University of Wisconsin-Extension

GEOLOGICAL AND NATURAL HISTORY SURVEY
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James Robertson, State Geologist and Director

CONDITIONS AROUND THE MARGIN OF THE GREEN BAY LOBE DURING THE HEIGHT OF THE WISCONSIN GLACIATION

by
Lee Clayton, John Attig
David Mickelson

Open-File Report 1997-01

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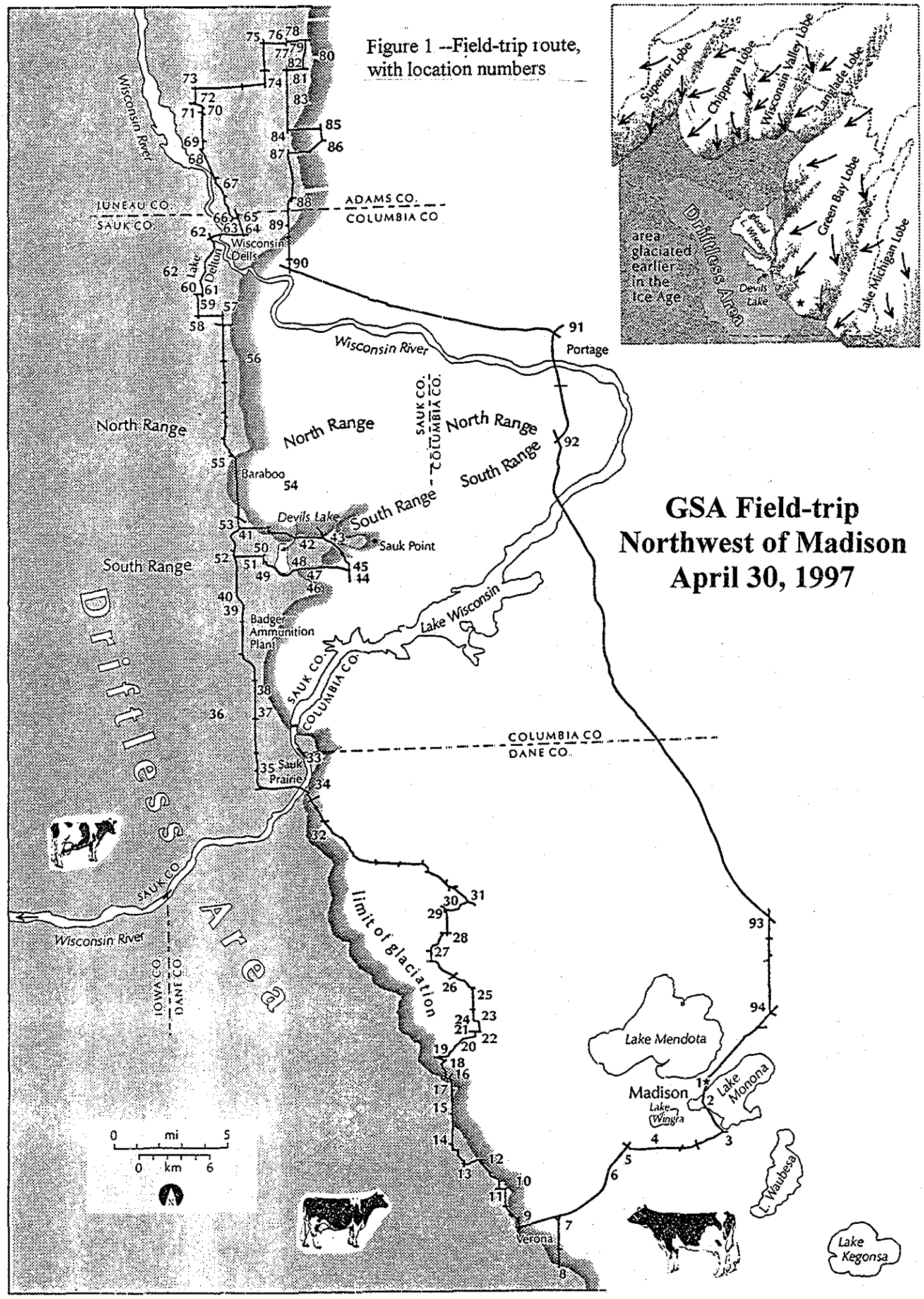
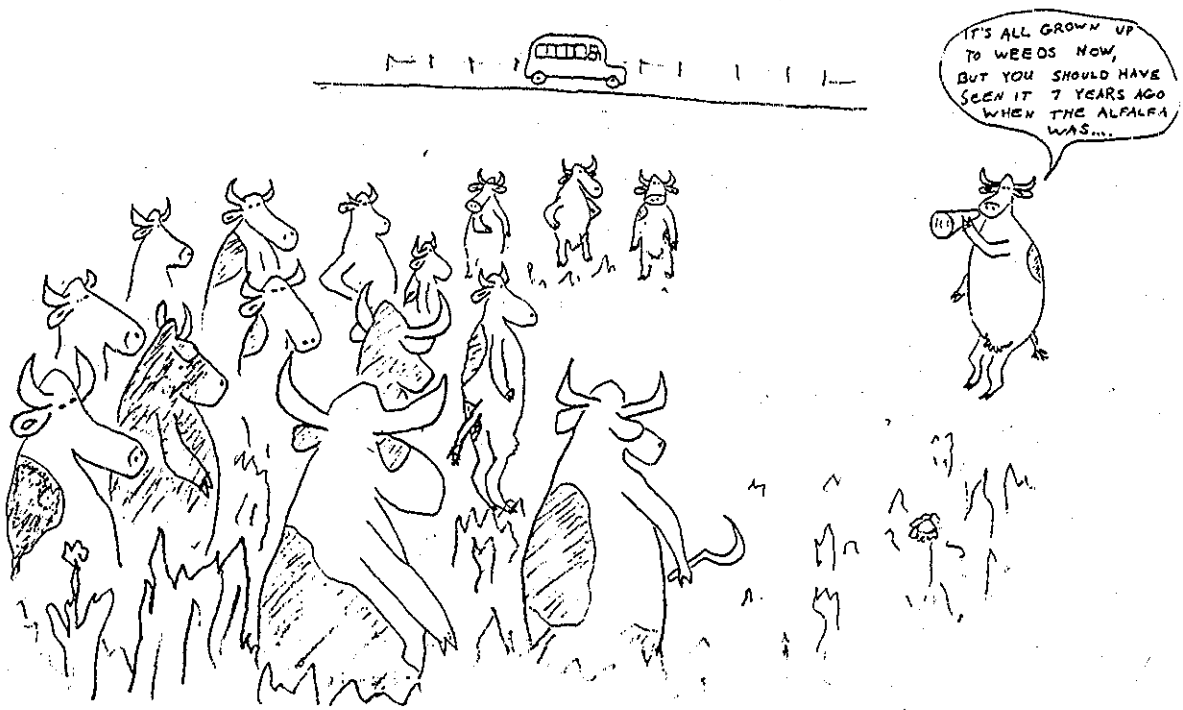


Figure 1 --Field-trip route, with location numbers
GSA Field-trip
Northwest of Madison
April 30, 1997
Driftless Area
limit of glaciation
Wisconsin River
Portage
Wisconsin Dells
Baraboo
Devils Lake
Sauk Point
Sauk Prairie
Badger Ammunition Plant
Lake Wisconsin
Lake Mendota
Lake Monona
Madison
Lake Wingra
L. Waubesa
Lake Kegonsa
Verona
North Range
South Range
JUNEAU CO.
SAUK CO.
ADAMS CO.
COLUMBIA CO.
DANE CO.
IOWA CO.
Superior Lobe
Chippewa Lobe
Wisconsin Valley Lobe
Langlade Lobe
Green Bay Lobe
Lake Michigan Lobe
Glacial L. Wisconsin
Driftless Area
area glaciated earlier in the Ice Age
0 mi 5
0 km 6



FIELD TRIP IN AMERICA'S DAIRYLAND

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Conditions Around the Margin of the Green Bay Lobe during the height of the Wisconsin Glaciation

Lee Clayton and John W. Attig
Wisconsin Geological and Natural History Survey
Madison, Wisconsin 53705-5100

David M. Mickelson
Department of Geology and Geophysics
University of Wisconsin
Madison, Wisconsin 53706

Today and Saturday we will travel through the heart of America's Dairyland Today our field trip will feature Chicagoland's favorite tourist spots, Devils Lake and the Dells. Our focus will be on the processes that operated near of the margin of the Green Bay Lobe during the height of the Wisconsin Glaciation We will concentrate on an area northwest of Madison, reviewing some of the mapping we have done during the past decade or two In the morning we will look at an area just west of Madison and then travel on or near Highway 12 to the Baraboo area, and in the afternoon we will continue north on Highway 12 to Wisconsin Dells and then return to Madison on Highway 90-94 (fig 1 on front cover)

We will see moraines in several places, but we will pay most attention to the one(s) formed when the ice pushed farthest west, during the Johnstown Phase of the Wisconsin Glaciation (fig. 11). If we're lucky, we will be able to see the interior structure of this outermost Johnstown moraine in one of the gravel pits along our route.

We will also look at the various outwash plains and lake plains on the west edge of the outer moraine, and we'll see some of the evidence for the catastrophic drainage of Lake Wisconsin, including dells In addition, we'll point out tunnel channels, shore-ice collapse trenches, drumlins, etc

This is the only guide you will need today The one in your GSA guide-book volume is an earlier, condensed, and more compact version of this one. In addition, the folded map in WGNHS Educational Series 35 (the gray pamphlet) may be useful More information can be found in the Dane County and Sauk County reports.

Location numbers are in bold type in the text. They are also shown on figure 1 (front cover) and on some of the other figures. *Route directions are in italics.*

1: From the Capitol square go onto John Nolen Drive and travel south 2.6 mi.

The capitol stands on the isthmus between Lake Mendota to the northwest and Lake Monona to the southeast, in the middle of Dane County The Madison lakes are aligned northwest to southeast in the Yahara River valley, following the course of the preglacial Yahara, which was never completely filled with glacial and meltwater sediment The Pleistocene geology of Dane County has been described by Mickelson (1983 and 1997) and Clayton and Attig (1997)

2: On the causeway across Lake Monona, look back to the left for a view of the capitol and the new Monona Terrace convention center The names of the four large lakes in the Yahara valley apparently are meaningless "Indian" words invented by real-estate speculators

Palimpsest preglacial topography.--The first stop will be at the east edge of the Driftless Area Up until the first stop, we will travel over a preglacial landscape that has been modified but not completely obliterated by glaciation This landscape, and much that we will see the rest of today, has thin Pleistocene sediment on the uplands and thick in the lowlands

The uplands consist of Ordovician dolomite, bounded by scarps and lower valley slopes of Cambrian or Ordovician sandstone Typically the uplands are covered by no more than a few tens of feet of till

The lowlands are underlain by several tens of feet to a few hundred feet of Pleistocene sediment In the Madison area and eastern Dane County, the marshy or once-marshy flats, such as those we have been passing, are underlain by offshore sediment of glacial lakes such as Lake Yahara Most of the rises are underlain by till, which is commonly underlain by Pleistocene stream or lake sediment

In much of the area we'll see today, the large-scale landforms are basically preglacial, and most of the small-scale ones are glacial

3: From John Nolan Drive turn right onto the Beltline (Highway 12 and 18) and go west 4.4 mi

4: Here the topography changes slightly From the isthmus to the University arboretum (woods on both sides of the Beltline) the small-scale landforms consist of nondescript, smooth irregularities and a few small inconspicuous drumlins (the last glacier moved southwest here) From the arboretum to the first stop, the small-scale landforms consist of low, inconspicuous collapse hummocks and a few small moraines

5: From the Beltline turn left onto Verona Road (Highway 18 and 151) and go southwest 4.5 mi

6: Sluiceway.-- About 1 5 mi southwest of the Beltline, at the southwestern extent of the Milton advance of the Green Bay Lobe, Verona Road enters the head of a meltwater sluiceway about a quarter mile wide, with many reclaimed gravel pits now covered by buildings For the first 2 mi, it has steep rock walls, with only a few feet of till on the upland; this may be a tunnel channel (cut during the Wisconsin Glaciation or a pre-Wisconsin glaciation) The quarries on either side are in the Ordovician dolomite of the Sinnipee (Platteville-Galena) Group; St Peter sandstone is exposed near the base of the valley walls The sluiceway breaks through the outer moraine on the south side of Verona, but before we reach Verona we turn south across the sluiceway and go onto a dolomite upland blanketed by till no more than a few tens of feet thick

7: From Highway 18 and 151 take exit 94, then left onto Old Highway PB and go south 2.3 mi

The large building on the right as we turn left is the county hospital, formerly the county poor farm, on the southwest side of

Badger Prairie County Park

Just after we turn left, the parking lot on the right is at the focus of local interest in our Ice Age heritage. Here the Ice Age National Scenic Trail intersects the Military Ridge State Trail, which continues eastward as the proposed Capital City Trail, which continues eastward as the Glacial Drumlin State Trail. A couple miles to the south, along the Ice Age Trail, is the Prairie Moraine County Parkway. A mile to the north is the county's proposed Ice Age Scenic Park

8. Turn left onto unmarked paved road and immediately left again into the parking lot.

STOP AT PRAIRIE MORAINE COUNTY PARKWAY

This is one of the handiest places to view the topography of the outermost moraine of the Green Bay Lobe, formed during the Johnstown Phase of the Wisconsin Glaciation. We will take a quick hike from the parking lot to the crest of the moraine

This was once the site of a leper colony attached to the county poor farm. It now is temporarily the "Tower Site," a county dog park--watch where you step

(It is 1000 ft to the moraine by way of the west route or the middle route shown on figure 2a. A full loop by way of the west route, the crest, and the east route is about a mile.)

The Ice Age National Scenic Trail will run along the narrow crest of the moraine here. Hummocky topography composed of collapsed supraglacial till can be seen just behind (north of) the moraine. To the south is the Driftless Area, with Sinnipee dolomite on the uplands, overlying St. Peter sandstone on the steeper valley sides and on the lower valley slopes.

The moraine here is 30 to 50 ft high and 300 ft wide. The back side (the ice-contact face) of the moraine is steeper than the front side; their lower parts, which have few surface boulders, are probably covered by glacial and postglacial debris-flow and slope-wash aprons (fig. 2b). The moraine has a inconspicuous second crest in places here.

From Highway PB eastward a quarter mile, the moraine is fronted by an outwash apron. For a few hundred feet east of the outwash apron, the moraine is draped over a low ridge of St. Peter sandstone. Note the lack of erratics on the sandstone beyond the base of the moraine. According to Alden (1918), the area from here to the Sugar River (a couple miles southwest of here) was glaciated during the Illinois Glaciation, but we have seen no conclusive evidence in Dane County for glaciation beyond the moraine. Alden saw scattered erratics, but they may have been rafted here on ice bergs; proglacial lakes covered most of this part of the Driftless Area during the Illinois Glaciation or before. East of the sandstone ridge is a gap in the moraine cut by a meltwater stream.

What are the ways this moraine might have formed? Simple passive accumulation of till, as the englacial debris melted out at the glacier margin? Or was it more active, with debris flowing down off the ice surface? Or lodging just under the snout of the moving glacier? Pushing, dragging, thrusting, shoving, shearing, stacking, squeezing, or subglacial deformation?

The outermost moraine formed along the margin of the Green Bay Lobe has always been considered to be *the* Johnstown moraine. However, there is more than one Johnstown moraine in some places in Dane County, and correlation across some gaps in the moraine is uncertain. In Dane County and on the South Range of the Baraboo Hills, the outermost moraine is a sharp-crested narrow ridge, as we see here. Northward from Dane County (except on the South Range) to Langlade County in north-central Wisconsin, it is a broad hummocky ridge. These two segments might have formed at

different times. In Waushara County in central Wisconsin, the moraine seems to split in two; it probably correlates with the later (Almond) rather than the earlier (Hancock) of the two.

