ɿuide to the Geology of the Mississippi Embayment Area, Johnson and Pulaski Counties, Illinois

Field Trip Guidebook 1997D
November 1, 1997

Department of Natural Resources
ILLINOIS STATE GEOLOGICAL SURVEY

Guide to the Geology of the Mississippi Embayment Area, Johnson and Pulaski Counties, Illinois

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Cover photo State Champion Bald Cypress located at the Lower Cache River Access Area on the canoe trails. *(photo by Jim Waycuilis).*

Geological Science Field Trip The Geoscience Education and Outreach unit of the Illinois State Geological Survey (ISGS) conducts four free tours each year to acquaint the public with the rocks, mineral resources, and landscapes of various regions of the state and the geological processes that have formed them. Each trip is an all-day excursion through one or more Illinois counties. Frequent stops are made to explore interesting phenomena, explain the processes that shape our environment, discuss principles of earth science, and collect rocks and fossils. People of all ages and interests are welcome. The trips are especially helpful to teachers preparing earth science units. Grade school students are welcome, but each must be accompanied by a parent or guardian. High school science classes should be supervised by at least one adult for each ten students.

A list of guidebooks of earlier field trips, useful for planning class tours and private outings, can be obtained by contacting the Geoscience Education and Outreach unit, Illinois State Geological Survey, Natural Resources Building, 615 East Peabody Drive, Champaign, IL 61820-6964. Telephone: (217) 244-2427 or 333-4747.

Five U.S. Geological Survey 7.5-Minute Quadrangle maps (Cypress, Dongola, Karnak, Olmstead, and Mt. Pulaski) cover this field trip area.

ILLINOIS DEPARTMENT OF NATURAL RESOURCES

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CONTENTS

Era		Period or System and Thickness	Epoch	Age (years ago)	General Types of Rocks
CENOZOIC "Recent Life"	Age of Mammals	Quaternary 0-500'	Holocene	10,000	Recent—alluvium in river valleys
			Pleistocene Glacial Age	1.6 m.	Glacial till, glacial outwash, gravel, sand, silt, lake deposits of clay and silt, loess and sand dunes; covers nearly all of state except northwest corner and southern tip
		Tertiary 0-500'	Pliocene	5.3 m. – 36.6 m.	Chert gravel; present in northern, southern, and western Illinois
			Eocene	57.8 m.	Mostly micaceous sand with some silt and clay; present only in southern Illinois
			Paleocene	66.4 m.	Mostly clay, little sand; present only in southern Illinois
MESOZOIC "Middle Life"	Age of Reptiles	Cretaceous 0-300'		144 m. – 286 m.	Mostly sand, some thin beds of clay and, locally, gravel; present only in southern Illinois
PALEOZOIC "Ancient Life"	Age of Amphibians and Early Plants	Pennsylvanian 0-3,000' ("Coal Measures")		320 m.	Largely shale and sandstone with beds of coal, limestone, and clay
		Mississippian 0-3,500'		360 m.	Black and gray shale at base; middle zone of thick limestone that grades to siltstone, chert, and shale; upper zone of interbedded sandstone, shale, and limestone
	Age of Fishes	Devonian 0-1,500'		408 m.	Thick limestone, minor sandstones and shales; largely chert and cherty limestone in southern Illinois; black shale at top
	Age of Invertebrates	Silurian 0-1,000'		438 m.	Principally dolomite and limestone
		Ordovician 500-2,000'		505 m.	Largely dolomite and limestone but contains sandstone, shale, and siltstone formations
		Cambrian 1,500-3,000'		570 m.	Chiefly sandstones with some dolomite and shale; exposed only in small areas in north-central Illinois
		Precambrian			Igneous and metamorphic rocks; known in Illinois only from deep wells

Generalized geologic column showing succession of rocks in Illinois.

MISSISSIPPI EMBAYMENT AREA

The Mississippi Embayment Area geological science field trip will acquaint you with the *geology**, landscape, and mineral resources for part of Johnson and Pulaski Counties, Illinois. The starting point for the field trip is Shawnee Community College, which is located approximately 7 miles east of the Ullin exit at mile marker 18 of Interstate 57. Ullin is approximately 360 miles south of Chicago, 210 miles southeast of Springfield, 135 miles southeast of East St. Louis, and 18 miles north of Cairo.

GEOLOGIC FRAMEWORK

Precambrian Era Through several billion years of geologic time, the area encompassing Johnson and Pulaski Counties has undergone many changes (see the rock succession column, facing page). The oldest rocks beneath the field trip area belong to the ancient Precambrian *basement complex*. We know relatively little about these rocks from direct observations because they are not exposed at the surface anywhere in Illinois. Only about 35 drill holes have reached deep enough for geologists to collect samples from the Precambrian rocks of Illinois. From these samples, however, we know that these ancient rocks consist mostly of granitic and rhyolitic *igneous*, and possibly *metamorphic*, crystalline rocks formed about 1.5 to 1 billion years ago. From about 1 billion to about 0.6 billion years ago, these Precambrian rocks were exposed at the Earth's surface. During this long period, the rocks were deeply weathered and eroded, and formed a landscape that was probably quite similar to that of the present Missouri Ozarks. We have no rock record in Illinois for the long interval of *weathering* and erosion that lasted from the time the Precambrian rocks were formed until the first Cambrian-age *sediments* accumulated, but that interval is almost as long as the time from the beginning of the Cambrian Period to the present.

Because geologists cannot see the Precambrian basement rocks in Illinois except as cuttings and cores from boreholes, they must use other various techniques, such as measurements of Earth's gravitational and magnetic fields, and seismic exploration, to map out the regional characteristics of the basement complex. The evidence indicates that in southernmost Illinois, near what is now the historic Kentucky–Illinois Fluorspar Mining District, *rift* valleys like those in east Africa formed as the movements of crustal plates (plate *tectonics*) began to rip apart the Precambrian North American continent. These rift valleys in the midcontinent region are referred to as the Rough Creek Graben and the Reelfoot Rift (fig. 1).

