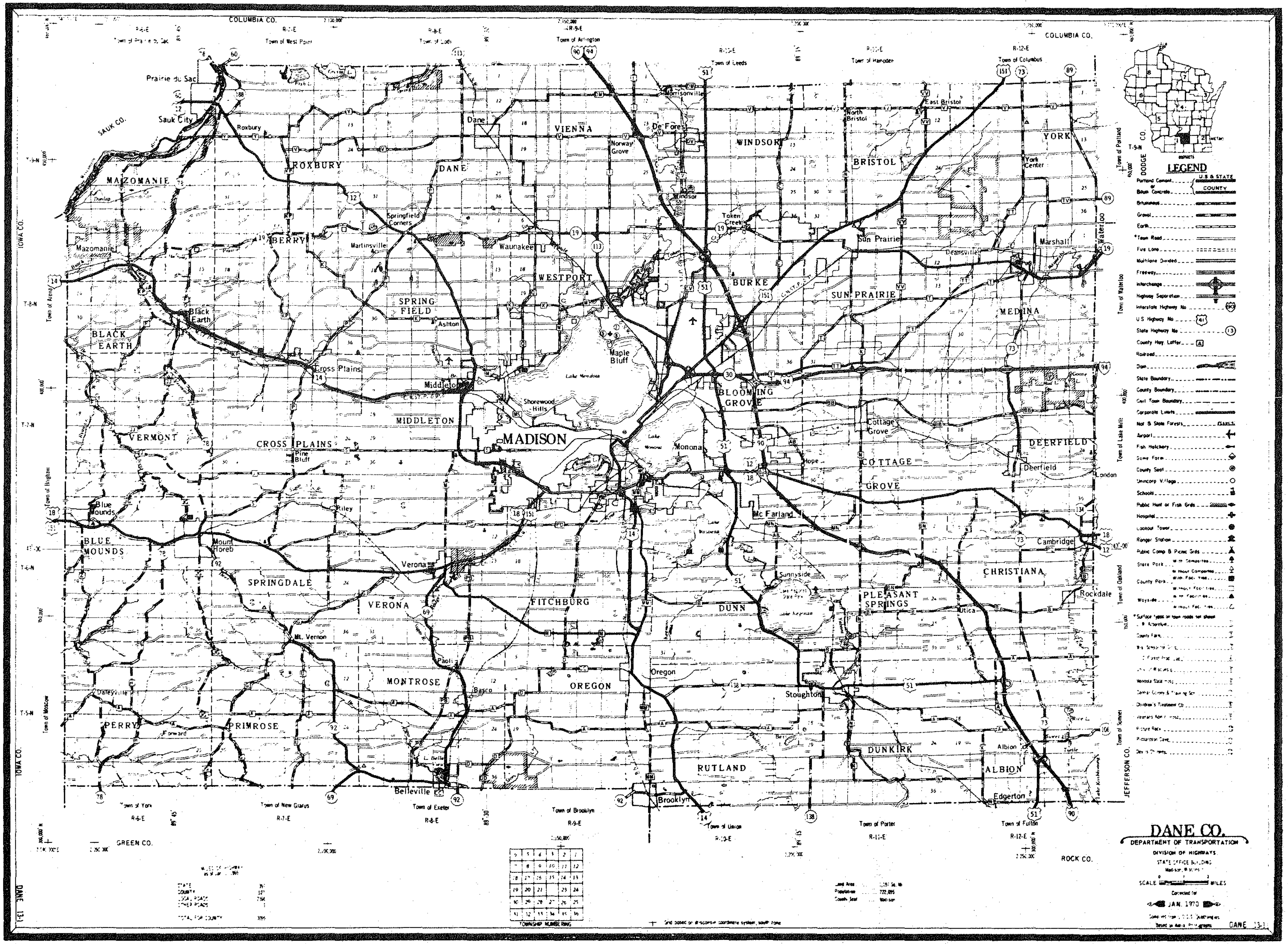
Absence of younger Paleozoic rocks makes interpretation of post-Devonian history in Wisconsin a matter of conjecture. If dinosaurs roamed Wisconsin, as they might well have in the Mesozoic Era some 200 million years ago, no trace of their presence remains. Available evidence from neighboring areas indicates that towards the close of the Paleozoic Era the area was gently uplifted and it has remained so to the present. The uplifted land surface has been carved by millions of years of rain, wind, running water, and glacial action. With the possible exception of some pebbles about 100 million years old, no Mesozoic age bedrock has been identified in Wisconsin.

In the last million years during a time called the Pleistocene, glaciers invaded Wisconsin from the north and modified the land surface by carving and gouging out soft bedrock, and depositing hills and ridges of sand and gravel as well as flat lake beds of sand, silt, and clay. In this manner, the glaciers smoothed the hill tops, filled the valleys, and left a deposit of debris over all except the southwestern part of the state. The numerous lakes and wetlands which dot northern Wisconsin occupy low spots in this Pleistocene land surface. Glacial deposits are not shown on the map of bedrock geology; however, the line of farthest glacial advance is shown. A separate glacial deposits map is available.