Till.--The Horicon Member of the Holy Hill Formation is the surface lithostratigraphic unit in most of the area we travel through today. It is characterized by brown sandy till that generally consists of a few percent gravel plus 55 to 85% sand, 5 to 30% silt, and 5 to 20% clay. Pebble lithology is typically 60 to 90% dolomite, although black coarse-grained igneous rock is abundant in places between here and Wisconsin Dells.

Holy Hill till is at the surface in much of eastern Wisconsin. To the north of the field-trip area it (Mapleview Member) is sandier and contains less dolomite. West of the Kettle Moraine (Horicon Member) the dolomite is Ordovician, but to the east (New Berlin Member) it is Silurian. For one or two tiers of counties inland from Lake Michigan, the Holy Hill is overlain by the clayier till of the Oak Creek and Kewaunee Formations.

The New Berlin Member is in part equivalent to the Haeger Member of the Lemont Formation of the Wedron Group in Illinois, and the Oak Creek Formation is in part equivalent to the Wadsworth Formation of the Wedron Group.

Vegetation --When emigrants from the northeastern states first settled in this area during the 1840s, many of the broad, level areas were covered by tall-grass prairies several miles wide. The characteristic grass was big bluestem, which reaches a height of 8 ft or more today in remnant and reclaimed patches of prairie in this area.

Much of the rest of area had oak forest (white, black, and red oak) or oak savanna ("oak openings") consisting of grassland with scattered bur oaks having wide-spread branches, like some of the oaks on the south side of the moraine in Prairie Moraine County Parkway. Part of the South Range of the Baraboo Hills is covered by a forest with sugar maple and basswood. The outwash plain in southern Adams County, at the north end of our field-trip route, has pine barrens with jack pine and scrub oak. South-facing slopes tend to have short-grass prairie, with some prickly-pear cactus, but in many places they have been converted to juniper thickets since farmers stopped burning the slopes in 1950s. North-facing slopes and deep gorges have trees, such as birch, that are more characteristic of northern Wisconsin.

Return north (right) 2.3 mi on Highway PB and Old Highway PB and go west 2 mi on Verona Avenue through Verona to Nine Mounds Road on the west side of town.

***9**: From Verona Avenue turn right onto Nine Mound Road and go north 1.9 mi.*

Moraine.--Leaving Verona, we drive for a mile along the outer Johnstown moraine, which is bordered on the west (left) by a spillway from the proglacial lake just to the north.

Proglacial lake.--We then cross an outwash delta, which half filled the mile-wide lake. Exposures in the gravel pits show that grain size ranges from boulder gravel at the apex of the fan to sand at the delta face. This will be stop 1 on the post-meeting paleoglaciology field trip.

***10:** From Nine Mound Road turn left onto Highway PD and go west 0.2 mi.*

***11:** From Highway PD turn right onto Shady Oak Lane and go north and northwest 1.6 mi.*

Moraine.--We continue along the distal (west) edge of the outer moraine.

***12:** From Shady Oak Lane turn left onto Mid-Town Road and go west 0.2 mi.*

Driftless Area.--Leave the moraine and jog out into the Driftless Area. For the first mile we driver over Sinnipee dolomite (fig. 3a). The steeper valley sides are St Peter sandstone.

From Mid-Town Road angle left onto Mound View Road and go southwest 0.6 mi.

***13:** From Mound View Road turn right onto Timber Lane and go north 2.8 mi.*

Outwash.--Cross three narrow strips of valley-bottom outwash.

14: St. Peter scarp.--Here we cross the St. Peter scarp and rise onto a Sinnipee upland (figure 3a).

Blue Mounds can be seen on the horizon 12 mi to the west. West Blue Mound is the highest point in southern Wisconsin, 1000 ft above the Wisconsin River. The caprock is 100 ft of boulder gravel of unknown age. The boulders are several feet, or even tens of feet, across, and consist of chert with Silurian fossils (fig. 3a).

We then descend from the upland into the basins of the Shoveler lakes.

We cross Mineral Point Road a quarter mile south of location 15. The Wisconsin Geological and Natural History Survey is three doors from the east end of Mineral Point Road, 8 mi east of here. Today, its west end is in western Dane County, but part of it at least was once the road to the town of Mineral Point, 40 mi to the southwest, where the mineral galena was mined from the Galena Formation (upper Sinnipee Group) in the upper Mississippi valley lead-zinc mining district.

PAUSE AT SHOVELER LAKES

15: We won't get out here. The outermost moraine is a tree-covered ridge a few hundred feet east (right) of the road; here it is about 30 ft high and 300 ft wide.

A series of four small proglacial lakes formed west of the moraine in small preglacial valleys that were dammed by the glacier and by glacial debris (fig. 4). The southern two still have ponds in their bottoms. The two southern basins have an outwash delta with a steep delta face; the delta face is just west (left) of the road. Meltwater flowed northward from basin to basin, and finally plunged down into the Black Earth trench.

Today, the largest of the ponds drains through a sinkhole, which may have been a spring pit fed by meltwater at the mouth of a cave originating to the east under the glacier.

Cross Plains Unit.--About 3 sq mi of the area shown in figure 4 (plus a bit to the north and northwest) are a unit of the Ice Age National Scientific Reserve. This unit has not yet been activated, but the National Park Service and the state DNR plan to build a visitors' center a quarter mile west of field-trip location 17. It will highlight the Shoveler Lakes and their deltas, the contrasts between the Driftless Area and the glacial area, the Johnstown moraine, the spring pits, the Black Earth trench, Wilkie Gorge (a deep gully on the east side of the visitors' center), erratics, vegetation, etc.

Continue on Timber Lane and go north 1.2 mi.

Moraine.--We here briefly cross over to the backside of the outermost moraine and turn west.

***16:** From Timber Lane turn left onto Old Sauk Pass and go west 0.2 mi.*

Moraine.--Cross over to the front side of the moraine again. The moraine is the low ridge on the right side of the road.

***17:** From Old Sauk Pass turn right onto Cleveland Road and go north 1.0 mi.*

Moraine.--As we turn north we again cross up over the front and down the back of the moraine. Then we descend into the Black Earth trench.

Black Earth trench --The Black Earth trench is now a half mile wide and 200 ft deep, with an additional several tens of feet of Pleistocene fill below the present floodplain at this point. The walls of the trench are Cambrian sandstone under Ordovician dolomite, with no more than a few tens of feet of till on the uplands.

Here the Black Earth trench was cut across the preglacial drainage divide between the Wisconsin valley to the west and the Yahara valley to the east. The rock bottom of the trench slopes eastward and westward from this point. Upstream, to the east, the Pleistocene fill is more than 300 ft thick. The trench may be a tunnel channel, or it may be the spillway of a proglacial lake. The water flowed west in either case, and in either case it could have been cut in Wisconsin or in pre-Wisconsin time.

Tunnel channels.--As we use the term here, a tunnel channel is the inverse of an esker--it is any channel that was cut by a subglacial river. In this region, most of them (at least most of the freshest looking ones) occur in the hummocky-till zone, within 10 miles of the outermost moraine, where the snout of the glacier may have been frozen to its bed and not sliding. The tunnel channels typically are much bigger than eskers that formed later in the drumlin zone, where the snout of the glacier was sliding and not frozen to its bed. We (and others) have suggested that they formed by occasional outbursts of subglacial water stored behind the frozen bed.

18: *From Cleveland Road turn left onto Highway 14 and go west 0.3 mi.*

19: *From Highway 14 turn right onto Rocky Dell Road and go northeast 2 mi.*

20: Rocky Dell--We leave Black Earth trench by way of a tributary that heads in Rocky Dell, a small rock gorge about 100 ft deep. Like the Black Earth trench, it was cut through the preglacial drainage divide, indicating that the gorge is either the spillway of a proglacial lake or it is a tunnel channel cut by a subglacial river. We interpret most of these divide-crossing channels to be tunnel channels, although we often lack evidence to conclusively rule out spillways.

21: *From Rocky Dell Road turn right onto Airport Road and go east 0.2 mi.*

22: *From Airport Road turn left on Bronger Road and go north 0.5 mi.*

Palimpsest preglacial topography.--Continue for several miles across preglacial topography that is blanketed by--but not obliterated by--till, with scattered inconspicuous small moraines.

Harder to recognize, but probably present in much of the area, is palimpsest topography where the pre-existing topography is not preglacial topography but is glacial topography of a previous advance.

Till on these upland areas is 0 to 20 or 30 ft thick.

23: *From Bronger Road turn left onto Koch Road and go west 0.2 mi.*

24: *From Koch Road turn right onto Vosen Road and go north 1.5 mi (crossing Schneider Road).*

25: *From Vosen Road turn left onto Highway K and go northwest 2.7 mi.*

26: Trench at Highway P.--Where Highway K crosses Highway P we are crossing the bottom of another probable rock-walled tunnel channel. It is over 100 ft deep, a half mile wide, and unnamed.

27: *From Highway K turn right onto Martinsville Road and go northeast 1.1 mi.*

From Martinsville Road turn right onto Indian Trail and go east 0.2 mi.

28: *From Indian Trail turn left onto Whippoorwill Road and go north 1.1 mi.*

29: *From Whippoorwill Road turn right onto Highway 19 and go east 1.2 mi.*

30: Gorge at junction of Whippoorwill and 19--Just east of the intersection of Whippoorwill Road and Highway 19, we drive through an unnamed rock gorge cut through the Prairie du Chien dolomite on the Wisconsin-Yahara drainage divide. Here it is 100 ft deep and only a few hundred feet wide, but just upstream (east) it is a half mile wide (at Brandenburg Lake), and further east for several miles is a network of trenches as much as a mile wide. Water-well logs indicate that the bottom of the trench beneath the Pleistocene fill here is

highly irregular, sloping up stream in places and down stream in others This is not easily explained except by subglacial stream erosion, as first suggested by Mickelson (1983, p 35-36) Tunnel-channel water would have to climb at least 200 ft to escape westward through the Whippoorwill-19 gorge

31: From Highway 19 turn left onto Highway 12 and go northwest 9.2 mi.

Highway 12.--This is one of the most dangerous segments of road in the state The signs in front yards along Highway 12 are protesting plans to widen it to four lanes The farmers are joined in their protest by environmentalists who fear that four lanes will trigger a building boom in the Baraboo Hills

Palimpsest preglacial topography.-- The uplands in this area are made of Ordovician dolomite (Prairie du Chien Group) blanketed by as much as a few tens of feet of till The steeper slopes bordering the uplands are underlain by Cambrian sandstone (Jordan Formation; fig 3a and b) The Pleistocene material has been washed off the steepest slopes Just after we turn northwest on Highway 12, we'll climb up onto a Prairie du Chien upland a couple miles wide at the divide between drainage west to the Wisconsin River and drainage east to the Yahara and Rock Rivers

The lowlands are generally underlain by sand and gravel deposited by meltwater rivers, commonly with hummocky collapse topography where deposited on stagnant masses of glacial ice Most of the rest of our way to the Wisconsin River is along a valley-bottom complex of collapsed and uncollapsed meltwater-river sediment

32: Black Hawk War --We're approaching the Wisconsin River Where Highway Y joins Highway 12, a historical marker describes the Battle of Wisconsin Heights The battle took place July 21, 1832, on the slope a mile to the southwest (left) Earlier, during the War of 1812, a band of Sauk people led by Black Hawk had sided with the British; 20 years later the Sauk were again in conflict with the Americans, as settlers began to move into the area During the summer of 1832, the U S army chased Black Hawk's people from the lower Rock River in Illinois, through the future site of Madison, to the Wisconsin Heights Only a half dozen were killed on either side, but the battle was considered a major victory for Black Hawk However, twelve days later the Sauk were slaughtered northwest of here when they tried to cross the Mississippi River Private Abe Lincoln, Lt Jefferson Davis, and Col Zachary Taylor were participants in the Black Hawk War

33: Prairie Fumé.-- A mile north of Highway 12, on Highway 188, is a winery built in the 1840s by Hungarian Count Agostin Haraszthy de Mokcsa (1812-1869) He soon gave up and moved to the Sonoma Valley to become the father of the California wine industry It is now the Wollersheim Winery (try their Prairie Fumé) Tours available

GENERAL DESCRIPTION OF A POSSIBLE STOP AT A MORAINE EXPOSURE

34.--At its maximum extent, the Green Bay Lobe reached a point a quarter mile beyond the junction with Highway 188, or a quarter mile east of the bridge over the Wisconsin River No moraine can be seen from the highway, but several years ago the outer moraine was well exposed in the Lycon pit north of the road here, as shown in figure 5a and 5b

We hope to show you an exposure of the internal structure of the outer moraine somewhere in the Sauk City or Baraboo area, perhaps here in the Lycon pit Exposures in gravel pits in the region have shown the moraine structure that is generalized in figure 5c

Much of the volume of the outer moraine in the Sauk City and Baraboo area is made up of esker-like bodies of gravel perpendicular to the moraine (fig. 5b and 5c, B). They grade laterally into the apexes of outwash fans (fig. 5c, C). The meaning of these features is unclear.

Draped over these gravel bodies is stratified till consisting of alternating layers of slightly different composition (fig. 5b and 5c, D). The till layers are generally a centimetre to a metre or more thick. The till layers are also draped over large boulders within the till, and the layers are down folded under the boulders, suggesting that the glacier forced the boulders down into the till during deposition. In addition, the folds under the boulders are asymmetrical, with the bedding bunched together on their downglacier side, indicating the ice was still moving during deposition. We have interpreted this material to include both lodgement till and melt-out till.

The outermost moraine in Taylor and Lincoln Counties in north-central Wisconsin is topographically similar to (and possible contemporaneous with) the outermost one in Dane County. There, however, it clearly is composed largely of supraglacial debris that flowed off the snout of the glacier (Attig, 1993, p. 9-11).

Continue west 2.1 mi and north 4.4 mi on Highway 12 to next stop at a wayside with a historical marker.

Wisconsin River.--Cross the Wisconsin River and enter Sauk County. The geology of Sauk County is described by Clayton and Attig (1990). The first known French-Canadian explorers to pass this way were Jacques Marquette and Louis Joliet, who canoed down the river in June of 1673.

DNR's famous Mazomanie Nude Beach (actually a sand bar) is 5 mi downstream.

Sac Prairie.--The twin villages of Sauk City and Prairie du Sac, on the west bank of the Wisconsin River, have been described in two dozen books by August Derleth (1909-1971). In his books, he combined the two villages into one called "Sac Prairie." Derleth has been compared to another regional writer, Sinclair Lewis (1885-1951), who wrote about Sauk Center, Minnesota (called "Gopher Prairie" in his *Main Street*). Derleth is better known today, with an international following, for his many stories about London detective Solar Pons.

Sauk people.--Sauk Prairie (Sac Prairie) was occupied by the Sauk people from the 1740s to the 1780s. In 1766, the explorer Jonathan Carver reported they had 90 houses, each 60 ft long and made of hewn planks; each was occupied by several families. They farmed 500 acres of corn, beans, melons, and so forth. Later this area was occupied by the Ho-Chunk (Winnebago) people, who ceded it to the United States in 1838, when the first Yankee and German settlers arrived in Sauk Prairie.