Paleozoic Era After the beginning of the Paleozoic Era, about 520 million years ago in the late Cambrian Period, the rifting stopped and the hilly Precambrian landscape began to sink slowly on a broad regional scale, allowing the invasion of a shallow sea from the south and southwest. During the 280 million years of the Paleozoic Era, the area that is now called the Illinois Basin continued to accumulate sediments deposited in the shallow seas that repeatedly covered it. The region continued to sink until at least 15,000 feet of sedimentary strata were deposited. At various times during this era, the seas withdrew and the deposits were weathered and eroded. As a result, there are some gaps in the sedimentary record in Illinois.

In the field trip area, *bedrock* strata range in age from more than 520 million years (the Cambrian *Period*) to approximately 1.6 million years old (the Quaternary Period). Figure 2 shows the succession of Paleozoic rock strata a drill bit would penetrate in this area if the rock record were complete and all the *formations* were present.

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*Words in italics are defined in the glossary at the back of the guidebook. Also please note: although all present localities have only recently appeared within the geologic time frame, we use the present names of places and geologic features because they provide clear reference points for describing the ancient landscape.

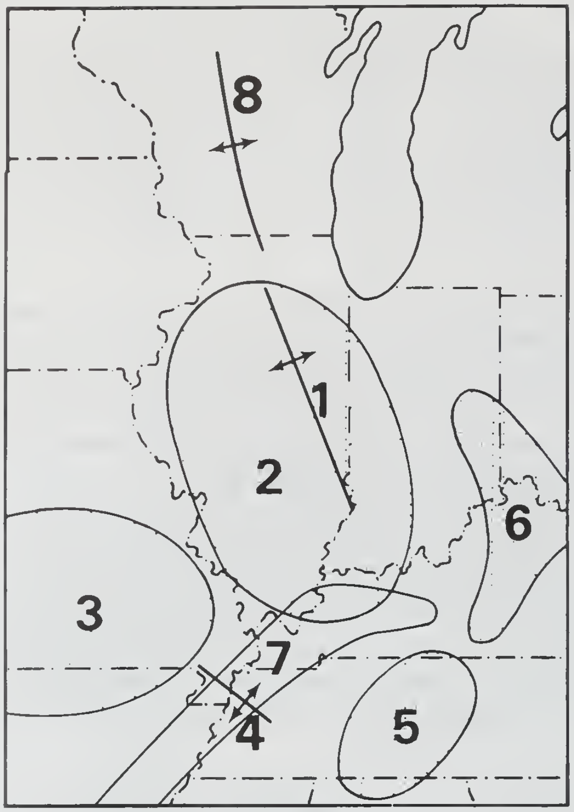


Figure 1 Location of some of the major structures in the Illinois region. (1) La Salle Anticlinorium, (2) Illinois Basin, (3) Ozark Dome, (4) Pascola Arch, (5) Nashville Dome, (6) Cincinnati Arch, (7) Rough Creek Graben-Reelfoot Rift, and (8) Wisconsin Arch.

The elevation of the top of the Precambrian basement rocks within the field trip area ranges from 11,000 feet below sea level in central Pulaski County to 12,000 feet below sea level in northern Johnson County. The thickness of the Paleozoic sedimentary strata deposited on top of the Precambrian basement ranges from about 11,300 feet in southern Pulaski County near Olmstead to about 12,600 feet in central Johnson County near Vienna.

STRUCTURAL AND DEPOSITIONAL HISTORY

As noted previously, the Rough Creek Graben and the Reelfoot Rift (figs. 1 and 3) were formed by tectonic activity that began in the latter part of the Precambrian Era and continued until the Late Cambrian. Toward the end of the Cambrian, rifting ended and the whole region began to subside, allowing shallow seas to cover the land.

Paleozoic Era From the Late Cambrian to the end of the Paleozoic Era, sediments continued to accumulate in the shallow seas that repeatedly covered Illinois and adjacent states. These inland seas connected with the open ocean to the south during much of the Paleozoic, and the area that is now southern Illinois was like an embayment. The southern part of Illinois and adjacent parts of Indiana and Kentucky sank more rapidly than the areas to the north, allowing a greater thickness of sediment to accumulate. During the Paleozoic and Mesozoic Eras, the Earth's thin crust was periodically flexed and warped in places as stresses built up in response to tectonic forces (plate movement and mountain building). These movements caused repeated invasions and withdrawals of the seas across the region. The former sea floors were thus periodically exposed to erosion, which removed some sediments from the rock record.