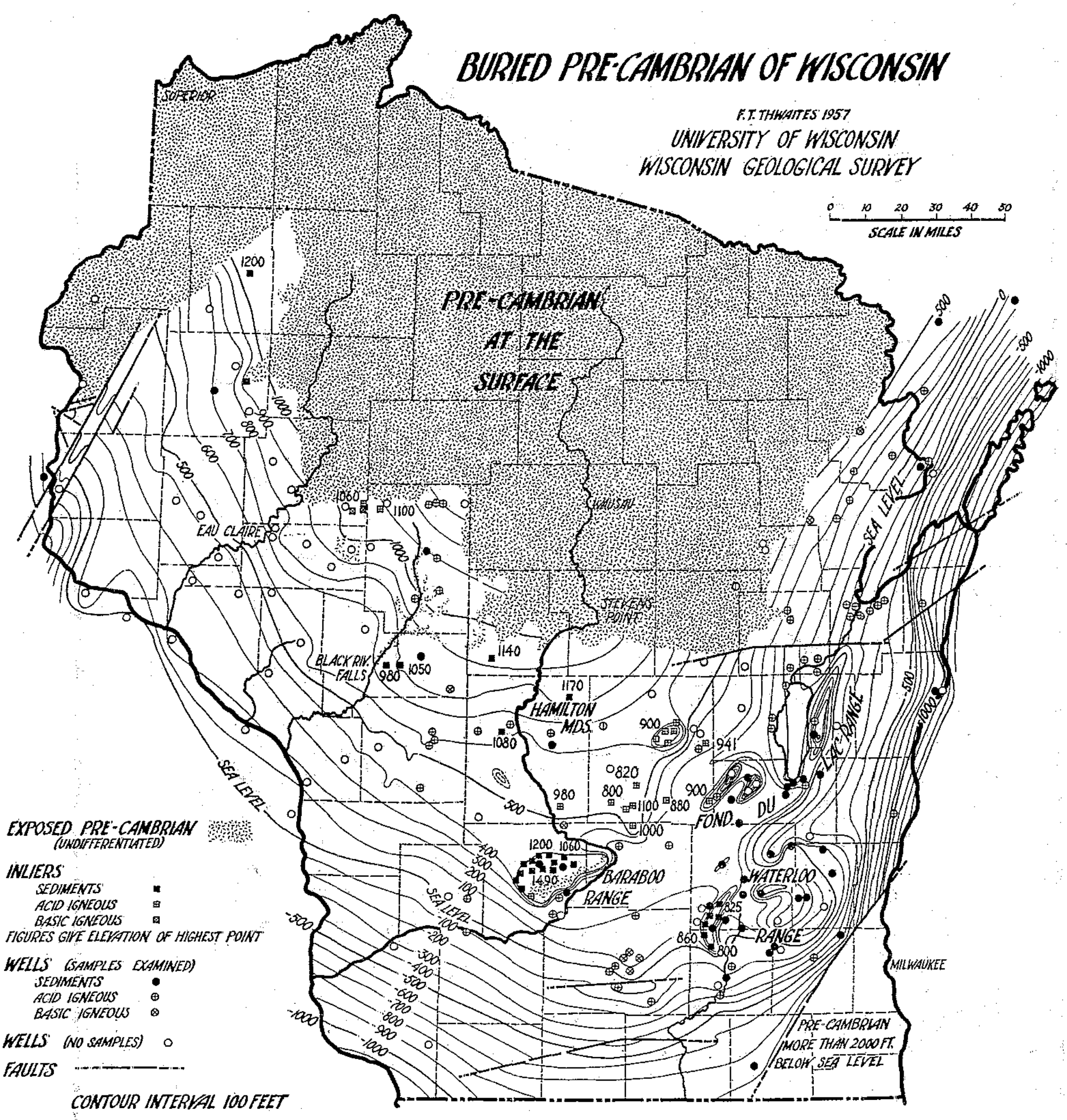
Cross Section

To assist in understanding the bedrock geology of Wisconsin, a cross section has been prepared (see reverse side). A cross section represents a vertical slice of the earth's crust showing the subsurface rock layers in much the same way as a vertical slice of cake shows the layers of cake and frosting. The Wisconsin cross section shows the subsurface geology along a line from Stoddard in Vernon County, through Devil's Lake near Baraboo in Sauk County, to Whitefish Bay in Milwaukee County. The horizontal scale is the same as that of the geologic map, but the vertical scale is exaggerated so that vertical thicknesses are expanded 50 times compared to horizontal distances. The Paleozoic rocks are shown as layers, the younger units lying above the older units. They are also shown dipping to the west in the western part of the state and dipping east in the eastern part of the state, thus forming an arch. The center and oldest parts of this arch are found in the Baraboo bluffs, where the Baraboo Quartzite is exposed at the surface. As shown in the cross section by fine lines in the quartzite, the Baraboo area was folded into a U-shaped structure, or syncline, before the Paleozoic rocks were deposited. Quartzite and granite underlie the Paleozoic rocks along this section.

The gray unit shown at the top of the rock sequence in the eastern part of the cross section represents glacial materials which do not occur to the west.