Ice-wedge polygons.--Ice-wedge polygons can be seen from the air in many parts of Wisconsin, generally on sand and gravel. A typical set of a few dozen can be seen on aerial photographs of the field to the left, at the west edge of town, between Meyer Oak Grove Park and the graveyard in the distance. Here the polygons are 100 to 200 ft in diameter, and the wedge casts are several feet wide. They have no topographic expression but show up as darker soil or as darker or lighter vegetation, depending on soil-moisture conditions. They are not rock joints because the Pleistocene sand here is over 100 ft thick and because they do not cross but meet in T or Y junctions. No wood from this region has been radiocarbon dated between 25,000 and 13,000 BP. This and the pollen indicate tundra with no trees at the time the polygons formed.

Taliesin.--Frank Lloyd Wright's (1867-1959) summer home, studio, school, and farm, called Taliesin, is near Spring

Green, 20 mi southwest down the Wisconsin valley. Tours are available.

Lake Wisconsin flood surface.--Sauk City and the area to the west are underlain by sand deposited when glacial Lake Wisconsin catastrophically drained during the waning part of the Milton (Elderon) Phase of the Wisconsin Glaciation (fig. 6 and 11). The low topography on this surface is stream channels and low terraces modified by eolian erosion and deposition.

35: Outwash plain.--A mile after we turn north, we rise 40 ft onto the outwash surface formed when the Green Bay Lobe stood at its outermost moraine, a mile to the east (right). We will continue across this outwash plain for 7 mi to the base of the Baraboo Hills.

36: Sauk Sequence --Six major sequences of rock above the Precambrian basement have been named in the interior of North America, the oldest being the Sauk Sequence. The hills a couple miles to the west (left) are the type area of the Sauk Sequence (fig. 3). The lowest Sauk unit is the Elk Mound Group, consisting of the Mount Simon Formation (150 ft of Cambrian sandstone overlying Precambrian rock), the Eau Claire Formation (200 ft of sandstone, siltstone, shale, and dolomite, but apparently only a few feet thick north of the Baraboo Hills), and the Wonewoc Formation (150 ft of sandstone); the very top of the group is exposed just above the level of the Wisconsin River, but all three of the formations crop out north of the Baraboo Hills. The lowest part of the Sauk Sequence exposed here is the Tunnel City Formation (over 100 ft of glauconitic sandstone) underlying the lower slopes. At the base of the steeper slopes is 50 ft of siltstone of the St. Lawrence Formation. The steep upper slopes are 50 ft of Cambrian sandstone in the Jordan Formation (fig. 3). The plateaus are capped by several feet or tens of feet of Ordovician dolomite of the Oneota Formation in the Prairie du Chein Group. The Sauk Sequence here is overlain by several feet of red Cenozoic clay of the Rountree Formation.

37 to 38: Lake Merrimac spillway --On the north side of the graveyard at the junction with Highway Z, 3 mi from were we turned north, we descend 20 ft into the mile-wide spillway from glacial Lake Merrimac. Lake Merrimac was roughly the same size and shape and in the same location as the present-day reservoir behind the dam at Prairie du Sac (fig. 1). (This reservoir is called Lake Wisconsin, which is at an entirely different location from proglacial Lake Wisconsin.) Lake Merrimac formed in the Wisconsin River valley when the glacier wasted back from the outermost moraine and outwash plain, which formed the dam across the valley at the west end of Lake Merrimac. When glacial Lake Wisconsin drained catastrophically through Lake Merrimac, this spillway was abandoned in favor of the outlet at Prairie du Sac, occupied by the present Wisconsin River.

STOP AT SAUK PRAIRIE WAYSIDE

38 --Stop at a wayside with a historical marker on the north side of the Lake Merrimac spillway. Here we will give you a general orientation to the Baraboo area.

Baraboo Hills.--The skyline to the north of us is the crest of the South Range of the Baraboo Hills, about 600 ft above our present position. These hills are composed of Proterozoic quartzite of the Baraboo Formation, which is about a mile thick. It is similar to--and may be the same age as--the Sioux quartzite.

The South Range is a ridge (hogback) formed by the south limb of the Baraboo Syncline. The syncline is boat shaped and is 25 mi long (east-west) and 10 mi wide. The south limb dips about 15 degrees to the north and the north limb is nearly vertical.

A few large quarries in the quartzite produce crushed rock that is in demand as a

highly durable pavement aggregate and railroad ballast.

The South Range is covered by one of largest continuous blocks of forest it this region, much of it owned by the Nature Conservancy. About 80 square miles of it has been designated a National Natural Landmark, the largest outside Alaska.

Outwash plain.--We here are on the outwash plain formed during the Johnstown Phase of the Wisconsin Glaciation, when the Green Bay Lobe was at its maximum extent The outwash sand is about 200 ft thick. Loess on the surface is a few feet thick.

Moraine.--The Johnstown moraine is a half mile east of us. Here it is a single hummocky ridge a quarter mile wide. To the north-northeast the outermost Johnstown moraine is small bump on the skyline. Where they cross the South Range, the Johnstown moraines consist of two or three sharp-crested ridges, each the same size and shape as the moraine at the first stop. A solitary Johnstown moraine is much broader and taller where it crosses the north and south ends of the Devils Lake gorge and to the north of the South Range as far as north-central Wisconsin

Outwash-dammed lakes.--In the uplands to the west, the valleys slope eastward. As the outwash plain grew westward from the moraine, lakes were dammed up in the valleys (Clayton and Attig, 1990, fig. 20). Lake Black Hawk, west of Sauk Prairie, was 10 mi long Stones Pocket Lake, northwest of here, was 2 mi long; as we continue north from this wayside, we will curve west and then north again, with a view west (left) up Highway C into Stones Pocket valley--the delta face can be seen a mile away, with the lake plain beyond. Both lakes spilled southward, where the outwash plain meets spurs of the upland, to the Wisconsin River

Lake Wisconsin.--The largest of the proglacial lakes in this area was Lake Wisconsin, on the north side of the South Range Like the smaller lakes mentioned in the previous paragraph, it also was separated from the Green Bay Lobe to the east by an outwash plain (delta) from one to several miles wide. To the north, it was contained by preglacial uplands of Precambrian rock; to the west, by the preglacial uplands of early Paleozoic sandstone and limestone; and to the south by the Baraboo Hills (fig. 6). At its greatest extent, it was about 70 mi long and 150 ft deep.

Lake Wisconsin was dammed when the Green Bay Lobe moved up onto the east end of the Baraboo Hills, near Portage, 17 mi to the northeast of this stop (we will pass that way this afternoon) The lake drained through its Black River outlet on the northwest side of the lake, at least during the Johnstown Phase and the earlier part of the Milton Phase. Earlier, it drained through the Devils Lake gorge.

Final drainage was to the southeast through the Alloa outlet at the east end of the Baraboo Hills Water from the Alloa outlet spilled into glacial Lake Merrimac We were stopped on the north side of the pre-flood outlet of Lake Merrimac The flood spillway and post-flood outlet was the present course of the Wisconsin River at Sauk City.

Continue on Highway 12 north 7.7 mi.

Powder plant.--Continue north across the outwash plain west of the Johnstown moraine The Badger Army Ammunition Plant on the east (right) side of the road occupies 10 sq mi It was built in 1942 and supplied gun powder for World War II, the Korean War, and the Vietnam War. It is inactive but is being maintained in a ready state A variety of chemicals were spilled or buried here, creating a significant groundwater-pollution problem in the 200 to 300 ft of Pleistocene sand beneath and to the southeast of the plant.

39: Fan.--At the north edge of the

powder plant, we ascend an alluvial fan with its apex at the mouth of an exhumed valley in the south side of the Baraboo Hills The fan is a half mile wide and 100 ft high The valley is only a half mile long and never held glacial meltwater.

Driftless Area.--For the next few miles, we continue through the area that apparently was never glaciated. The Baraboo quartzite crops out in a road cut on the right just as we enter the Baraboo Hills

40: Exhumed landforms.--We cross the South Range through a saddle that is 200 ft below the flat plain at the summit of the range. Cambrian sandstone crops out at the south edge of the saddle (roadcut on the left), as well as in the saddle We drive north from the saddle, down a valley that extends 2 mi north to the north edge of the South Range This is an partly exhumed Cambrian valley, cut before deposition of the 150 ft of late Cambrian sandstone that still underlies the present valley. The valley walls above the level of the saddle are Proterozoic quartzite of the Baraboo Formation Thin patches of early Paleozoic sediment occur on the quartzite in many parts of the Baraboo Hills, indicating that most of the major landforms of the South Range, as well as the South Range itself, are exhumed earliest Paleozoic landforms (Clayton and Attig, 1993). The summit plain may be an exhumed Ordovician marine erosion surface (fig. 7)

41: From Highway 12 turn right onto Highway 159 and go east 1.1 mi.

Leave the Driftless Area.--We exit the mouth of the exhumed Cambrian valley and turn east across the outwash plain for a half mile along the north edge of the South Range. Then we cross the outermost moraine, which here is 40 ft high and a quarter mile wide.

From Highway 159 turn right onto Highway 123 and go south 0.3 mi.

From Highway 123 turn left onto Highway DL and go east 1.6 mi to the parking lot on the right.

Re-enter Driftless Area.-- We then drive up into the South Range again, into its unglaciated central area, to the next stop

Devils Lake State Park.--Here we are at the north edge of Devils Lake State Park, and we will remain in the park for the next several miles The park straddles South Range, including all of Devils Lake gorge. The Pleistocene geology of the park is described the gray brochure by Attig and others (1990) in your field-trip envelope. The park is part of the Ice Age National Scientific Reserve, and the Ice Age National Scenic Trail runs through it

STOP AT STEINKE BASIN

42.--The parking lot is in the unglaciated area. You can orient yourself on the map in the back pocket in the Devils Lake brochure: we were driving east on Highway DL in the north-central part of the map. We will hike up onto the outermost of three closely-spaced Johnstown moraines, formed during the Johnstown Phase (named after a town southeast of Madison) The trail along the moraine crest is named the Johnson Moraine Loop (without the t and the w--this was once the Johnson farmstead)

In the Baraboo Hills, the outer Johnstown moraine is generally about the same size and shape as in Dane County: less than 300 ft wide and 30 ft high (but it is much bigger where it crosses the Devils Lake gorge). Here, as in other parts of the Baraboo Hills, the outer moraine is bordered by one or more slightly younger Johnstown moraines about the same size and shape. Among the boulders of far-traveled rock on the moraine is a red porphyritic rhyolite, probably from the eastern part of the Superior basin. The outer Johnstown moraine loops eastward 4 mi where it crosses the South Range, with lobes extending into either end of the Devils Lake gorge

A breach in the Johnstown moraine

contains the Johnson Ponds, just east of the old Johnson farmstead. This sag is probably a small tunnel channel because it rises up to its mouth. A fluvial fan several hundred feet wide has its apex at the mouth of the tunnel channel. The fan was built out into Steinke Basin, which held a meltwater lake up to a level about 10 ft above the parking lot. A drillhole 1000 ft south of the parking lot showed 30 ft of lake sediment overlying quartzite. Before glaciation, the stream in this exhumed Cambrian valley flowed north off the north side of the range. During glaciation, drainage shifted to the south end of the basin and from there spilled into the north end of Devils Lake.

Continue on Highway DL east 0.7 mi.

Sauk Point interlobe area.--We drive east, travelling a few hundred feet beyond (south of) the outer moraine, going through Steinke Basin, across a low quartzite ridge and into Feltz Basin, which is floored by another glacial-lake plain underlain by thick offshore sediment.

We have entered an unglaciated area between sublobes of the Green Bay Lobe on the north side of the South Range and those on the south side (fig. 1). The high point at its apex is called Sauk Point (fig. 1). Just west of Sauk Point is a widely visible gravel pit, which might be our moraine-exposure stop, mentioned at location 34.

43: *From Highway DL turn either left (43a) or right (43b) onto Highway 113.*

43a: *If we go to the Sauk Point gravel pit, turn left (north) and go a couple hundred feet; then turn right (east) onto Tower Road and go 1.7 mi to the gravel pit road.*

SAUK POINT GRAVEL PIT

This is a rapidly changing pit, so we won't know if we're going here until the last minute. The back (south) side of the pit is in till of the outermost Johnstown moraine at the eastern point of the interlobe area. The main part of the pit was in an outwash fan deposited by meltwater coming out of the interlobe area, probably from subglacial tunnels. The bedding in the outwash fan seems to merge laterally with esker-like bodies of gravel similar to those at B in figure 5c.

Return to location 43.

43b: *If we do not go to the Sauk Pit gravel pit, turn right and go south about 2.4 mi.*

Leave Driftless Area.--We turn south and drive another half mile across the lake plain and then up through a saddle in the crest of the South Range. Here we cross the outer moraine, formed by ice on the south side of the range; the ice here flowed north rather than south as at Steinke Basin. We then descend through an exhumed Cambrian valley thinly covered with till, and into the east end of Devils Lake gorge.

44: Moraine view.--We will drive a short way past South Shore Drive into the middle of the east end of the gorge and turn around to get a view west up into the gorge. The view ends at the back side of the of the large moraine plugging the gorge.

Turn around and return about 0.2 mi.

45: *From Highway 113 turn left onto South Shore Drive [Road] and go west 2.5 mi.*

46: Hanging lake plain.--High on each side of the gorge are exhumed hanging valleys filled with lake clay. Each valley held a proglacial lake when a lobe of the glacier filled this end of the gorge. The lip of the one on the south (left) side of the gorge is a Johnstown moraine.

Talus.--We then drive west along the north side of the gorge. Farther on, both sides of the unglaciated part of the gorge are covered with coarse talus, but here the fine talus on the right is spoil from an old quarry.

47: Moraine.--The road crosses the tree-covered moraine in the bottom of the gorge where the moraine is a half mile wide,

170 ft high on its back side, and 70 ft high on its front side

Turn right into the picnic ground just beyond the railroad.

STOP FOR LUNCH IN DEVILS LAKE GORGE

48.--We will have lunch in the picnic grounds at the southeast corner of the lake. There are several things to see here. We won't have time to look at all of them, but you may want to come back. See WGNHS Educational Series 35, in your field-trip envelope; trails are marked on plate 1 (Attig and others, 1990).

The best views of the gorge are from the top of East Bluff and West Bluff, but we won't have time to make that climb. The gorge is 4 mi long and a half mile wide. It is now 500 ft deep, but before Pleistocene sediment was deposited in its bottom, it was 900 ft deep.

The gorge was originally cut through the quartzite of the South Range before Late Cambrian time. It was then filled with sediment, mostly sand, during Late Cambrian and later Paleozoic time; remnants of sandstone have been seen several places in the gorge (Dalziel and Dott, 1970). The gorge was later exhumed, perhaps starting during Mesozoic or early Cenozoic time.

A Wisconsin River Myth.--Nearly everyone knows that the Devils Lake gorge was cut by the preglacial Wisconsin River. But there isn't any reason to think the preglacial Wisconsin River ever flowed anywhere near the Baraboo Hills. The present valleys of the Yellow and Lemonweir Rivers slope from northwest to southeast, draining the area west and northwest of glacial Lake Wisconsin. The combined preglacial Yellow and Lemonweir valley passes beneath thick Pleistocene fill tens of miles northeast of Wisconsin Dells, well beyond the South Range. Any preglacial river flowing south out of central Wisconsin would have been intercepted by the Yellow-Lemonweir valley before it was anywhere near the South Range.

Except for the river spilling out of Lake Wisconsin, there is no need to postulate *any* river flowing through the gorge since it was filled in Cambrian time. Several other gorges in the South Range were cut into the quartzite, then filled with lower Paleozoic sand, and then at least partially exhumed. Several of these were cut by rivers that were only 1 to 2 miles long; their cirque-like heads are just below the crest of the South Range--they do not cut through the range. Examples west of here include the one we drove through between locations 40 and 41, Baxters Hollow, and Pine Creek valley. The only thing required to form Devils Lake gorge is a similar short stream at each end of the future gorge to erode enough sandstone so Lake Wisconsin can spill that way.