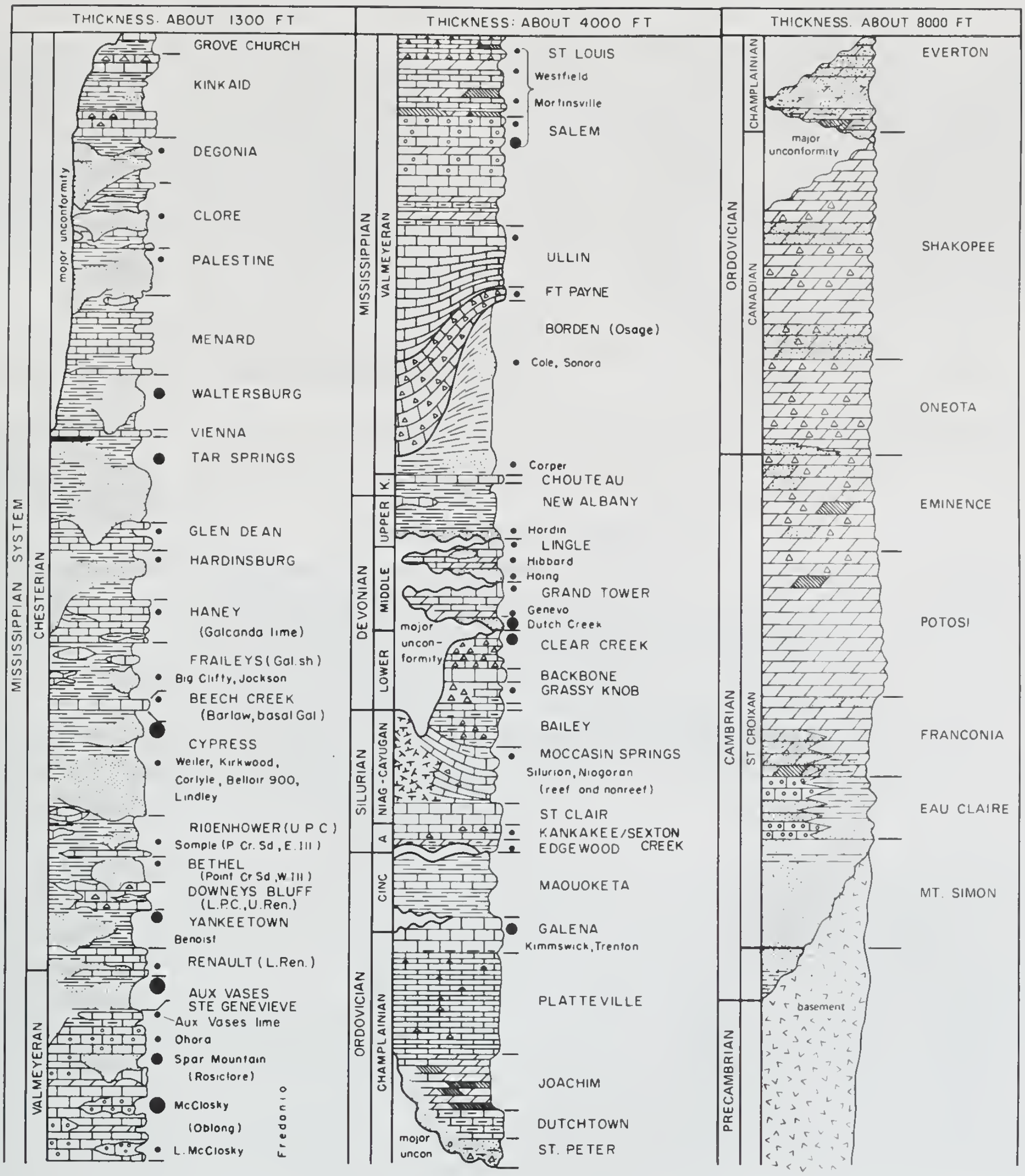


Figure 2 Generalized stratigraphic column of the Paleozoic rocks in the field trip area. Black dots indicate oil and gas pay zones.. Unconformities are indicated by wavy lines.

Many of the sedimentary units, called formations, have *conformable* contacts—that is, no significant interruption in deposition occurred as one formation was succeeded by another (figs. 2 and 4). In some instances, even though the composition and appearance of the rocks change significantly at the contact between two formations, the *fossils* in the rocks and the relationships between the rocks at the contact indicate that deposition was virtually continuous. In contrast however, in some places, the top of the lower formation was at least partially eroded before deposition of the next formation began. In these instances, fossils and other evidence in the two formations indicate that there is a significant age difference between the lower unit and the overlying unit. This type of contact is called an *unconformity* (fig. 4). If the *beds* above and below an unconformity are parallel, the unconformity is called a *disconformity*. However, if the lower beds were tilted and eroded prior to deposition of overlying beds, the contact is called an angular unconformity.