DANE CO.
DEPARTMENT OF TRANSPORTATION
DIVISION OF HIGHWAYS
STATE OFFICE BUILDING
SCALE
MILES
Corrected for
JAN. 1970
DANE 13-1
LEGEND
U.S. & STATE
COUNTY
COLUMBIA CO.
IOWA CO.
GREEN CO.
ROCK CO.
JEFFERSON CO.
SAUK CO.
DODGE CO.
MADISON
MAZOMANIE
ROXBURY
DANE
VIENNA
WINDSOR
BRISTOL
YORK
BERRY
SPRING FIELD
WESTPORT
BURKE
SUN PRAIRIE
MEDINA
BLACK EARTH
CROSS PLAINS
MIDDLETON
BLOOMING GROVE
COTTAGE GROVE
DEERFIELD
VERMONT
BLUE MOUNDS
SPRINGDALE
VERONA
FITCHBURG
DUNN
PLEASANT SPRINGS
CHRISTIANA
PERRY
PRIMROSE
MONTROSE
OREGON
RUTLAND
DUNKIRK
ALBION
Prairie du Sac
Sauk City
Roxbury
Mazomanie
Black Earth
Cross Plains
Middleton
Shorewood Hills
Maple Bluff
Waunakee
Dane
De Forest
Windsor
Token Creek
Sun Prairie
Marshall
Waterloo
Deansville
Cottage Grove
Monona
McFarland
Deerfield
Cambridge
Rockdale
Utica
Stoughton
Albion
Edgerton
Brooklyn
Oregon
Belleville
Paoli
Verona
Mount Horeb
Blue Mounds
Mt. Vernon
Springfield Corners
Martinsville
Ashton
Pine Bluff
Riley
Basco
Sunnyside
Dunlap
Morrisonville
North Bristol
East Bristol
York Center
Norway Grove
Hope
London
Daleyville
Forward
TOWNSHIP NUMBERING

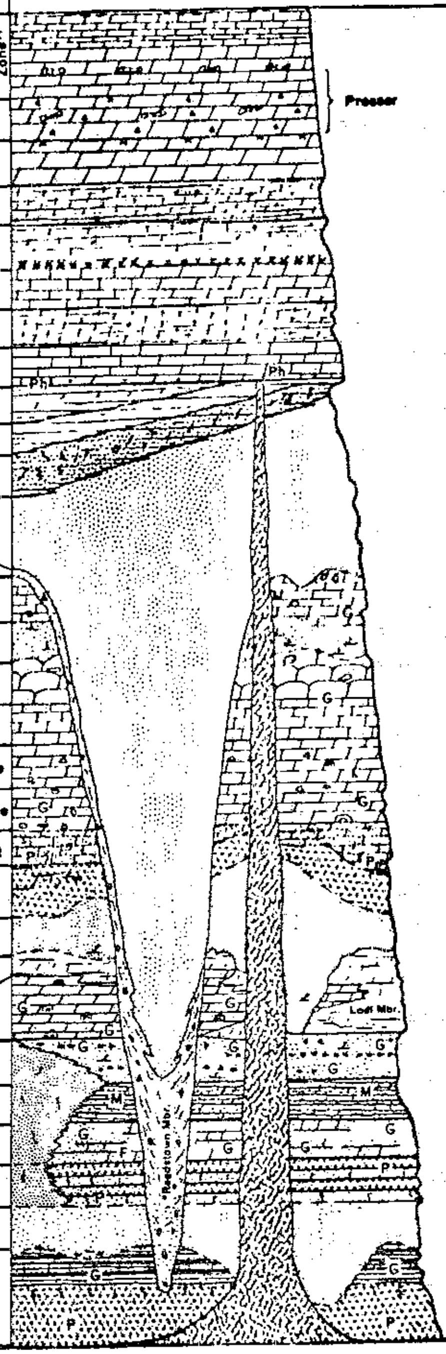

BURIED PRE-CAMBRIAN OF WISCONSIN
F. T. THWAITES 1957
UNIVERSITY OF WISCONSIN
WISCONSIN GEOLOGICAL SURVEY
0 10 20 30 40 50
SCALE IN MILES
PRE-CAMBRIAN AT THE SURFACE
SUPERIOR
EAU CLAIRE
WAUSAU
STEVENS POINT
BLACK RIV. FALLS
HAMILTON MDS.
BARABOO RANGE
FOND DU LAC RANGE
WATERLOO RANGE
MILWAUKEE
SEA LEVEL
PRE-CAMBRIAN MORE THAN 2000 FT. BELOW SEA LEVEL
EXPOSED PRE-CAMBRIAN (UNDIFFERENTIATED)
INLIERS
SEDIMENTS
ACID IGNEOUS
BASIC IGNEOUS
FIGURES GIVE ELEVATION OF HIGHEST POINT
WELLS (SAMPLES EXAMINED)
SEDIMENTS
ACID IGNEOUS
BASIC IGNEOUS
WELLS (NO SAMPLES)
FAULTS
CONTOUR INTERVAL 100 FEET