The last surge in erosion of sandstone from the gorge probably occurred when early versions of glacial Lake Wisconsin spilled southeastward through the gorge. Then, during the Wisconsin Glaciation, the gorge was clogged with glacial and fluvial sediment to a depth of at least 450 ft in places. This plug prevented Lake Wisconsin from again spilling through the gorge, forcing it instead to spill to the northwest down the Black River northeast of La Crosse.

Johnstown moraine --Devils Lake is in a part of the gorge that was never glaciated, but it owes its existence to the moraine plugs in either end of the gorge. From the picnic grounds, the plug at the north end of the gorge can be seen beyond lake. The northern plug is smaller than the other, about 100 ft high and a quarter mile wide. The nature center is perched on top it.

Talus --The talus cones along the walls of the gorge are up to 300 ft high. They are composed of blocks of Baraboo quartzite 10 ft or more across. The blocks were eroded from the cliff tops during the

Wisconsin Glaciation or earlier. The abrupt termination of the talus on South Bluff at the west edge of the outer Johnstown moraine indicates that little of the talus formed during the Holocene. Instead, the talus probably formed when permafrost was present and frost action was most active in the cliffs. We know of no evidence that the talus is still accumulating. The toe of the nearest talus is easily accessible by a trail crossing the railroad north of the picnic grounds.

Vultures.--Turkey vultures can probably be seen riding the updrafts along the bluffs. They nest in the pore space of the talus and in the crevasses behind large blocks of quartzite that had just started to slide off the top of the bluffs when the permafrost episode came to an end.

"Grottos".--In a few places at the toe of the talus fans you can see depressions that are a few feet deep and 10 ft long or longer. In the park, they are called "grottos." Their origin is unclear. Are they shore-ice collapse trenches, formed where chunks of ice were buried under the talus, much like those we will discuss at field-trip location 76? In the summer they trap pockets of cold air that drains out of the spaces between the talus blocks; each once held a small patch of vegetation adapted to cooler climates, but most of it has been trampled out of existence. You can see "grottos" east along Grottos Trail, across the railroad north of the picnic grounds.

Potholes with "Windrow" gravel.--We don't have time to look at them, but a few dozen potholes are present at the edge of the summit plain 450 ft above the picnic grounds. They are a few inches to a few feet across and were cut into the quartzite by stones in eddies in the bottom of a river. In a few places the quartzite surface between the potholes is polished, perhaps as a result of sandblasting on the river bed. Most known potholes occur on the summit plain within 300 ft to the west of the junction of the Potholes Trail and the Devils Doorway Trail. Some occur several tens of feet below the summit plain along the Potholes Trail.

Evidence of glaciation and glacial meltwater is lacking at this point on East Bluff. Most likely the potholes were cut by a river when the South Range was beginning to be exhumed. Gravel consisting of pebbles of polished chert, some well rounded and some with Silurian fossils, has been found in the potholes. The gravel has been considered part of the Windrow Formation, which consists of scattered patches of fluvial sand or gravel in the highest parts of the Driftless Area, which may have been deposited in late Mesozoic or early or middle Cenozoic time.

Effigy mounds.--Prehistoric ceremonial mounds in the shape of animals were once common in the southern half of Wisconsin, especially in the Madison area, and in parts of adjacent states. Many have been preserved in parks and graveyards. They commonly have the form of a cougar, bear, goose, hawk, deer, buffalo, turtle, lizard, wolf, fox, or beaver. They were constructed between about AD 300 and 1000. You can see an example of a bird mound at the north end of the picnic grounds.

Return to South Shore Drive and continue west 1.9 mi.

PHOTO STOP

We can stop at the boat ramp at the southwest corner of the lake for a view of the talus and the moraine plugs at both ends of the gorge.

Leave the gorge.--Drive up out of the west side of the gorge. An outcrop of lower Paleozoic sandstone can be seen on the right, just as we start to climb--this is evidence that the gorge was originally cut at least this deep into the quartzite before late Cambrian time, when the oldest Paleozoic rock in this region was deposited.

50: *From South Shore Drive turn left onto Ski Hi Road and go west 0.7 mi.*

51: Ski Hi.--We will loop through the parking lot at Ski Hi Orchard so you can have a view either right or left out the window at the summit plain 2 mi to the west-northwest, as illustrated on p 23 of WGNHS Educational Series 35, which you have. The summit plain may be an exhumed marine erosion surface (Ordovician?). A notch can be seen 100 ft below the brink of the summit plain. It is probably an exhumed early Paleozoic shore terrace (fig. 7)

Continue on Ski Hi Road west 0.5 mi.

52: From Ski Hi Road turn right onto Highway 12 and go north 11.0 mi.

53: Baraboo.--North of the South Range, we travel a mile across the outwash plain in front of the outer moraine (to our right), then cross the moraine (here about 10 ft high and a few hundred feet wide) and continue down into the low area occupied by the city of Baraboo. The moraine is on the skyline to the south, west, and north, at the rim of this low area. As we cross the Baraboo River, the moraine is a half mile to our left (west). The river flows through the moraine in a trench that connected the west Baraboo basin of Lake Wisconsin to the east Baraboo basin.

54: Circus World Museum.--We recommend the Circus World Museum on the southeast side of Baraboo. It is run by the State Historical Society at the site of the winter headquarters of the Ringling Brothers Circus beginning in 1882. It includes a small working circus and a fine collection of elaborate circus wagons.

55: Outwash delta.--We drive up out of the east Baraboo basin, cross the outer moraine, back onto the outwash plain. But before we're onto the flat plain, we cross a half mile of rough topography, which is postglacial gullies cut into the outwash plain. Almost all the outwash plains we've seen today have been deltas into proglacial lakes. The outwash plain here is a delta into the west Baraboo basin of Lake Wisconsin. The delta face is 60 ft high and is a quarter to a half mile to our left (west). The gullies were cut after the lake drained--that is, after the Green Bay Lobe wasted off the east end of the Baraboo Hills during the last part of the Milton (Elderon) Phase.

Moraine exposure.--A mile east of here is another gravel pit that could provide a look into the interior of the outermost moraine, as mentioned at location 34.

Outwash delta.--After the gullied section, we continue across 5 mi of outwash plain. The first half mile is delta into the west Baraboo basin of Lake Wisconsin (fig. 6). The next half mile is a continuation of the outwash plain through a gap in the North Range. The next 4 mi is outwash delta into the Dell Creek basin; the delta front is a couple miles to the west (left).

The moraine is a half mile to the east (right). It is here a half mile wide and 30 to 60 ft high, and it has been breached every few miles by tunnel channels, which were the source of much of the material in the outwash plains.

56: Cranes.--North of the airport is the Ho-Chunk (Winnebago) casino, and a mile north and a mile east of the casino on Shady Lane is the International Crane Foundation, with live examples of every kind of crane in the world. It is devoted to protecting and restoring the world's crane populations. It's worth a visit.

Hulburt basin.--At the south edge of the interchange, we leave the outwash plain, cross the gullied delta face, and drive into the Hulburt basin of Lake Wisconsin (fig. 6).

57: From Highway 12 (first stoplight north of interchange) turn left onto N. Gasser Road and go west 0.9 mi.

Possible shore of Lake Wisconsin.--The knob to the right of the Gasser-Ishnala junction has a bench around its base that is at the level of the high shoreline of Lake Wisconsin. However, it most likely is the Ironton stratigraphic bench (fig. 3b). Few

beach ridges or shore terraces formed around Lake Wisconsin have survived

***58:** From N. Gasser Road turn right onto Ishnala Road and go north 0.9 mi.*

59: Dell Creek gorge.--We will slow down as we cross the sandstone gorge of Dell Creek (view to right and left). This is one of the numerous dells cut into the floor of the Hulburt basin (fig. 8). Mirror Lake State Park, just up stream (to the left), features the Dell Creek gorge.

***60:** From Ishnala Road turn right onto Highway 23 (Monroe Street) and go east two blocks.*

***61:** From Highway 23 turn left onto Highway 12 and 23 and go north 2.7 mi.*

The city of Wisconsin Dells.--Go through the village of Lake Delton (dell-town) and enter the city of Wisconsin Dells. The Dells has over 100 motels but has a population of only 2500.

***62:** From Highway 12 and 23 turn right onto Highway 16 and 23 and go east 1.4 mi.*

The Dells in Wisconsin Dells.--Some of the larger flood-cut dells in and near the city of Wisconsin Dells are shown in figure 8. The parking lot by the entry of Rocky Arbor State Park, a mile north of the highway junction, is in the bottom of a large flood-cut dell. The gorges in Mirror Lake State Park and Rock Arbor State Park can be easily reached by car and foot.

East of the highway junction we cross the gorge of the Wisconsin River. Most of the gorge and adjacent upland is state owned and is fairly primeval. A only way to see this gorge is on one of the frequent boat tours in the Upper Dells (left) or Lower Dells (right). Bring ear plugs to block out the inane commentary. In the Upper Dells, the Wisconsin River gorge is as deep as 100 ft and as narrow as 50 ft.

Origin of the dells.--The word "dells" (or "dalles") is used in Wisconsin for narrow rock-walled gorges, many of which were cut during the drainage of glacial lakes. The Wisconsin Dells were probably cut when glacial Lake Wisconsin drained.

In this area the preglacial drainage was generally to the southeast. The Dells area was on the drainage divide between the Lemonwier River valley to the northeast and the Baraboo River valley to the southwest.

At its maximum extent, the Green Bay Lobe came within 3 mi of the Dells. At that time the Dells area was submerged under the water of glacial Lake Wisconsin up to about 150 ft above present river level; only the highest hills in this area were above water.

The Green Bay Lobe wasted back eastward until, near the end of the Elderon (Milton) Phase of glaciation, a spillway opened around the east end of the Baraboo Hills, allowing the Lewiston basin to drain through the Alloa outlet (fig. 6). The Lewiston basin and the main basin (fig. 6) were separated by a narrow dam, consisting of the Johnstown moraine and a narrow outwash plain. This dam failed, causing the main basin, the Hulburt basin, and the other southeastern basins to drain.

The deeper parts of the Lemonwier and Baraboo valleys had been clogged with glacial debris, leaving the Dells area as the lowest possible and therefore the only likely outlet. The numerous sandstone gorges cut through the main drainage divide as well as through various minor divides are the main evidence of this drainage event.

How long did it take to erode these dells? How long did it take for Lake Wisconsin to drain? We don't know, but probably the drainage was catastrophic. The flood from the Lewiston basin through the Alloa outlet (fig. 6) may have taken no more than a few days, because the water only had the ice to cut through. The flood from the main basin and the smaller southern basins (fig. 6) may also have been sudden, because the moraine dam was narrow. Once the

water level in the main basin had dropped about 30 ft, most of the Pleistocene sediment in the Dells area had been washed away, leaving the soft, easily eroded Cambrian sandstone, which probably was also rapidly entrenched.

63: Bennett studio --If you visit the Dells, we suggest a visit to the Bennett studio, at 215 Broadway (main street). H H. Bennett (1843-1908) began his photographic career in 1865. He photographed from Chicago to Minneapolis, but concentrated on landscapes in the Dells. His studio, his darkrooms, and his collection of 8000 glass-plate negatives (many 8 by 10 inches or 18 by 22 inches) are largely intact. You can still buy prints made from his original negatives. Look for a display of large Bennett prints of the Dells at the Survey open house.

64: From main street (Highway 16 and 23) turn left onto Highway 13 and go north 1.0 mi.

65: From Highway 13 turn left onto service road and go west 0.1 mi.

From the service road turn right onto Waubeek Road and go west 0.2 mi.

66: From Waubeek Road turn right onto River Road and go north 1.5 mi, several hundred feet beyond the Artist Glen road.

Flood-flushed area.--We leave the city of Wisconsin Dells and travel north a few miles across an area with sandstone at the surface--or thin loess on sandstone. Like much of the area shown on figure 8, this area was flushed free of Pleistocene sediment when water flowed southward from the main basin of Lake Wisconsin as it drained. We here enter Adams County, whose Pleistocene geology has been described by Clayton (1987)

PAUSE AT COLDWATER CANYON

67: If traffic permits, we will pause briefly on the bridge and look into the canyon. We won't get out. This and Witches Gulch can be visited on the North Dells boat tours. On a hot day, Coldwater Canyon can be refreshingly cool; notice the hemlock trees in the canyon on the left, which are considerably south of their normal range.

Continue north 1.8 mi.

STOP AT WITCHES GULCH

68: Like Coldwater Canyon, Witches Gulch is a dell that is as deep as 100 ft and in places only few feet wide. These sandstone gorges appear to be a series of interconnected potholes or meander loops.

These and similar gorges could not have been cut by meltwater coming directly from the glacier, as often suggested. Any time the glacier was far enough west to send meltwater into this area, it was far enough west to cover the east end of the Baraboo Hills and dam glacial Lake Wisconsin, which completely inundated the area of these gorges. And any time this area was exposed to subaerial erosion, the glacier margin had to have been far enough east that meltwater flowed southward along the glacier margin east of the Baraboo Hills, completely missing the Dells area. More likely, these gorges were cut by lake water rushing through the Dells area when Lake Wisconsin catastrophically drained.

Lake Wisconsin may have filled and emptied several times through the Pleistocene. Therefore some of the dells may have been cut by earlier floods, then filled with offshore sediment, and finally exhumed by the last flood.

Sandstone.--The walls of the dells are composed of sandstone of the Elk Mound Group (Late Cambrian); different geologists have considered it to be in the Mt. Simon, Eau Claire, or Wonewoc Formation of the Elk Mound Group. The sandstone is poorly cemented and consists largely of unfossiliferous medium to fine quartz sand. The larger grains have undergone considerable rounding. High-angle, trough-shaped, cross bedding several feet thick is

present in many areas. Dott and others (1986) have concluded, on the basis of sedimentary structures (including adhesion-ripple bedding), that much of this sand was deposited in a coastal eolian environment.

Plants.--Several species of plants living in the gorge more typically grow in cooler regions a few hundred miles to the north. Elsewhere, on sunnier outcrops than these, the Elk Mound sandstone is generally free of lichens but has blue-green algae (cyanobacteria) living within the rock, in the intergranular spaces a few millimetres below the surface. They appear as a green band on freshly broken surfaces. Cryptoendolithic algae such as this are better known in sandstone in the hot deserts of Middle East and North America and in the cold deserts of the Arctic and Antarctica (in the Beacon sandstone).

68: Continue north on River Road for 0.4 mi.

69: From River Road turn right onto Highway Q, cross Highway 13, and go 1.8 mi.

Delta face.--For the next 3 mi we will drive north along the base of the delta face of the outwash delta; the delta extends to the outermost moraine 4 mi to the east. For the first mile, we drive over sandstone that has been swept free of lake sediment, but for the next 2 mi we drive over intact offshore sediment. The delta face here (on our right) is 30 to 50 ft high, but its form has been obscured by subsequent erosion and trees.

Delta-face valleys.--Valleys a few hundred feet wide and up to 4 mi long have been cut back into the outwash plain (fig. 9). The mouths of the valleys, at the delta face, are at the level of the offshore plain west of the delta face, indicating that the valleys were cut after the lake drained, near the end of the Elderon Phase of the Wisconsin Glaciation, roughly 15 000 BP (fig. 11). A fan of postglacial fluvial sand has been spread out onto the lake plain beyond the mouths of the valleys. The lower parts of these valleys are near the water table and contain intermittent streams. The upper ends of the valleys, however, have no streams and appear to have never had any during the Holocene, indicating they were cut when the water table was higher, probably when permafrost was present, as explained at location 76.

70: From Highway Q turn left onto Highway K and go west 0.4 mi.