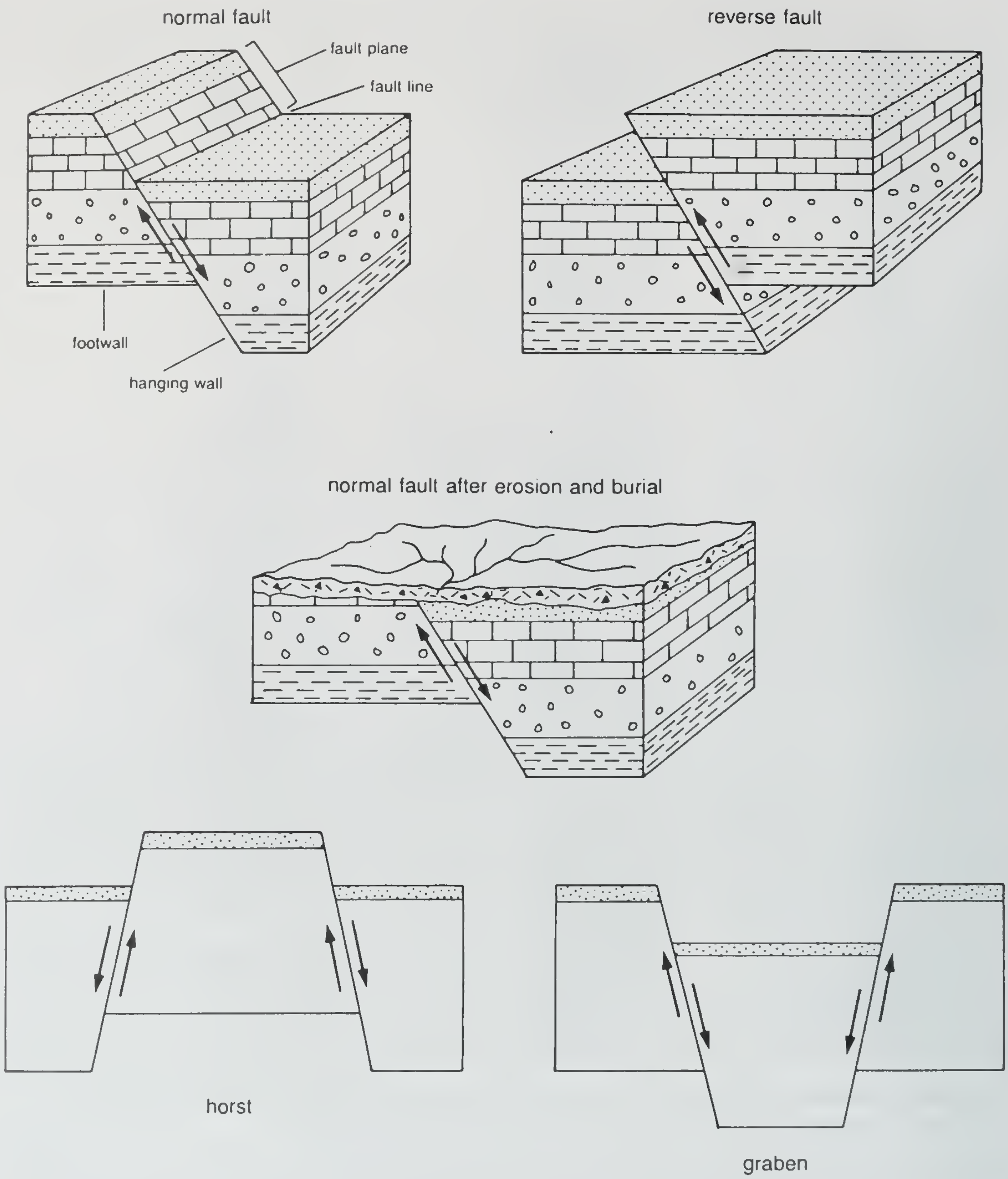


Figure 3 Diagrammatic illustrations of fault types that may be present in the field trip area (arrows indicate relative directions of movement on each side of the fault).

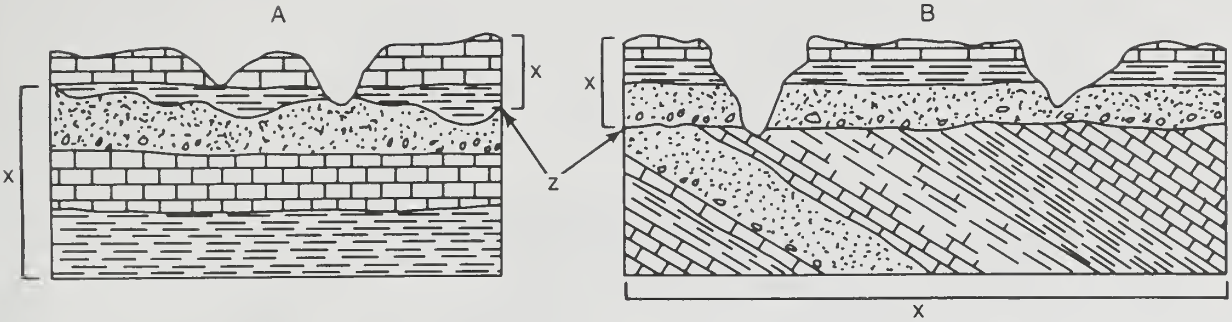


Figure 4 Schematic drawings of (A) a disconformity and (B) an angular unconformity (x represents the conformable rock sequence and z is the plane of unconformity).

Unconformities occur throughout the Paleozoic rock record and are shown in the generalized stratigraphic column (fig. 2) as wavy lines. Each unconformity represents an extended interval of time for which there is no rock record in this area.

Near the close of the Mississippian Period, gentle arching of the rocks in eastern Illinois initiated the development of the La Salle Anticlinorium (figs. 1 and 5). This is a complex structure having smaller structures such as domes, *anticlines*, and *synclines* superimposed on the broad upwarp of the anticlinorium. Further gradual arching continued through the Pennsylvanian Period. Because the youngest Pennsylvanian strata are absent from the area of the anticlinorium (either because they were not deposited or because they were later eroded away), we cannot determine just when folding ceased—perhaps by the end of the Pennsylvanian or during the Permian Period a little later, near the close of the Paleozoic Era.

Mesozoic Era During the Mesozoic Era, the rise of the Pascola Arch (figs. 1 and 5) in southeastern Missouri and western Tennessee produced a structural barrier that helped form the current shape of the Illinois *Basin* by closing off the embayment and separating it from the open sea to the south. The Illinois Basin is a broad, subsided region covering much of Illinois, southwestern Indiana, and western Kentucky (fig. 1). Development of the Pascola Arch, in conjunction with the earlier sinking of the deeper portion of the basin to the north, gave the basin its present asymmetrical, spoon-shaped configuration (fig. 6). The tectonic uplifting of the Pascola Arch is responsible for the regional northward dipping nature of the Paleozoic rocks along the southern portion of the Illinois basin (see fig. 6). This uplifting of the Paleozoic rocks and subsequent erosion created the east–west escarpment of Mississippian- and Pennsylvanian-aged strata in southern Illinois. This escarpment forms the southern edge of the Illinois Basin. South of this escarpment the deeply eroded Paleozoic rocks are overlain by Cretaceous- and Tertiary-aged sediments (fig. 7), which were deposited in an area called the Mississippi Embayment (fig. 5). The geologic map (fig. 8) shows the distribution of the rock *systems* of the various geologic time periods as they would appear if all the glacial, windblown, and surface materials were removed.