STRATIGRAPHIC NOMENCLATURE

WISCONSIN GEOLOGICAL AND NATURAL HISTORY SURVEY

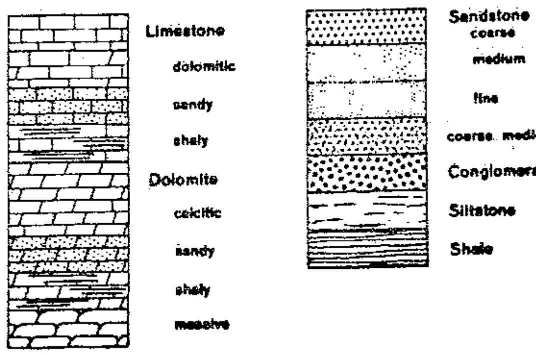
System	Series	Stage	Group	Formation	Members and Submembers		Approximate maximum thickness in feet	
ORDOVICIAN	Champlainian	Trentonian	Sinnipee	Galena	Dubuque	"Noncherty Zone"	230	45
					Wise Lake	Stewartville; Sinsinawa		85
					Dunleith	"Cherty Zone"; Ion Submbr.		125
				Decorah	Guttenberg		25	15
					Spechts Ferry			10
		Blackriveran		Platteville	Quimbys Mill		75	20
					McGregor			30
					Pecatonica			25
			Ancell	Glenwood	Hennepin		13	2
					Harmony Hill			3
					Nokomis			8
				St. Peter	Tonti; Readstown		336	
	Canadian		Prairie du Chien	Shakopee	Willow River; New Richmond		140	
				Oneota	Hager City	Stoddard; Genoa	180	
						Mound Ridge	15	
—?—	—?—	—?—			Stockton Hill	Hickory Ridge; Sunset Point	36	
CAMBRIAN	St. Croixan	Trempealeauan		Jordan	Van Oser; Norwalk		80	
				St. Lawrence	Lodi; Black Earth		80	
		Franconian	Tunnel City	Mazomanie / Lone Rock	Reno; Tomah; Birkmose		200	
			Elk Mound	Wonewoc	Ironton; Galesville		100	
		Dresbachian		Eau Claire			250	
				Mt. Simon			300	

DOMINANT LITHOLOGY



KEY TO SYMBOLS

- chert
- oolitic chert
- oolites
- openings (vugs, etc.)
- dolomitic
- bentonite
- glauconite
- pyrite
- mica
- Receptaculites
- Prasopora
- algae
- burrows
- conglomeratic
- questionable relationship
- F feldspar
- Ph phosphate pellets



ROAD LOG

Assemble at Stop 1.

University Parking Lot 60, University Bay Area, Madison (SE¼, SE¼, Sec. 16, T.7N., R.9E., Madison West 7.5' topographic quadrangle).

Lot #60 is situated on what was once the bottom of Lake Mendota. The lake as we see it today is a very transitory geologic feature being steadily destroyed by the deposition of sediment from incoming streams and the encroachment of vegetation. The Willows Drive is a sandbar which was formed by wave action in shallow water and which cut off part of the University Bay. Behind the bar a marsh developed which gradually became filled with vegetation. The marsh was mostly drained and utilized for agriculture. Today it is being converted by the University to parking lots, buildings, and athletic fields. Eventually only a small pond will remain, an example of Man's impact on the physical environment and his ability to modify the environment to his needs.

Lake Mendota is a product of glaciation. Prior to glaciation (say 40,000 years ago) the view from here looking north would have been much like standing on the bluffs of the upper Mississippi valley. The pre-glacial Yahara River valley would be some 250 feet below us and would be bounded by craggy cliffs of dolomite underlain by sandstone.

With the advent of glaciation the hillcrests were smoothed off, the valleys partially filled, and the rivers dammed or diverted from their courses. Within the glaciated portion of the state some hills may be predominantly bedrock. These are called rock-cored hills. Such are the Shorewood Hills seen to the west. In many cases the hills are no more than mounds of "till" deposited by the glaciers. "Till" consists of an unassorted mixture of boulders, gravel, sand, silt, and clay. Throughout the whole of the glaciated area, till mantles the surface of the bedrock in varying thicknesses.

"Ground moraine" is the term used to denote the till that was deposited under the ice or dropped in place by the ice as it melted. "Terminal moraine" is the till deposited at the margin of the ice front.

We will be traveling mainly over ground moraine until we reach approximately Stop 4 where we will pass over the terminal moraine of the last glacial stage.

As we travel toward the next stop look carefully and note the rolling topography, subdued hills, and "closed" depressions (i.e. pockets) in the landscape, some of which may contain ponds.

The glacial phenomena seen in Wisconsin are the result of continental glaciation when the ice covered much of the northern part of the North American continent. In Wisconsin the glacier covered even the highest hills in the eastern and northern areas and attained a thickness of some 10,000 feet. The southwest area of the state is referred to as the "Driftless" area because it contains no deposits of glacial origin. The term "drift" had its origin in the early belief that what we now know to be glacial deposits were materials rafted by icebergs during the biblical Noachian deluge.

Stop 2.

Shorewood Quarry (NE cor., SW$\frac{1}{4}$, SE$\frac{1}{4}$, Sec.17, T.7N., R.9E., Madison West 7.5' topographic quadrangle).

The rock exposed in this quarry is the Prairie du Chien Dolomite group. This dolomite is the major hill-forming rock in the Madison area. It was formed in marine waters on a continental shelf about 400,000,000 years ago. Originally it was composed of fossil debris and chemically precipitated carbonates. Chemical changes through time have altered the rock so that most evidence of fossils has been destroyed. The remains of algal structures are, however, quite well preserved locally. Some sandstone, chert, and shale are also present.

How do we know this rock is 400,000,000 years old?

Stone taken from this quarry was used for building purposes. Ordinarily the high chert (flint), shale, and sand content here would argue against its use. However, because it was located close to a market haulage costs were low and the stone could be sold at a lower price than better quality materials that were imported from outside the area. The Prairie du Chien finds wide application for road and concrete aggregate and for agricultural limestone in most areas of the state where it occurs.