71: From Highway K turn right onto 11th Avenue and go north 0.7 mi.

72: Ice-wedge polygons --Networks of sharply-defined ice-wedge polygons are conspicuous here on air photos. The individual polygons are about 60 ft across here, and the wedge casts are a few feet wide. They have no topographic expression but show up as differences in soil or vegetation tone--typically darker during dry periods when the thicker soil filling the trench above the wedge holds more moisture than the adjacent thinner soil. The presence of a wedge cast below each dark soil stripe has been confirmed here and elsewhere using ground-penetrating radar. Similar polygons have been seen over most the state, most commonly on lacustrine or fluvial sand plains (fig. 9a). The polygons occur here on post-lacustrine fans, indicating that the fans were deposited and the valleys were cut into the delta before the permafrost melted around 13 000 BP. The valleys may have been cut as a result of permafrost, as explained at location 76.

73: From 11th Avenue turn right onto Gale Drive and go east 3.0 mi.

Outwash plain.--We then leave the offshore plain and turn east for 2 mi up one of the valleys cut into the outwash delta. At the head of the valley, we reach the nearly flat, uneroded surface of the outwash plain. For the next few miles we zigzag east and north across the outwash plain, looking at shore-ice collapse trenches.

The pine barrens here, with jack pine

and scrub oak, occurs on a dry infertile soil, which developed on outwash consisting largely of quartz sand. The sand was deposited by meltwater that had eroded soft Cambrian sandstone and till, 90% of which consists of sand in this area. The till is so sandy because it was derived largely from Cambrian sandstone, which underlies the till for 50 miles up the glacial flow line.

74: From Gale Drive turn left onto 8th Avenue and go north 1.6 mi.

75: From 8th Avenue turn right onto Fur Drive and go east 1.0 mi.

PAUSE AT SHORE-ICE COLLAPSE TRENCHES

76: These trenches are an obvious feature on air photos of the outwash plain (delta) along the southeast shore of Lake Wisconsin, a mile or two beyond the outermost moraine (fig. 9). They are typically a few feet deep and several tens of feet wide, and some continuous segments are a mile or more in length. They are straight or gently curved. They are oriented north-south, parallel to the shoreline and perpendicular to braided channels on the outwash plain. They intersect in Y junctions and never cross each other. Pleistocene sediment (mostly sand) is around 200 ft thick here. All are above the highest known level of Lake Wisconsin (Clayton and Attig, 1987).

What are they? We are not familiar with anything comparable elsewhere. If they had been ridges, our first guess would have been beaches. Instead, our first guess was collapse trenches formed by the melting of the core of small ice-cored moraines; however, this area was probably never glaciated because of a lack erratic pebbles on the adjacent sandstone hills (fig. 9a). They are not animal trails, because they continue to be trenches were they cross the small valleys cut unto the outwash plain--they don't turn to ridges, as trails should (Clayton, 1975). After eliminating everything else we could think of, we were left with the interpretation that they are collapse trenches formed by the melting of shore ice that had been buried in sand at the edge of a rapidly aggrading outwash delta.

Some of the trenches continue from the outwash plain down the sides and across the bottoms of the upper ends of the small valleys cut back from the delta face, as shown in figure 9a. Therefore the trenches formed after the valleys were cut. Because the valleys were cut after the lake drained but before the last of the permafrost melted, the trenches must have formed when the permafrost melted or later. But the shore ice must have been buried before the lake drained, and it couldn't have lasted through many summers unless there was permafrost to preserve it. Therefore the ice must have melted, forming the trenches, when the permafrost melted, about 13 000 BP. The trenches are sharply defined and well preserved, in contrast to older landforms that have undergone cryoturbation or solifluction and as a result are much more poorly preserved--for example, the braided channels on the outwash.

So we visualize Lake Wisconsin freezing over every winter during the Johnstown Phase. During the spring thaw, wind rammed the lake ice (and small icebergs) against the southeast shore. During a spring tunnel-channel flood, the outwash delta aggraded and was built farther out into the lake, burying the shore ice to a depth greater than the depth of seasonal soil thaw. This happened many times. Finally, around 13 000, all the buried masses of shore ice melted, causing the overlying outwash sand to collapse, producing trenches at the land surface. Are they annual?

77: From Fur Avenue turn left onto Highway B and go north 0.2 mi.

78: From Highway B turn right onto Highway I and go east 0.8 mi.

We are crossing the area shown on the air photo of figure 9b.

79: From Highway I turn right onto 6th Court and go south 1.3 mi.

Moraine.--When we turn to go south, the outermost moraine is a few hundred feet to the left. We continue south a few miles along the outwash plain.

80: We pass the mouth of a tunnel channel that has breached the moraine

81: From 6th Court turn right onto Gale Avenue and go west 0.7 mi.

82: From Gale Avenue turn left onto Highway B and go south ***2.5 mi.***

83: We pass the mouth of a tunnel channel that has breached the moraine.

Tunnel channels.--South of the Baraboo Hills few tunnel channels can be identified with much confidence. However, north of the Baraboo Hills, as far as Langlade County in northern Wisconsin, a hundred have been confidently identified. Most are 0.1 to 0.3 mi wide, but a few are 0.5 mi or more wide. They are less than 10 mi long. Their original depth is unknown because their bottoms are hidden by later sediment, but present depths are 15 to 100 ft. All have a slope of 0.001 to 0.020 or more up glacier, some ascending more than 150 ft from head to mouth. Their mouths are at the outer edge of the outer moraine (or outer two moraines in central Wisconsin); the gap in the moraine is the same width as the tunnel channel. At the mouth of each is the apex of an outwash fan; these fans coalesce to form the outwash plains (deltas).

Eskers are generally absent from the tunnel channel area, but they do occur in the drumlin zone to the east (fig. 10). The tunnel channels are an order of magnitude wider than the eskers, suggesting that the tunnel channels carried much more water. However, the eskers apparently formed when more meltwater was available, at a time of general glacial wasting. For these reasons the tunnel channels probably resulted from the sudden discharge of water stored in subglacial lakes (jokulhlaups).

84: From Highway B turn left onto Gillette Drive and go east 1.4 mi.

Cross the moraine.--We turn east (left) and cross the moraine, which here is a few tens of feet high and a third of a mile wide. Behind the moraine, we cross collapsed supraglacial till with hummocky topography for a mile.

85: From Gillette Drive turn right onto 5th Drive and go south 0.6 mi.

Lewiston basin.--From hummocky till, cross shore deposits of the Lewiston basin of Lake Wisconsin (fig. 6).

86: From 5th Drive turn right onto Highway P and go west 1.6.

Through a moraine gap.-- After turning west, we travel for a mile across wave-washed till in the Lewiston basin. Then we return to the outwash plain through another breach in the moraine at the mouth of another tunnel channel.

87: From Highway P turn left onto Highway B and go south 2.0 mi.

Tunnel channel.--We travel south on the outwash plain, with the moraine to our left. We pass another gap in the moraine at the mouth of a tunnel channel behind the large building, which originally was a convention center of the World Wide Church of God (Ambassador College) founded by Herbert W. Armstrong in Pasadena, California, at a time when his son Garner Ted Armstrong was well known to geologists for his radio programs debunking paleontology, stratigraphy, and geochronology.

Gravel pits.--Most gravel pits in this region, like the one on the left, are at the head of the outwash plain, generally within a few hundred feet of the outermost moraine, especially at the apex of a fan at the mouth of a tunnel channel, especially where the slope on the outwash surface is steepest. In most other places, the outwash is too sandy for most uses.

88: From Highway B turn right onto Highway 23 and go west and south 1.2 mi.

Terra incognita.--We enter Columbia County just east of the Dells and continue across the outwash plain. The Pleistocene geology of Columbia County has not yet been mapped in detail.

89: From Highway 23 continue straight ahead onto Highway O and go south 1.5 mi, cross Highway 127 and continue another 0.5 mi.

Moraine.--Cross the moraine a half mile south of location 89 and descend into the Lewiston basin.

90: From Highway O turn left onto Highway 16 and go east 11.8 mi.

Mounds.--Effigy mounds can be seen in the wayside park on the right a half mile after we turn east.

The sand counties.--Aldo Leopold's shack still stands next to the Wisconsin River a mile south of here. His *Sand County Almanac* was set here in the sand plains of central Wisconsin.

Lewiston basin.--For the next several miles we travel east through the Lewiston basin of Lake Wisconsin, with the North Range of the Baraboo Hills several miles to the south (fig. 1). Most of this area is flat lake plain, but we also cross a couple of Elderon moraines that project up through the lake sediment. These moraines were deposited in Lake Wisconsin.

Overview.--If there were such a thing as a type area for the Wisconsin Glaciation, we've probably driven through it today. Madison geologists such as T.C. Chamberlin and F.T. Thwaites did much to shape our nomenclature and our approaches to glacial geology. And the landscape we saw today probably had a considerable influence on their nomenclature and approaches, because the Baraboo Hills and the area we went through west of Madison were favored sites for class field trips.

During earlier glaciations, the part of the Green Bay Lobe just north and just south of today's field-trip area expanded farther west than during the Wisconsin Glaciation, but we know of no evidence for this in the field-trip area. Radiocarbon dates from the Wisconsin Glaciation are scarce in south-central Wisconsin, but the Green Bay Lobe probably began to expand out of the Green Bay lowland roughly 25 000 to 20 000 B.P. The Johnstown and Milton Phases probably occurred around 15 000 or 14 000 B.P. A tundra climate with permafrost persisted in front of the glacier until about 13 000 B.P.

The presence of melt-out and lodgement till and esker bodies in the outermost moraine suggest that at least the outer edge of the glacier snout was not frozen solid to its bed while the moraine formed. The presence of tunnel channels and the lack of drumlins and eskers in the hummocky zone suggests that the glacier was frozen to its bed in a zone behind the snout; however, Colgan (1996, p. 83-90) is skeptical that there was any frozen-bed zone. Behind that, in the drumlin zone, the glacier was sliding over an unfrozen bed. The frozen-bed zone seems to have largely disappeared towards the end of the Milton Phase.

Colgan and Mickelson's post-meeting field trip will review the glaciology of the Green Bay Lobe, with emphasis on the drumlin field northeast of Madison.

91: From Highway 16 turn right onto Highway 39 and go south 5.2 mi.

The portage.--Cross Wisconsin River just west of the city of Portage. On the east side of Portage was the voyageurs' portage from the St. Lawrence drainage to the Mississippi drainage, on the fur-trade canoe route from Montreal, through the Great Lakes, up the Fox River, and down the Wisconsin River. The drainage divide at the portage is a marsh 2 mi wide and less than 5 ft above the levels of the Wisconsin and Fox Rivers. The south-flowing Wisconsin River is only a mile from the north-flowing Fox

River. It seems mere happenstance that Wisconsin River water now flows to the Gulf of Mexico rather than to the Gulf of St. Lawrence.

The portage was the site of an early outlet of glacial Lake Oshkosh in the Green Bay lowland northeast of here.

92. From Highway 39 turn left onto Highway 90-94 and go south 24 mi.

Alloa outlet.--We join Highway 90-94 at the east end of the Baraboo Hills, where Lake Wisconsin was first dammed by the Green Bay Lobe and where the lake finally drained through its Alloa outlet (fig. 1 and 6). The west bank of the spillway was the quartzite slope just west of the interchange, and the east bank was the edge of the glacier near the interchange or just east of it.

Alloa delta.--About 2 mi south of the interchange is a small lake on the left. A half mile to the right is a gravel pit in the delta into Lake Merrimac at the south end of the Alloa outlet (fig. 6). This gravel pit was first described by J Harlan Bretz (1950), who is known for his 1920s hypothesis of a catastrophic Spokane Flood. In the pit, he observed "foresets of extraordinary open-work coarse gravel" that dip southward and are 12 m or more high. He noted that the gravel contains boulders as large as 1.5 m. He recognized this "torrential delta" as the result of drainage of Lake Wisconsin into Lake Merrimac, but he concluded that "no debacle occurred during this failure of the ice barrier at the east end of the [Baraboo] Ranges."

Drumlin zone.--Most of today we have been in or west of a 10-mi-wide zone of hummocky collapsed supraglacial debris. Behind the hummocky zone is a drumlin zone several tens of miles wide with subglacial till at or near the surface, which we travel through the rest of the trip.

Southward through Columbia County, the preglacial topography dominates the landscape. Drumlins and small moraines are present but not obvious in most places along our route. In Dane County, the topography has been more smoothed and streamlined than in Columbia County. An example of a drumlin cut by the highway can be seen just beyond milepost 129.

Drumlin form.--Examples of drumlins can be seen in the Dane County report (Clayton and Attig, 1997, fig. 24 to 29), which you have. The drumlins in this area are the result of subglacial streamlining, involving glacial erosion, deposition, and squeezing, in various combinations.

The drumlins of Dane County range from stubby to spindly. The stubby ones are interpreted by Clayton and Attig to be unfinished drumlins that are pre-existing hills that have been only partially streamlined. The spindly ones are interpreted (by Clayton and Attig) to be more-finished equilibrium forms that owe little to the pre-existing topography.

Mickelson and Colgan (post-meeting field trip) consider these to be two separate kinds of landforms. They call the stubbly ones drumlins and the spindly ones flutes.

Small moraines.--Hundreds of small moraines are present throughout Dane County, for example, in the first mile after we cross the Dane County boundary, on either side of milepost 124. A couple dozen are present here, mostly east of the highway. They are north-south ridges with their crests only 100 to 200 ft apart. They are only a few feet high and can generally be recognized from the air but not from the ground (fig. 12 and 13 and plate 1 of the Dane County bulletin).

Eskers.--Small eskers are scattered through the drumlin zone. Most are simple meandering ridges no more than about 15 ft high, 50 ft wide, and 1 mi long. The gravel pit on the right just after milepost 126 is in a complex of intertwined eskers illustrated in figure 37 of the Dane County report.

93: From Highway 90-94 turn right onto Highway 51 at exit 132 and go south 4.3 mi.

Glacial Lake Yahara.--The airport, on the right, is on the offshore plain of glacial Lake Yahara.

94: From Highway 51 turn right onto Highway 151 and go southwest 4 mi to Capitol Square.

MADISON

Much of east Madison is built on the flat, once marshy, offshore plain of Lake Yahara. Some drumlins project through the lake sediment. They are parallel to our line of travel.

Here are some suggested walking tours if you have spare time while in Madison (fig. 12).

Capitol Square.--There are museums near the west corner of the square, and the civic center has an art museum, a couple blocks west of the square, on State Street. The capitol is worth a visit; take the guided tour to see the newly restored chambers, and take an elevator or the stairs to the top floor for access to the outside balcony at the base of the dome.

The new Frank Lloyd Wright convention center (Monona Terrace) is two blocks southeast of the square at the end of Martin Luther King Jr. Boulevard (M in fig. 12). It was originally designed by Wright in 1938 as a civic center and then redesigned several times by Wright and his disciples. After decades squabbling, it will finally be dedicated in July.

A short hike to a drumlin.--Go four blocks northwest from the Concourse Hotel up Wisconsin Avenue to its end. The drumlin is a half mile long and trends southwest, angled a bit more to the west than Langdon Street (L in fig. 12). F.T. Thwaites was born in a house in the 3rd block of Langdon Street, at the southwest end of the drumlin. Thorton Wilder (*Our Town*) was also born on Langdon Street--100 yr ago last week.

Capitol hill is sometimes considered a drumlin, but it hasn't undergone much streamlining.

A longer hike, with local color and restaurants --It is a mile from the west corner of Capitol Square down State Street to the center of the University.