Younger rocks of the latest Pennsylvanian Period, and perhaps the Permian (the youngest rock systems of the Paleozoic), may at one time have covered the Mississippian strata that are exposed in the northern part of the field trip area. Mesozoic and Cenozoic rocks, which are deposited south of the Mississippian Escarpment (see fig. 7 and generalized geologic column) were also possibly deposited here. Indirect evidence, based on the stage of development (rank) of coal deposits and the generation and maturation of petroleum from source rocks (Damberger 1971), indicates that perhaps as much as 1.5 miles of additional sedimentary rocks of latest Pennsylvanian age and younger once covered southern Illinois. During the more than 240 million years since the end of the Paleozoic

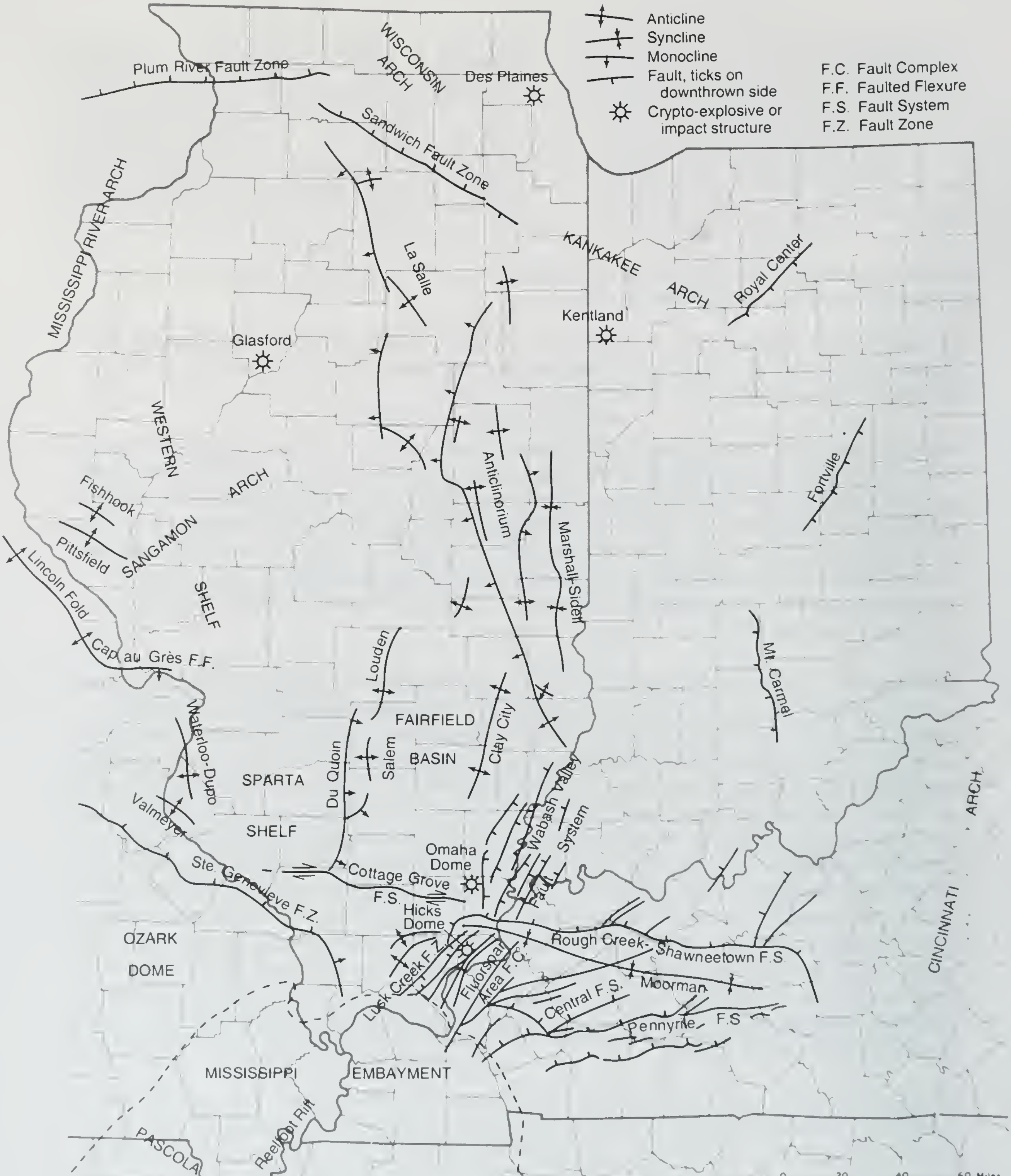


Figure 5 Structural features of Illinois (modified from Buschbach and Kolata 1991).