A first step in quarrying is to remove undesirable overburden materials. The stone is quarried by drilling holes downward from the surface. These holes are then packed with dynamite which is exploded causing stone to break free from the main rock mass. Some of the old drill holes can be seen on the quarry face. The blast rubble, in sizes from sand to 2 or 3 feet in diameter, may then be sized by hand for individual jobs. In modern quarries this material is run through a crusher to reduce it to the desired size, generally less than 4 inches. The crushed material is separated into different size fractions using screens with different sized openings. The sizes produced at a quarry are dependent upon the user's desire.

Dolomite is a mixture of calcium and magnesium carbonate. Although the material was initially deposited as calcium carbonate, replacement of some of the calcium by magnesium through a process, only poorly known, has resulted in its present composition.

Dolomite is one of a large group of what are called industrial minerals (non-metallics) which are generally lower-cost products. For this reason it is economically bad business to haul the stone any great distance. The numerous quarries scattered throughout southern and southwestern Wisconsin attest to this fact.

In 1968 production of crushed and broken dolomite accounted for 23 percent of the total value of minerals produced in Wisconsin and we ranked 16th among states nationally.

Rocks which can be collected from this quarry include dolomite, sandstone, chert, and possibly shale. Mineral specimens are rare and generally small, but include dolomite, calcite, and pyrite (fool's gold). At some horizons, notably the small bench in the floor below the upper face, small "BB-type" structures can be seen in the chert. These are called oolites and are formed by chemical precipitation of calcium carbonate from sea water onto small sand grains or fossil fragments in areas where wave agitation can roll the particles around.

Through a process of replacement of carbonate by silicate the oolites attained their present composition (SiO_2).

Algae are the most abundant fossils. Other forms including brachiopods and gastropods are rare. A zone of algal formations can be seen approximately 5 feet above the base of the upper level on its west face.

Dolomite is particularly dense, with few if any, openings. Such openings occur as vertical joints or as cavities along bedding planes. For this reason dolomite is not considered to be a good water-producing rock (aquifer). In the west face of the upper bench of the quarry water can be seen coming from openings in the rock. As the water moves through openings in such rocks it dissolves the rock thus enlarging the cavity. Under the right conditions this solution produces large cavities which when drained of their water, become caves. Small caves occur at many places in southwestern Wisconsin.

Stop 3.

West Towne Shopping Center (NW¼, Sec. 25, T.7N., R.8E., Middleton 7.5' topographic quadrangle).

This site is interesting because it is an excellent example of how resources available at a site can be utilized in site development and local construction projects.

The aggregate material used to construct the West Towne Shopping Center and the new portions of its service roads; Gammon Road and Mineral Point Road, were derived chiefly from the land on which the shopping center now stands. In the process of preliminary investigation of the site it was learned that sand and gravel in sufficient quantity was available on the site to accommodate all planned construction. The only drawback appeared to be that all specifications called for crushed stone rather than sand and gravel. It is notable that in this instance the regulatory agencies saw fit to alter their standards and permitted use of equally suitable materials in the form of glacial gravels which were available from the property being developed. This decision resulted in a considerable savings in terms of money that would otherwise have been spent on transportation costs to import the aggregate. This is an excellent example of compatible use of the land, namely material removed to level and make the site suitable for use as a shopping center was used to construct roads and buildings which service or are a part of the center. Fortuitously, in this instance, essentially all of the available gravel and sand on the property was utilized so that none was lost or made unavailable through land-use for another purpose.

Stop 4.

Abandoned and unrehabilitated pits of the Hartland-Verona Gravel Co., Verona. (NW¼, SE¼, sec. 22, T.6N., R.8E., Verona 7.5' topographic quadrangle).

The significant point of this stop is to consider the potential this land has if rehabilitated in the light of the fact that Verona is a growing and progressive community. What must be considered are the urban, residential, and recreational potentials of this site.

Stop 5.

Active and rehabilitated pits of the Hartland-Verona Gravel Co., Verona (on south line of the $NW\frac{1}{4}$, sec. 22, T.6N., R.8E., Verona 7.5' topographic quadrangle).

The water-filled abandoned pit at the east side of Highway 69 has been developed as a water recreation site for the Village of Verona. At the same time across the highway to the west there is an operating pit. The use potential of the active pit includes water supply, recreation, and/or residential development. The Hartland-Verona Gravel Company is an economic benefit to the village because it provides employment and supplies aggregate materials near at hand while at the same time creating a potential future benefit in the form of a lake for water supply, recreation, or very desirable residential development. The village is an economic benefit to the producer because it purchases his materials. This is an example of a compatible relationship of an extractive industry with a community to the benefit of all concerned. It is a relationship based on the principal of multiple-sequential land-use.

These gravel deposits were formed by melt-waters which drained westward away from the glacier front which stood a short distance to the east. The water carried sand and gravel which was deposited as outwash. Sand and gravel in glacial deposits is derived from all of the rocks and soils over which a glacier travels. Thus, a great variety of rock types can be found in glacial gravel deposits. How many different types of rocks can you find in 15 minutes? Where do you think they came from? How can they be used to decipher glacial history?

Sand and gravel constitute the major mineral production in Wisconsin in terms of both dollars and tonnage and in 1968 accounted for 43 percent of the total dollar value produced. That year we ranked 7th nationally in terms of dollar value of sand and gravel produced.

Do you believe sand and gravel are important to Man? Name as many uses for gravel and sand as you can. Do you believe these uses are critical to Man? Could modern society exist without sand and gravel and, if you believe yes, what are the alternatives to using sand and gravel?