A longer jog.--It is 0.8 mi from the Concourse Hotel (C in fig. 12) to Memorial Union (U in fig. 12), near the northeast corner of campus. Beer and food are available at the Rathskeller in the Union, and you can take them out onto the terrace if it's a nice day. From the terrace (on the north side of the Union) follow Lakeshore Path westward. It is 1.2 mi from the Union to a bridge over a small creek where buildings give way to playing fields. (It's an additional 1½ mi along the shore to the end of Picnic Point, shown at the northwestern corner of fig. 12). If you return through the middle of campus, you might use Observatory Drive. Observatory Hill (O in fig. 12) is a drumlin trending a little south of west; look for the Chamberlin Erratic, named for T.C. Chamberlin. Or take Linden Drive; excellent ice cream is sold in Babcock Hall (M-F, 9:30-5:30; Sat, 10-1:30; B in fig. 12).

Food and drink --There are 600 restaurants in Madison (many are ethnic), 100 of them within walking distance of the capitol. Walk down State Street and you'll find something you like. Or see the yellow pages in the phone book (p. 742-761) or the restaurant guide in your registration envelope.

REFERENCES

Alden, W. C., 1918, The Quaternary geology of southeastern Wisconsin: U. S. Geological Survey Professional Paper 106, 356 p.

Attig, J. W., 1993, Pleistocene geology of Taylor County: Wisconsin

Geological and Natural History Survey Bulletin 90, 25 p.

Attig, J. W., and Clayton, Lee, 1992, Conditions beyond the ice margin during the last glacial maximum: Geological Society of America Abstracts with Programs, v. 24, p. 3.

Attig, J. W., Clayton, Lee, Lange, K. I., and Maher, L. J., 1990, The Ice Age geology of Devils Lake State Park: Wisconsin Geological and Natural History Survey Educational Series 35, 28 p.

Bretz, J Harlan, 1950, Glacial Lake Merrimac: Illinois Academy of Science Transactions, v. 43, p. 132-136.

Clayton, Lee, 1975, Buffalo trails and their geologic significance: Geology, v. 3, p. 498-500.

Clayton, Lee, 1987, Pleistocene geology of Adams County, Wisconsin: Wisconsin Geological and Natural History Survey Information Circular 59, 14 p.

Clayton, Lee, and Attig, J. W., 1987, Lake-ice collapse trenches in Wisconsin, U.S.A.: Earth Surface Processes and Landforms, v. 12, p. 167-172

Clayton, Lee, and Attig, J. W., 1989, Glacial Lake Wisconsin: Geological Society of America Memoir 173, 80 p.

Clayton, Lee, and Attig, J. W., 1990, Geology of Sauk County, Wisconsin: Wisconsin Geological and Natural History Survey Information Circular 67, 68 p

Clayton, Lee, and Attig, J. W., 1993, Exhumed early Paleozoic landforms on the Baraboo Hills, Wisconsin: Wisconsin Academy of Sciences, Arts and Letters Transactions, v. 81, p. 31-38.

Clayton, Lee, and Attig, J. W., 1997, Pleistocene geology of Dane County: Wisconsin Geological and Natural History Survey Bulletin 95, xx p.

Clayton, Lee, Attig, J. W., Mickelson, D. M., and Johnson, Mark, 1991 [1992], Glaciation of Wisconsin: Wisconsin Geological and Natural History Survey Educational Series 36, 4 p.

Colgan, P. M., 1996, The Green Bay and Des Moines Lobes of the Laurentide Ice Sheet: evidence for stable and unstable glacier dynamics, 18,000 to 12,000 B.P.: Madison, University of Wisconsin doctoral dissertation, 293 p.

Dalziel, I.W.D., and Dott, R.H., Jr., 1970, Geology of the Baraboo District, Wisconsin: Wisconsin Geological and Natural History Survey Information Circular 14, p. 164 p

Dott, R. H., Jr., Byers, C. W., Stenzel, S. R., and Winfree, K. E., 1986, Aeolian to marine transition in Cambro-Ordovician cratonic sheet sandstones of the northern Mississippi valley, U.S.A.: Sedimentology, v. 33, p. 345-367

Lundqvist, Jan, Clayton, Lee, and Mickelson, D. M., 1993, Deposition of the late Wisconsin Johnstown moraine, south-central Wisconsin: Quaternary International, v. 18, p. 53-59.

Mickelson, D. M., 1983, A guide to the glacial landscape of Dane County, Wisconsin: Wisconsin Geological and Natural History Survey Field Trip Guide Book 6, 53 p.

Mickelson, D. M., 1997, Landscapes of Dane County: Wisconsin Geological and Natural History Survey Educational Series 42.

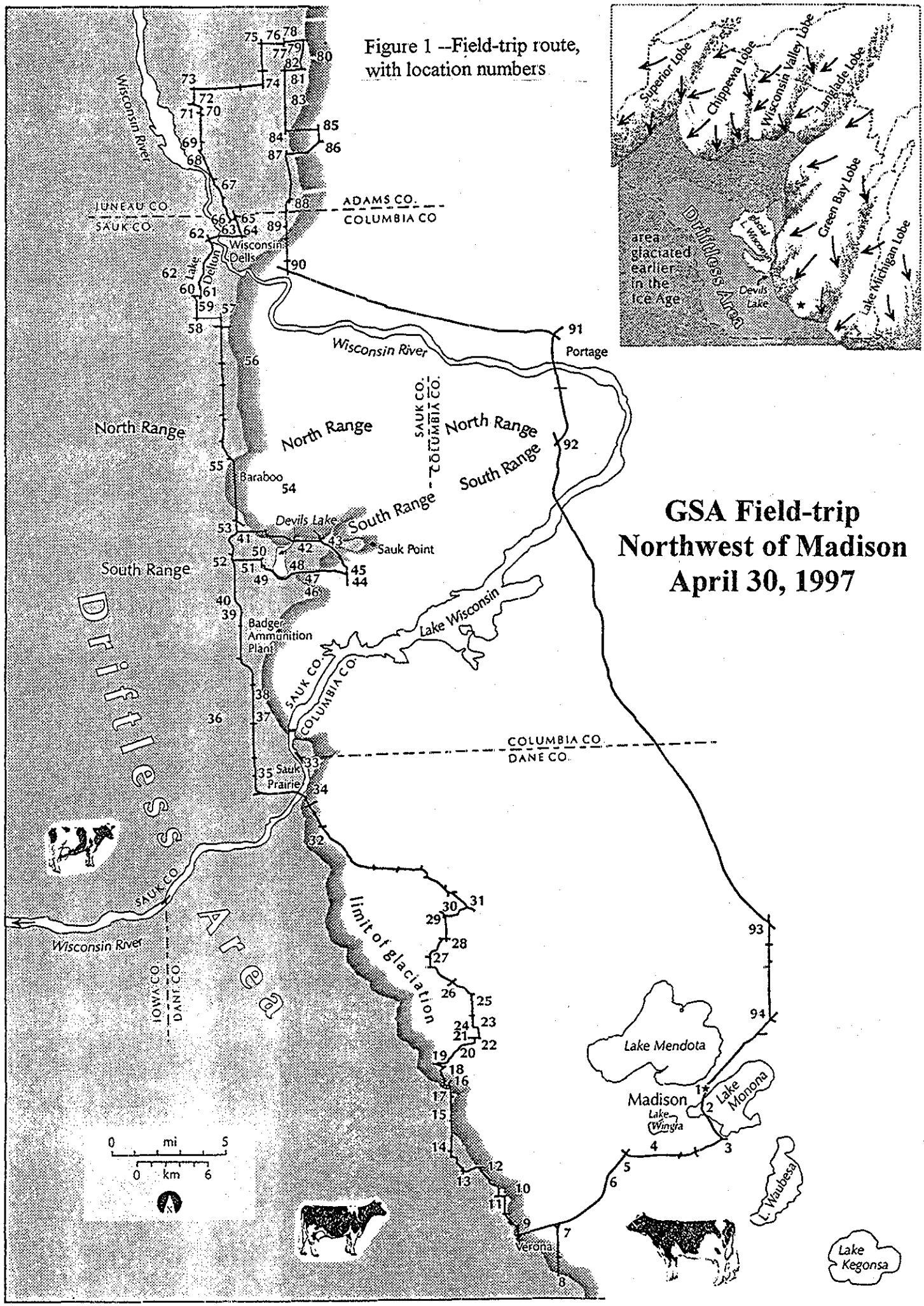
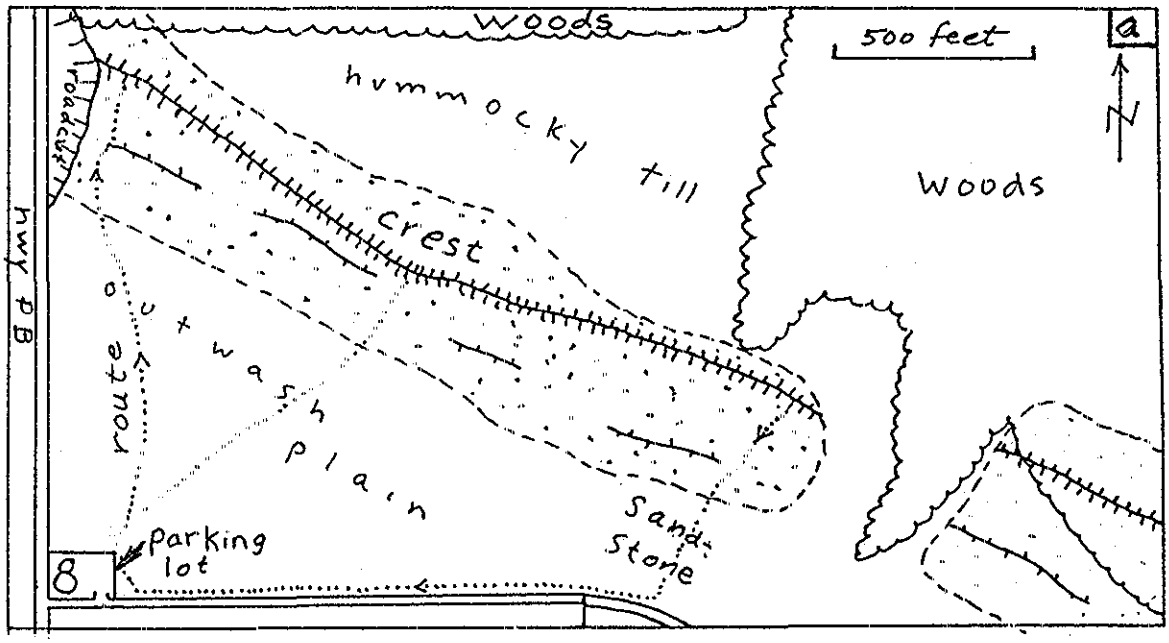


Figure 1 --Field-trip route, with location numbers

GSA Field-trip Northwest of Madison April 30, 1997



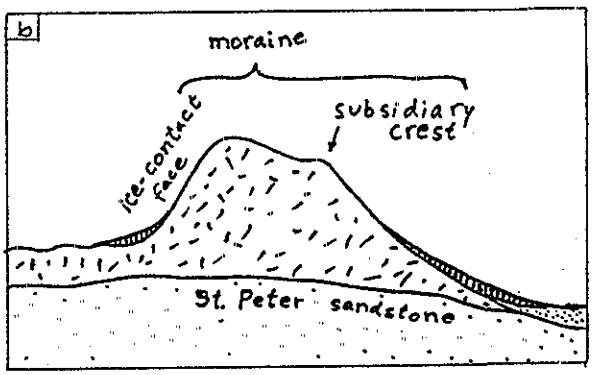


Figure 2.--Prairie Moraine County Parkway (first stop).

a: The outermost Johnstown moraine (dotted area). Hachured lines are the main crest (heavy line) and the subsidiary crest (light line). Dotted lines show suggested routes

b: Approximate profile of the moraine, with hummocky collapse topography behind the moraine, postglacial debris-flow and slope-wash apron on either side (vertical-line pattern), and an outwash plain in front

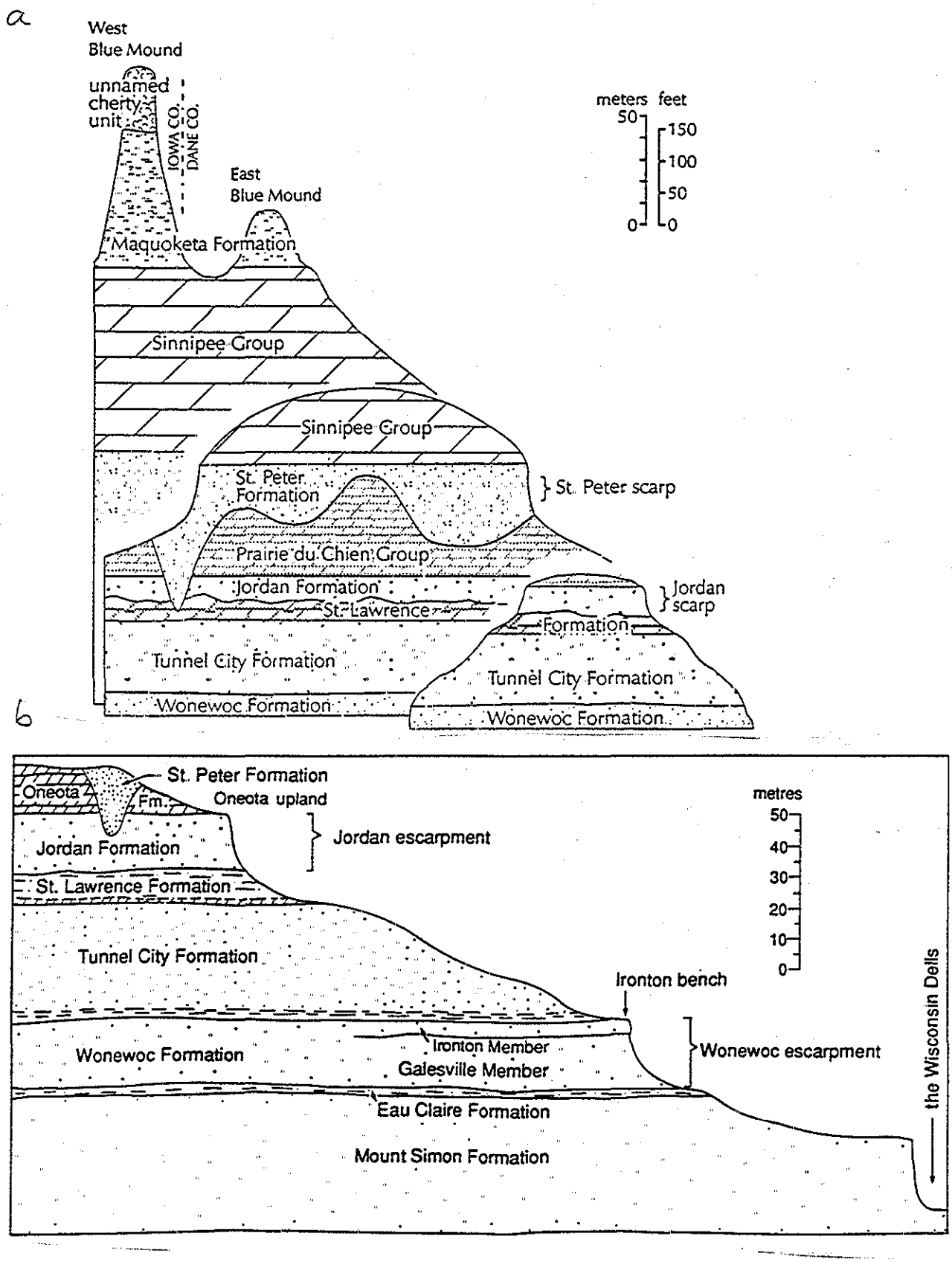


Figure 3 --a: Schematic topographic profile through the Driftless Area of western Dane County; back panel shows Blue Mounds; middle panel shows a Sinnipee plateau; front panel shows a Prairie du Chien (Oneota) plateau. b: Profile through the Driftless Area of northern Sauk County Vertical dimension is highly exaggerated. From Clayton and Attig (1990 and 1997).