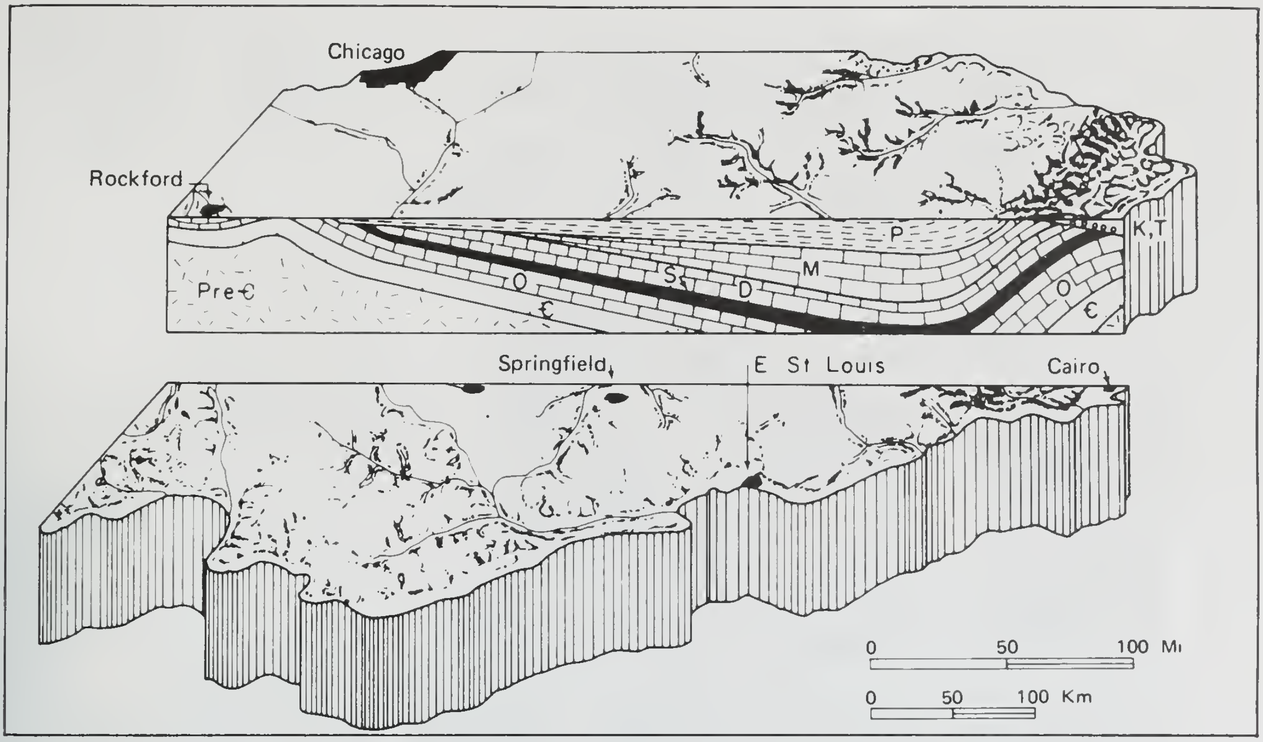


Figure 6 Stylized north–south cross section shows the structure of the Illinois Basin. To show detail, the thickness of the sedimentary rocks has been greatly exaggerated and younger, unconsolidated surface deposits have been eliminated. The oldest rocks are Precambrian (Pre-Є) granites. They form a depression filled with layers of sedimentary rocks of various ages: Cambrian (Є), Ordovician (O), Silurian (S), Devonian (D), Mississippian (M), Pennsylvanian (P), Cretaceous (K), and Tertiary (T). Scale is approximate.

Era (and before the onset of *glaciation* 1 to 2 million years ago), however, several thousands of feet of strata may have been eroded. Nearly all traces of any post-Pennsylvanian bedrock that may have been present in Illinois north of the Mississippi Embayment were removed. During this extended period of erosion, deep valleys were carved into the gently tilted bedrock formations (fig. 9). Later, the topographic *relief* was reduced by repeated advances and melting back of continental *glaciers* that scoured and scraped the bedrock surface. This glacial erosion affected all the formations exposed at the bedrock surface in Illinois. The final melting of the glaciers left behind the nonlithified deposits in which our Modern Soil has developed.

Cenozoic Era: Glacial History As stated above, erosion that took place long before the glaciers advanced across the state left a network of deep valleys carved into the bedrock surface. As glaciation began, the streams probably stopped eroding and began to aggrade. That is, their channels began to build up and fill in because the streams did not have sufficient volumes of water to carry and move the increased volumes of sediment. These ancient stream valleys were completely filled by the outwash from later glaciations.

During the Pleistocene *Epoch*, beginning about 1.6 million years ago, massive sheets of ice (called continental glaciers) built up to thousands of feet thick and flowed slowly southward from Canada. During the Illinois Episode, which began around 300,000 years before the present (B.P.), North American continental glaciers reached their southernmost position, approximately 25 miles north of here, in the northern part of Johnson County (fig. 10). The last of these glaciers retreated (melted) from northeastern Illinois about 13,500 years B.P. The maximum thickness of these later Wisconsin

Era	System	Series	Formation	Graphic Column	Thickness (feet)
CENOZOIC	Quaternary	Pleistocene	Peoria, Roxana, Loveland, and older silts; Cahokia, Equality, and undifferentiated alluvial and colluvial sediments		0–250
	Tertiary–Quaternary	Pliocene–Pleistocene	Mounds Gravel		0–50
	Tertiary	Eocene	Wilcox		0–250
		Paleocene	Porters Creek "clay"		0–150
			Clayton		0–20
MESOZOIC	Cretaceous	Gulfian	Owl Creek		0–10
			McNairy "sand"		25–455
			Tuscaloosa "gravel"		0–170
			Little Bear Soil		0–10
PALEOZOIC	Mississippian–Ordovician		Bedrock; mostly limestone, chert, and sandstone		

Figure 7 Generalized stratigraphic column of the Mississippi Embayment sediments in southernmost Illinois.

Episode glaciers in Illinois was about 2,000 feet in the Lake Michigan Basin, but the ice was only about 700 feet thick over most of Illinois' land surface (Clark et al. 1988).

The *topography* of the bedrock surface throughout much of Illinois is largely hidden by glacial deposits, except along the major streams. In many areas, the glacial drift is thick enough to completely mask the underlying bedrock surface. Studies of mine shafts, water-well logs, and other drill-hole information, in addition to the scattered bedrock exposures in some stream valleys and roadcuts, show that