Stop 6

Road cuts on State Highway 69, 3.5 miles north of New Glarus and 4.5 miles west of Brooklyn ($SW\frac{1}{4}$, $SW\frac{1}{4}$, sec. 36, T.5N., R.8E., New Glarus 15' topographic quadrangle).

Near the base of the hill is a high roadcut in the Middle Ordovician St. Peter Sandstone. This sandstone, like others in the Ordovician and the Upper Cambrian of Wisconsin, is believed to have formed in a nearshore and beach area of a sea which advanced over an uneven and eroded land surface from the southeast (Western Tennessee) to the northwest (Wisconsin and Minnesota). The sand was delivered to the sea by streams which eroded and drained the land area as the sea advanced. After reaching the sea the sand was redistributed by waves and currents in the beach and nearshore areas.

Examination of the sandstone reveals many things about how it formed. For example, the sand is distinctly bedded in beds up to 2 feet thick which are laterally persistent. This suggests deposition in water rather than in sand dunes which would not be so uniformly bedded. Cross-beds within individual beds reveal the direction of sediment transport which was most likely parallel to the shoreline. Absence of fossils suggests that animals either did not live in the area, or that only swimming forms lived there, or that all of their remains were destroyed by wave and current action, or that only soft-bodied forms were present. The St. Peter consists almost entirely of quartz sand grains. Purity of the sand is attributed to the belief that the St. Peter sand was derived from erosion of preexisting sandstones of equal or nearly equal purity and ultimately from rocks of very high quartz content. That the grains traveled a long distance or were reworked many times is suggested on the basis of their rounding which is exceptionally good.

The purity of the St. Peter and other Lower Paleozoic sandstones in the upper Mississippi Valley area has led to its use as a major source of sand for glass manufacture and steel molding (foundry sand). A major use of the high-silica sandstones of Wisconsin is in the foundry industry.

Overlying the St. Peter Sandstone is the Sinnipee Group of dolomites which is subdivided in ascending order into the Platteville, Decorah, and Galena formations. The Sinnipee formed on a sea bottom in an area conducive to the existence of animals and algae. Thus, the water must have been clear, well-aeriated, and less than 300 feet deep which is an approximate maximum depth of light penetration. A wide variety of fossil forms can be found in the Sinnipee including brachiopods, molluscs, trilobites, bryozoans, ostracods, and corals. How many varieties can you find in 15 minutes? What do they tell you about conditions here at the time the Sinnipee was being formed?

While the St. Peter was forming in the beach area the Sinnipee was forming further out on the continental shelf in deeper water. As the sea progressively advanced over the beach deposits so did the Sinnipee dolomite deposits advance over the St. Peter sandstone. At the time the Sinnipee was forming in the area of this outcrop more St. Peter was forming in the beach area which had shifted to the northwest.

The Sinnipee dolomites are widely used as a source of aggregate materials in Wisconsin although they are not generally as suitable as the Prairie du Chien Dolomite seen at Stop 2 or the Silurian dolomites which border the eastern coast of the State. The majority of the quarries found in Southwestern Wisconsin are, however, developed in the Sinnipee because it is the most readily available at the surface.

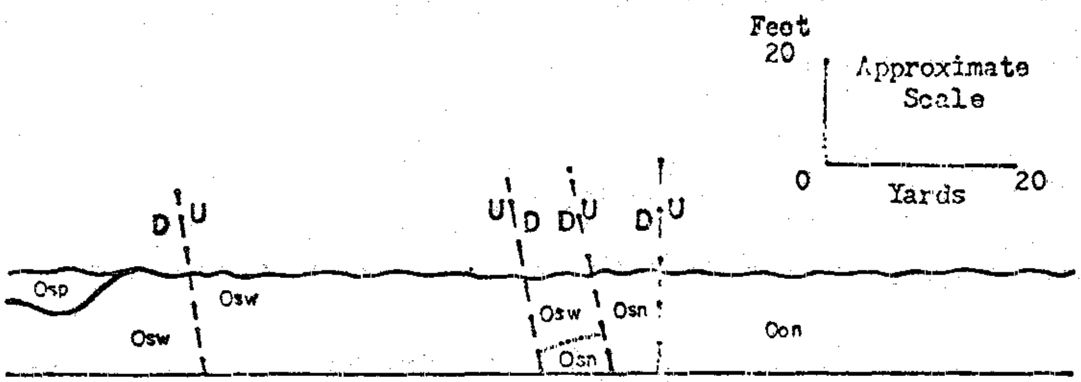
Stop 7

Roadcut on County Highway G, 0.2 miles west of Village of Mt. Vernon (NW$\frac{1}{4}$, NW$\frac{1}{4}$, sec. 3, T.5N., R.7E., New Glarus 15' topographic quadrangle).

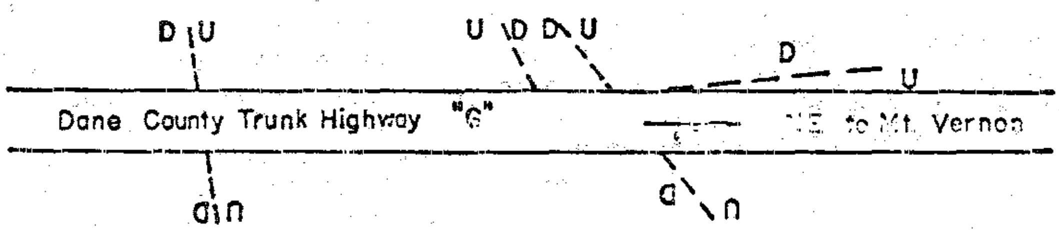
This exposure presents an excellent opportunity to see a small portion of the erosion surface on which the St. Peter Sandstone was deposited and to examine a fault which is a break in the earth's crust along which some movement has occurred.