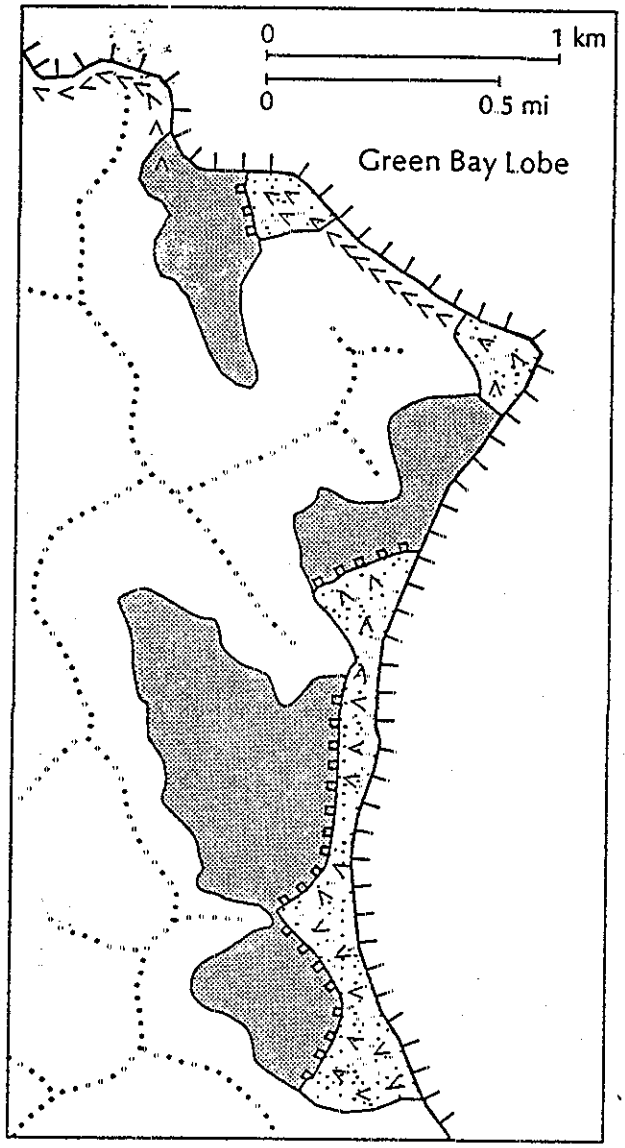


Figure 4.--The Shoveler Lakes during the height of the Johnstown Phase, when the Green Bay Lobe was at its maximum extent, with outwash plains and delta slipfaces (line with square hachures). The arrowheads indicate the direction of flow of meltwater rivers. The dotted lines in the Driftless Area are drainage divides. The numbers correspond to road-log locations. From Clayton and Attig (1997)

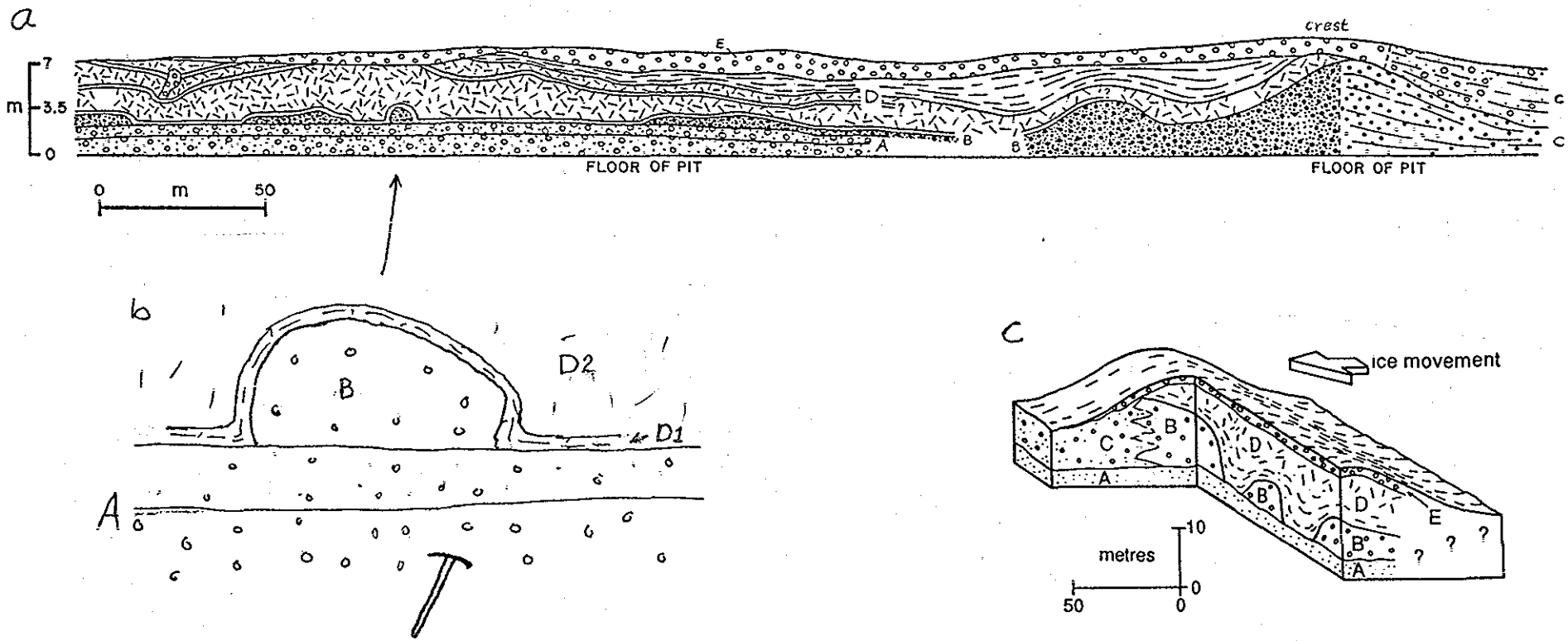


Figure 5.--Sections through outermost Johnstown moraine.

(a) The Lycon pit in 1983; most of the section is parallel to and just behind the crest of the moraine, but the right end curves and crosses the crest at right angles (Lundqvist, Clayton, and Mickelson, 1993, fig. 5); the glacier was moving toward the observer except for the right end where it was moving to the right. A: two units of pre-existing meltwater-stream gravel. B: five separate esker (?) bodies. C: two units of outwash gravel. D: stratified till, with the thicker, more uniform layers shown with a pattern of haphazard dashes. E: supraglacial (?) gravel.

(b) The middle (third) esker (?) body (B), draped with a few inches of thinly stratified till (D1), which is overlain by thickly stratified till (D2).

(c) Block diagram showing a generalized view of the internal structure of the outermost Johnstown moraine in Sauk County and northwestern Dane County. A: pre-existing meltwater-stream sand and gravel. B: poorly-sorted sand and gravel, probably deposited in esker tunnels. C: sand and gravel deposited by meltwater-streams in front of moraine while moraine was forming. D: stratified till. E: poorly-sorted gravelly sediment that is probably supraglacial debris or postglacial solifluction debris. From Clayton and Attig (1990, fig. 17).

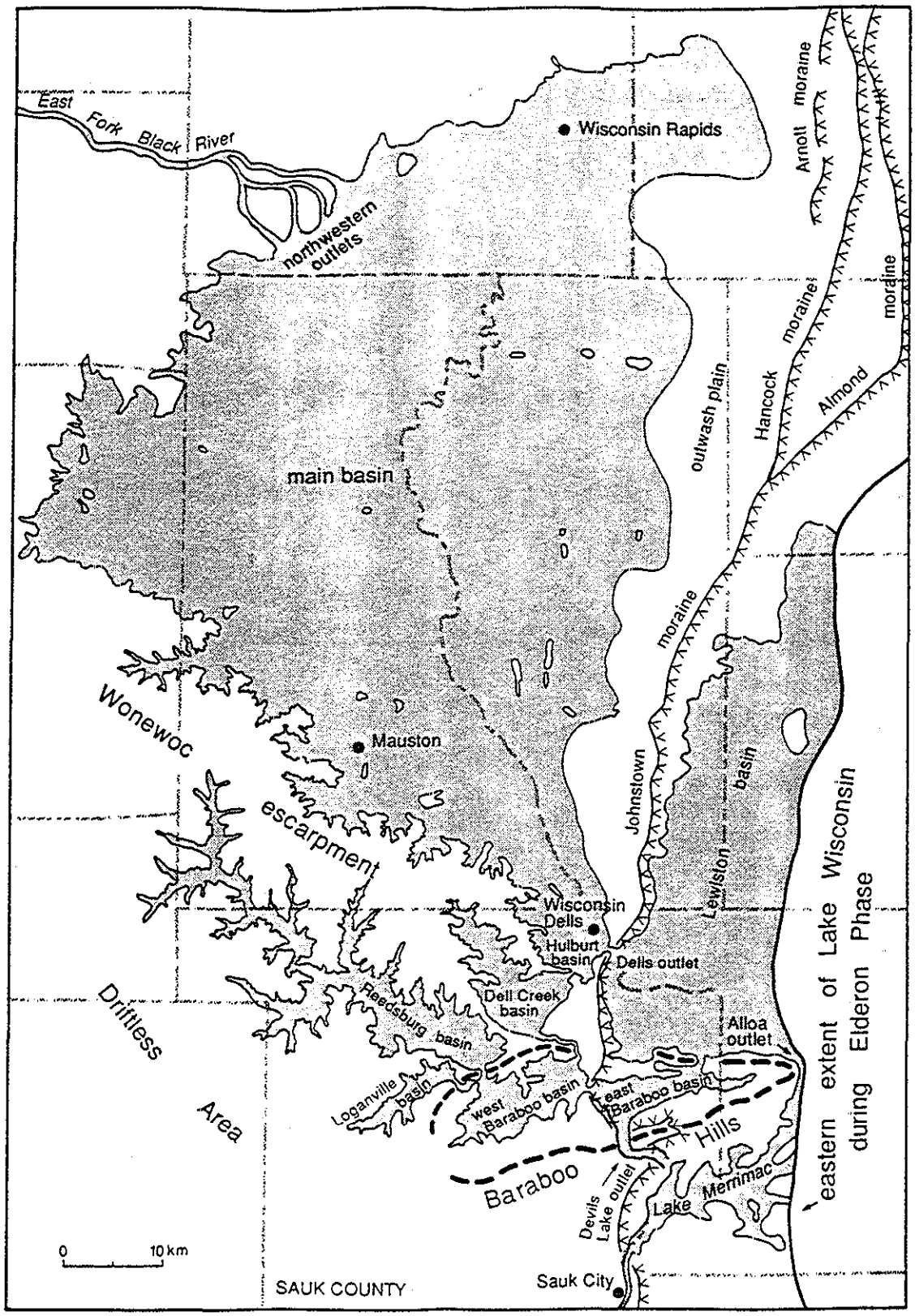


Figure 6.--Map of central Wisconsin showing the main features of Lake Wisconsin. The map shows the approximate maximum extent of the lake during the last part of the Wisconsin Glaciation, but it never occupied this entire area at any one time. The heavy dashed line is the crest of the Baraboo Hills. From Clayton and Attig (1989)

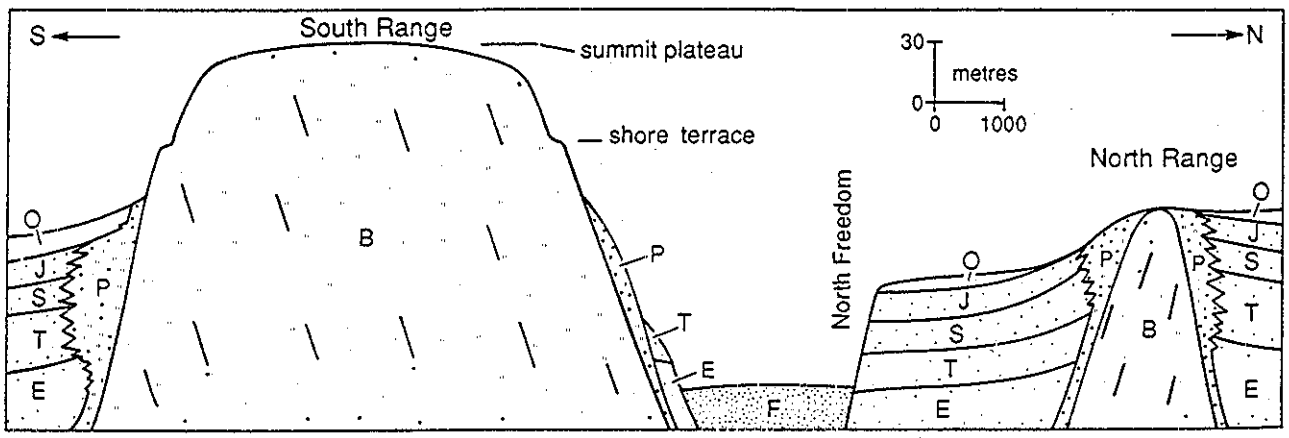


Figure 7 --North-south cross section through the village of North Freedom, showing the relationship between the Paleozoic formations and the North and South Ranges of the Baraboo Hills. B: Baraboo Formation. E: Elk Mound Group. T: Tunnel City Formation. S: St. Lawrence Formation. J: Jordan Formation. O: Oneota Formation of the Prairie du Chien Group. P: Parfreys Glen Formation (Paleozoic rock that resembles the Baraboo quartzite and can't be assigned to one of the regional stratigraphic units). F: Big Flats Formation (Pleistocene). From Clayton and Attig (1990).