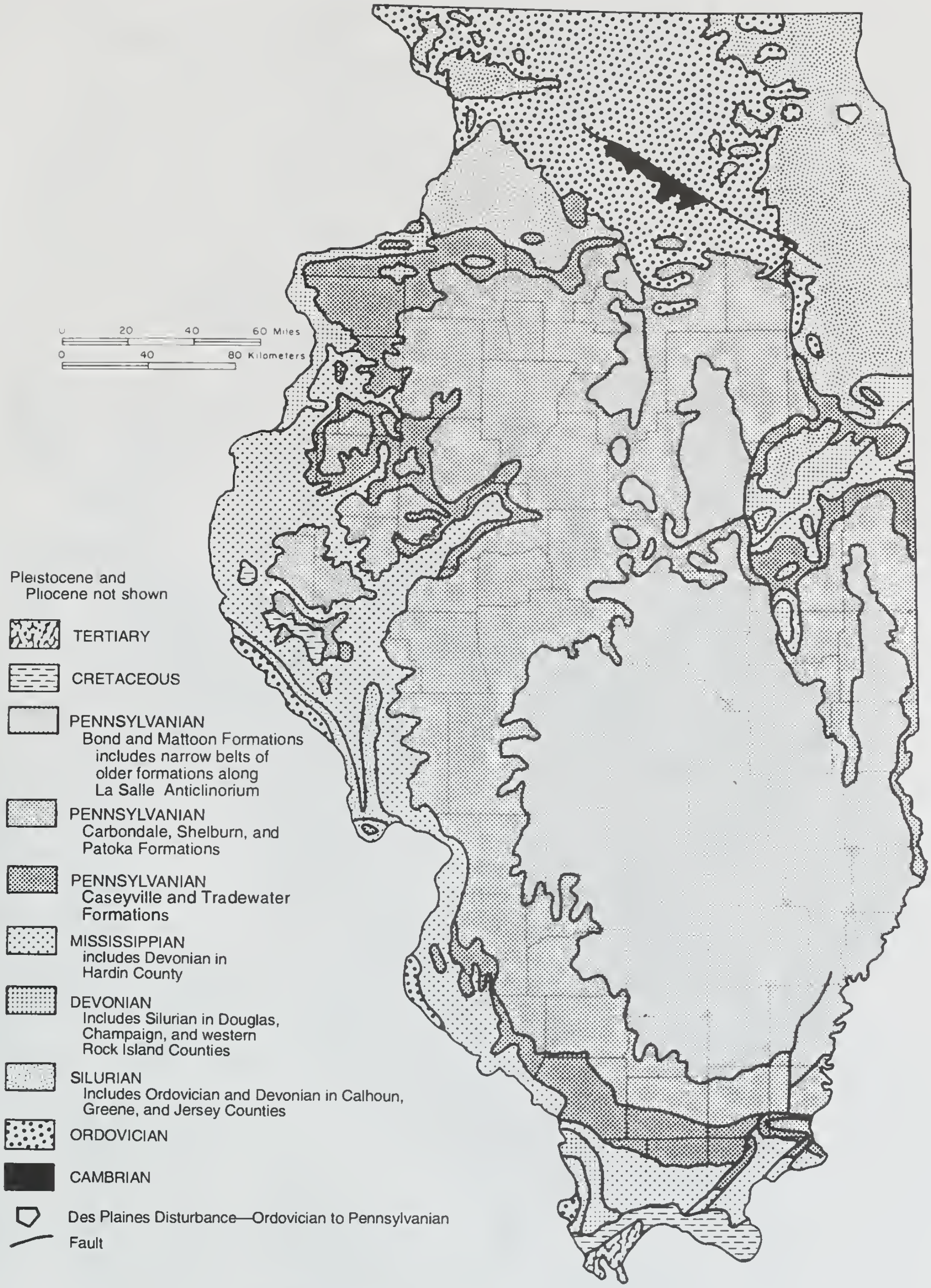


Figure 8 Bedrock geology beneath surficial deposits in Illinois.