Reference to the diagram on the next page indicates that the erosion surface at the base of the St. Peter Sandstone is exposed at the west end of the northside roadcut. Here the St. Peter can be seen occupying a shallow channel cut in the underlying Prairie du Chien Dolomite.

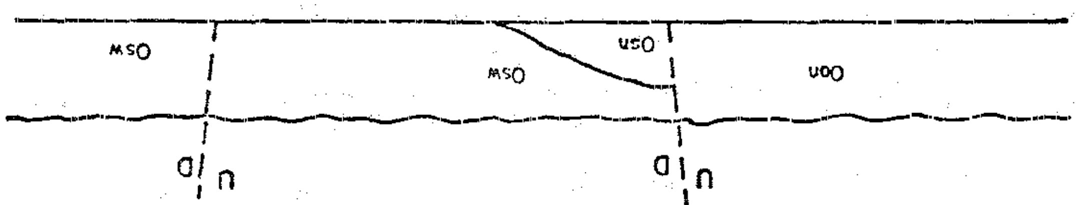
Although many faults are present in this exposure the most prominent can be seen near the center of the southside roadcut as shown in the diagram. The fault is well-defined because of the differences in rock types which occur on either



A. Outcrop in northwest roadcut.



B. Plan view.



C. Outcrop in southeast roadcut (turn upside down to read).

Diagrammatic sketch of roadcuts on Dane County Trunk Highway "G" west of Mt. Vernon at Stop # 7. Oon, Oneota Formation; Osn, New Richmond Member of Shakopee Formation; Osw, Willow River Member of Shakopee Formation; Osp, St. Peter Formation.

side. The left or east side has moved up relative to the west side. We know this because the rock on the left side is older than that on the right as determined from stratigraphy (the study of layered rocks). In a normal sequence the rock formation which occurs on the east (left) side of the fault would occur below the sandstone which appears on the west (right) side of the fault.

Why are faults important to Man? One reason that is of immediate concern is that when the earth's crust breaks today, such as it is doing along the San Andreas fault in California, earthquakes are produced. There have been no significant earthquakes in Wisconsin during the last 50 years thus Wisconsin is regarded as a stable area.

Faults are also important to geologists because their presence may bear directly on the occurrence of mineral deposits such as lead, zinc, or copper, and because their presence may affect construction projects such as dams or bridges.

Recently the Wisconsin Geological Survey became involved in assisting the city of Madison with geologic data to locate a water supply for the Yahara Hills Golf Course. Based on all existing geologic information there should have been no problem with obtaining a supply from a deep well sufficient to satisfy the specified requirements. However, several deep holes failed to produce the required amount of water. In an attempt to determine why these holes produced so little water a detailed study of rock samples collected from the new holes revealed the presence of extensive and completely unsuspected faulting. The pattern of faulting, which involved vertical movements of over 300 feet in some cases, is believed responsible for the low water yields. The problem has since been solved by resorting to a series of shallow wells.

Stop 8

Klevenville sandstone quarry of the General Silica Division, George M. Pendergast & Co., Inc. (center NW¼, sec. 3, T.6N., R.7E., Cross Plains 7.5' topographic quadrangle).

The sandstone being quarried here is the St. Peter Formation. Near the top of the quarry can be seen a thin layer of Sinnipee dolomite.

In the mining operation the Sinnipee dolomite is drilled, blasted, and stripped off the top. Then the St. Peter Sandstone is drilled and blasted. After blasting the sand is passed through a crusher to separate the individual grains which requires very little effort inasmuch as the grains are only slightly cemented together. From the crusher the sand is delivered to the plant by means of a conveyor belt and there dried and finally screened to separate the desired size fractions.

The St. Peter Sandstone consists almost entirely of quartz or silica sand grains. Because quartz is extremely resistant to heat the sand from this quarry is used primarily in the foundry industry to prepare molds for making steel castings and for lining furnaces. Its high iron content rules out its possible use for glass manufacture. Because of its extreme hardness silica sand is also used for abrasives and in the manufacture of pottery, porcelain, and tile.

Do you believe silica sand is essential to modern society? Could we get along without silica sand, and if you belive yes what are the alternatives to using silica sand?

Note how "loose" the sand is in the quarry face and how rapidly it is breaking down in spite of the fact that it is almost 400 million years old. It is obvious that "age" does not make a rock "solid". Rocks are held together mainly by "cement" or by recrystallization of the compacted minerals. Lime, silica, and iron oxide are the most common cements in Wisconsin sandstones.

Stops 9 & 10

Camel Hill roadcut on County Trunk Highway S about 2.5 miles east of Pine Bluff (SW$\frac{1}{4}$, SW$\frac{1}{4}$, SE$\frac{1}{4}$, sec. 24, T.7N., R.7E., Middleton 7.5' topographic quadrangle).

Camel Hill is a bedrock ridge composed of Sinnipee dolomite underlain by St. Peter Sandstone, both of which are exposed in the roadcut. The gravel road at the north side of the roadcut leads to a dolomite quarry in the Sinnipee dolomite operated by the Capital Sand and Gravel Company whose gravel pit we will visit at Stop 11. A point to be noted here is that the quarry is hidden from view of the road by design on the part of the operator so that those who find exposed quarries objectionable are not offended: thus, material critical to local growth and development is made available. Capital Sand & Gravel Company is a leader in quarry and pit rehabilitation in the Madison area.