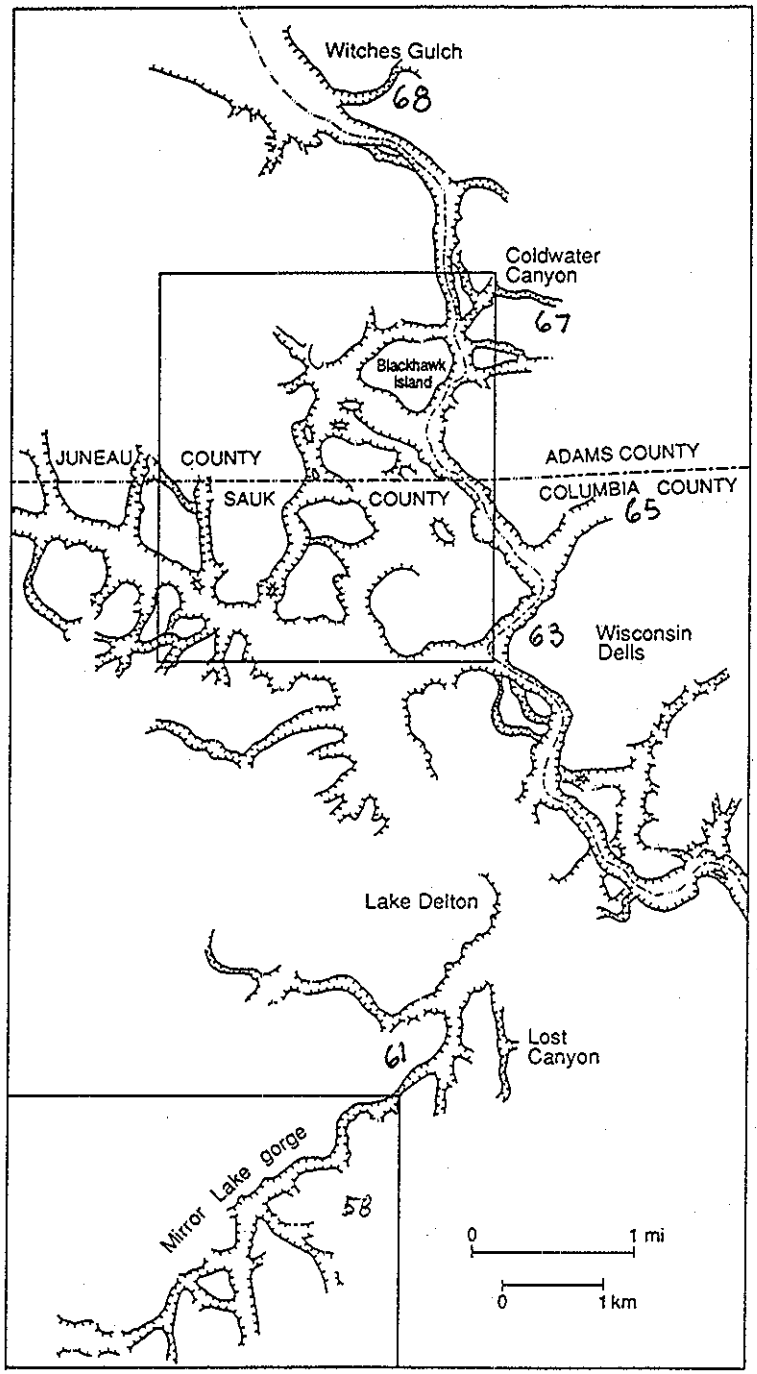


Figure 8.--The larger gorges around the city of Wisconsin Dells; many smaller ones are not shown. The Wisconsin River gorge is marked by a dot-dash line (county boundaries). The numbers correspond to field-trip locations. From Clayton and Attig (1990)

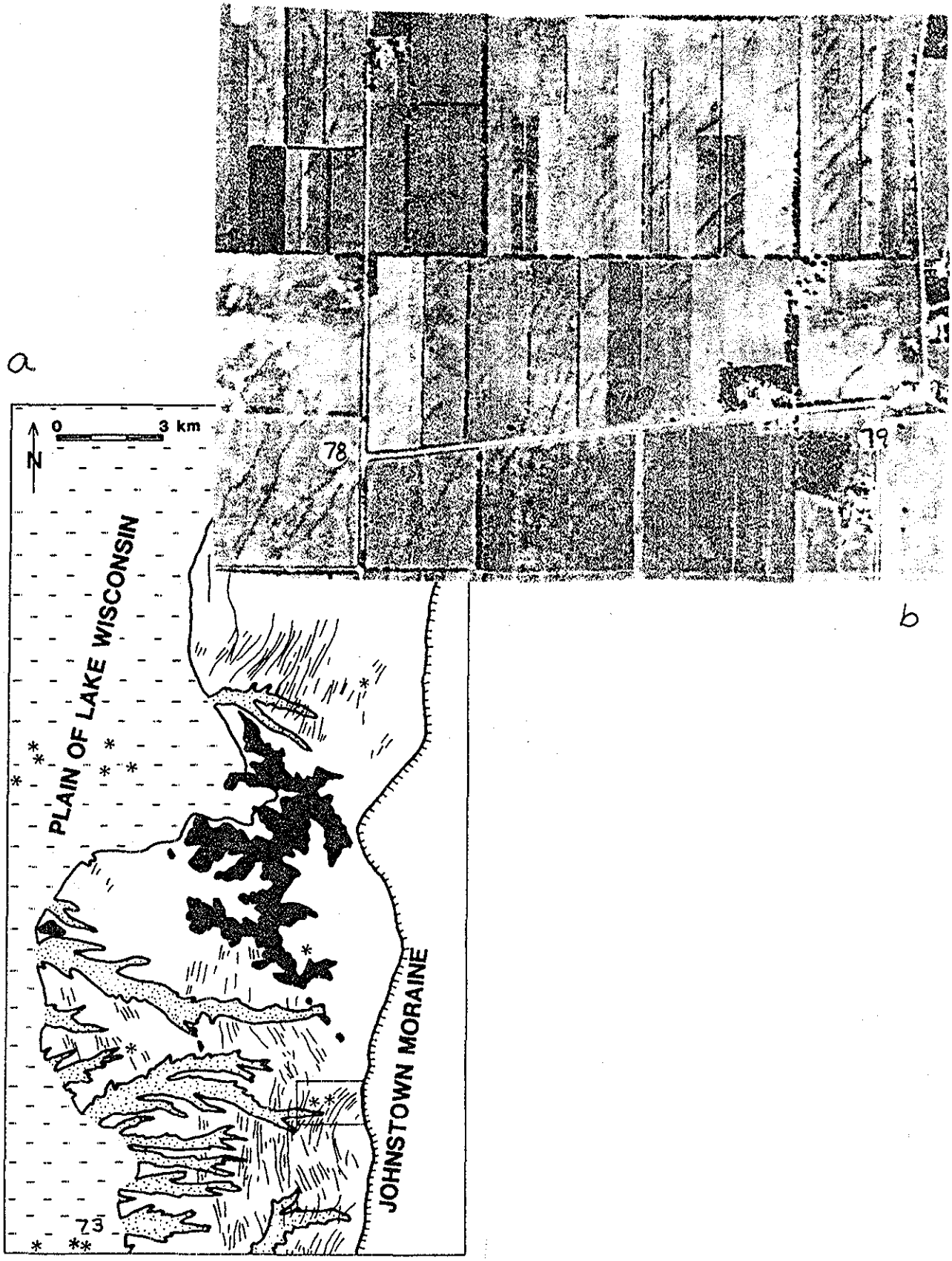


Figure 9 --a: Shore-ice collapse trenches (lines), hills of Cambrian sandstone (black), lake plain (dashed), outwash plain (white, west of moraine), small valleys cut into the outwash plain (dotted), the outermost Johnstown moraine (hachured line), and areas of ice-wedge polygons (stars) along the southeast side of Lake Wisconsin in southern Adams County (fig. 6)

b: Air photo of shore-ice collapse trenches; the area shown is the rectangle in the lower-right part of figure 9a. The numbers are road log locations From Clayton and Attig (1987)

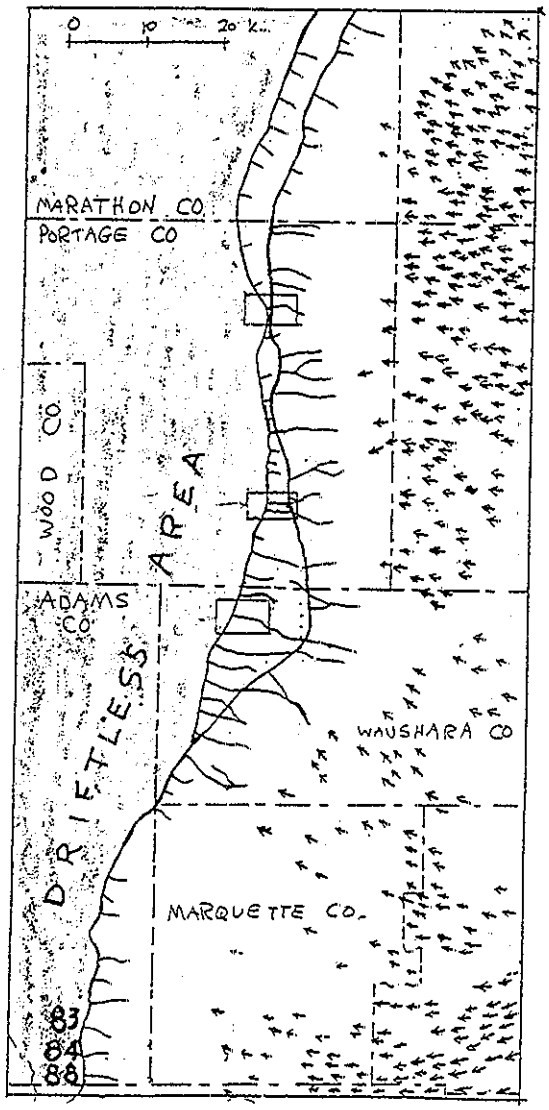


Figure 10 --Tunnel channels in the hummocky-till zone of central Wisconsin, between the drumlin zone (arrows) and the western extent of the ice during the Hancock and Almond (=Johnstown?) Phases (solid north-south lines) The numbers correspond to road-log locations (Work in progress)

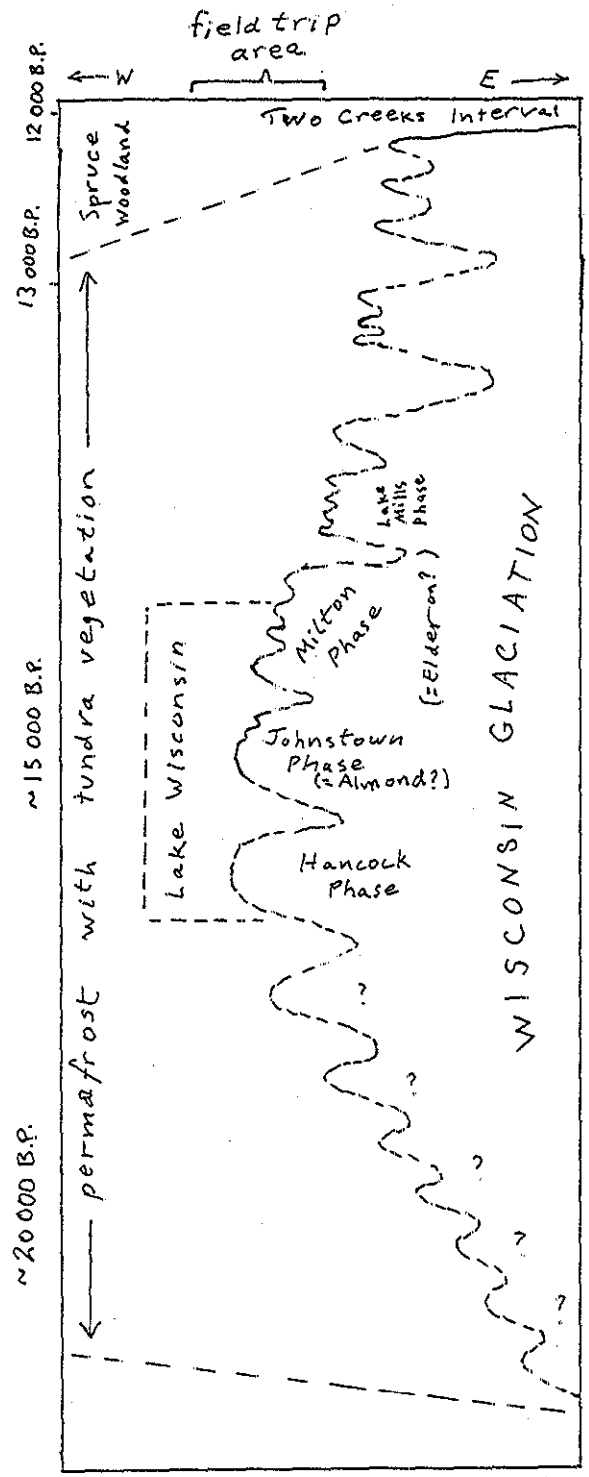
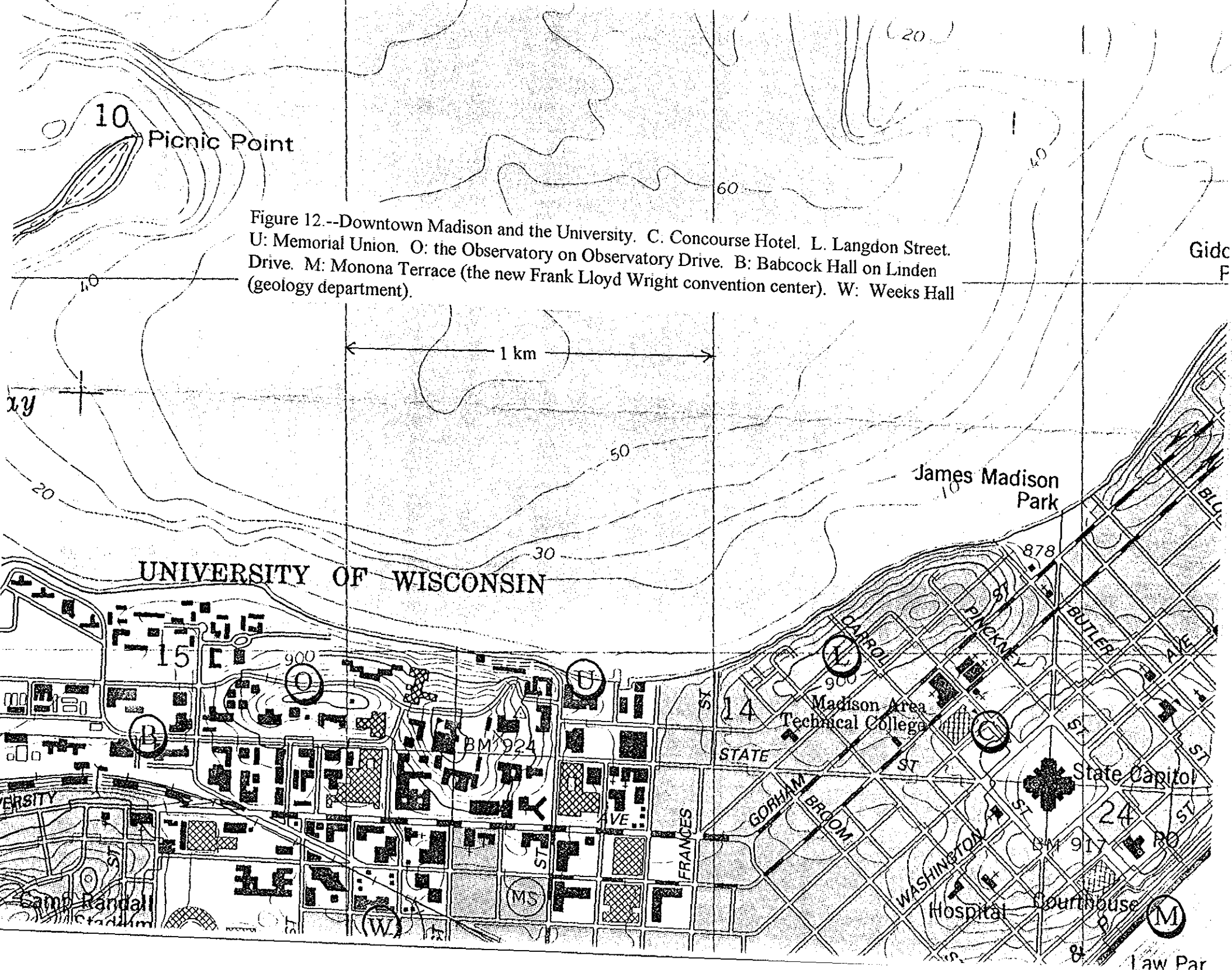


Figure 11 --Time-distance diagram for field-trip area


10
Picnic Point
60
40
20
Figure 12.--Downtown Madison and the University. C. Concourse Hotel. L. Langdon Street. U: Memorial Union. O: the Observatory on Observatory Drive. B: Babcock Hall on Linden Drive. M: Monona Terrace (the new Frank Lloyd Wright convention center). W: Weeks Hall (geology department).
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UNIVERSITY OF WISCONSIN
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Madison Area Technical College
STATE ST
GORHAM
BROOM
FRANCES ST
WASHINGTON AVE
State Capitol
24
BM 917
RO
Camp Randall Stadium
MS
W
Hospital
Courthouse
M
Law Par