Examine the piles of crushed stone near the quarry. How many different varieties of stone can you find? Name as many uses as you can for crushed stone and of dolomite? Are these uses critical to our modern society? Could modern society exist without dolomite, and if you believe yes what are the alternatives to using dolomite?

Camel Hill is located just $\frac{1}{2}$ mile west of the terminal moraine of the last glacial episode in this area. Thus, Camel Hill is located at the east edge of the Driftless area. Note that the topography of the Driftless area is characteristically different from that of the drift-covered area to the east.

The Driftless area encompasses the southwestern quarter of Wisconsin and extends into Iowa and Illinois. It is unique in that it is surrounded by drift on all sides but apparently escaped glaciation itself.

The level hilltops of the Driftless area are due to a resistant cap of Sinnipee dolomite. When streams cut below this level they encountered the St. Peter Sandstone which is soft hence easily eroded so that wide valleys developed. The Sinnipee is termed a "ridge maker" and the St. Peter is a "valley maker". In the Driftless area the nature of the bedrock is reflected in the topography. Gentle slopes develop on soft formations and steep slopes or cliffs on more resistant rocks.

As we proceed eastward on Highway S note the change in drainage pattern from dendritic and interconnected drainage, i.e. like the veins of a maple leaf, of the Driftless area to the unconnected drainage with many depressions and lakes, hence potholes, of the glaciated area. With dendritic drainage every gully leads to a creek which leads to a stream which leads to a bigger stream thence to the Mississippi. In the glaciated area drainage shows less tendency to interconnection and there are numerous potholes. The Driftless area is a classical example of the "mature" stage of the erosion cycle in which nearly all the land surface is in slope.

The ridge $\frac{1}{2}$ mile east of Camel Hill is the terminal moraine as was mentioned before. The glacier extended this far but lacked the energy to surmount the Camel

Hill ridge. Between the moraine and Camel Hill are depressions occupied by shallow lakes during wet seasons. These lakes developed in the depressions formed between the moraine and the Sinnipee dolomite ridge. The area east of the terminal moraine is referred to as swell and swale topography which is predominantly a gently rolling landscape. This character becomes more prominent eastward as the thickness of glacial deposits increases and the bedrock becomes more deeply buried.

Our route will take us north along the west edge of the terminal moraine and back into the driftless area to Stop 11.

Stop 11

Gravel and sand pit of the Capital Sand & Gravel Company (NE$\frac{1}{4}$, SW$\frac{1}{4}$, sec. 11, T.7N., R.7E., Cross Plains 7.5' topographic quadrangle).

This sand and gravel pit is located in a valley train deposit at the west edge of the terminal moraine which marks the eastern boundary of the Driftless area. Valley train deposits consist of materials washed out of a glacier and deposited on the floor of preexisting valleys which serve to confine the water. The terminal moraine extends from Adams and Sauk counties on the north through Dane and Rock counties on the south. It is the same moraine as was seen at Verona where the gravel occurred in an outwash deposit and as that located east of Camel Hill at Stop 10.

The Black Earth Creek valley contains many feet of glacial outwash, consisting of sand, gravel, silt, and clay as determined from drilling. Useful sand and gravel deposits in the valley are unevenly distributed and must be located by drilling. The gravel pit operation here will eventually extend downward to a depth of 90 feet.

It is postulated that as the ice moved from east to west it effectively blocked the Black Earth Creek valley with ice and debris which formed the terminal moraine that can be seen east of the pit. When the glacier retreated large quantities of meltwater were ponded between the moraine and the receeding ice. The lake thus formed is referred to as glacial Lake Middleton. It occupied the area from the terminal moraine back to approximately the west edge of present Lake Mendota.

As the supply of ponded water in the lake increased the moraine was finally breached and large quantities of water were released to flow down the Black Earth Creek valley and deposit more outwash. The date of ice retreat has been determined as about 11,500 years ago on the basis of radiocarbon analysis of wood found in deposits of glacial Lake Middleton in the vicinity of Middleton.

How many different rock types can be seen in this pit? Do they differ from those seen at Verona? What do they tell us about the history of glaciation in this area? What do they tell us about the route traced by the glacier in its journey to this area? How does the sorting of particles here differ from that which might be expected in a glacial till formed of material dropped directly from the ice as it melted with a minimum of sorting?

Consider the rehabilitation potential of this pit. Ultimately the operator intends to mine out an area of approximately 40 acres to a depth of about 90 feet. As mining proceeds the shoreline will be progressively graded so that the final product will be a lake with rehabilitated shoreline area. As the Madison area expands lake areas will be at a premium and this area should be one of the more desirable in terms of residential or recreational development.

Intelligent land-use planning relies on specific and adequate information about the physical environment, namely our rocks, soils, and waters. This information is essential to development of an area under the multiple-sequential land use concept. Only in this way can we derive maximum present and future benefit from our natural resources which basically is conservation in its present form. The gravel pits seen here and at Verona are examples which illustrate this concept. They show how the extractive mineral industry which is essential to maintain the growth and development of our society can exist compatibly with expanding urban areas to their mutual benefit through a process of multiple-sequential land use planning.