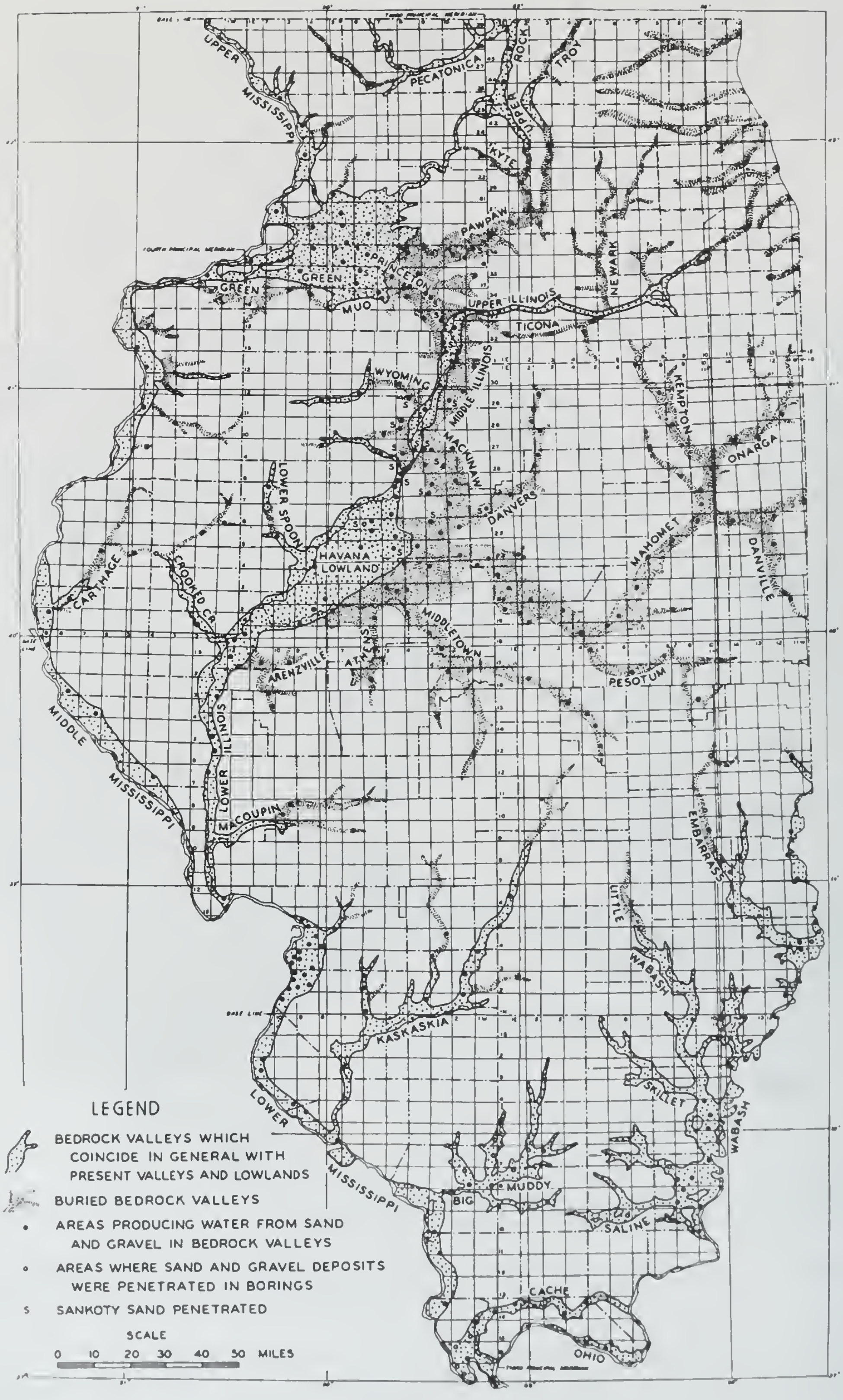


Figure 9 Bedrock valleys of Illinois (modified from Horberg 1950).

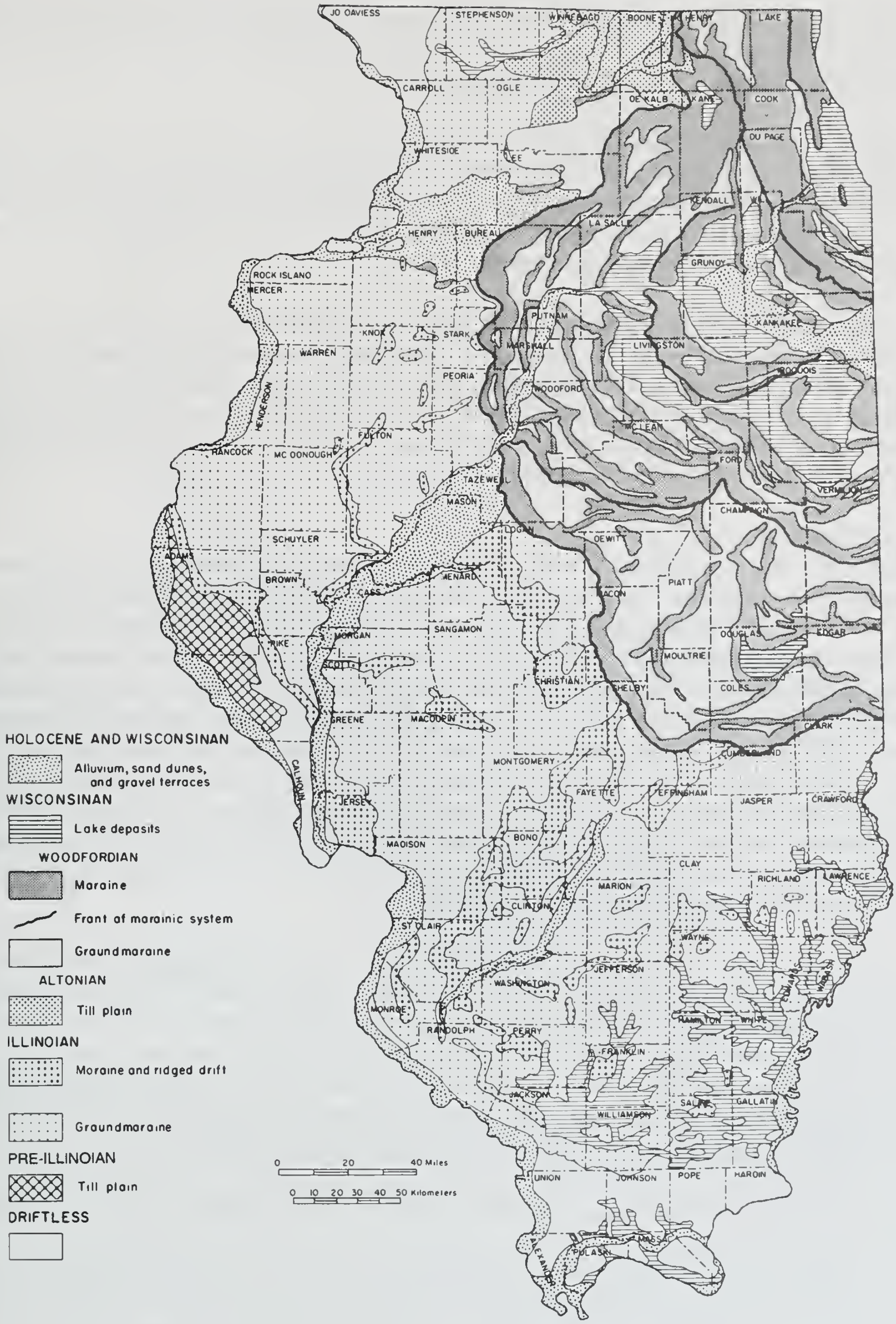


Figure 10 Generalized map of glacial deposits in Illinois (modified from Willman and Frye 1970).

the present land surface in the areas of Illinois where the glacial deposits are thickest does not reflect the underlying bedrock surface. The topography of the preglacial surface has been significantly modified by glacial erosion and is subdued by glacial deposits.

Although the Illinois Episode glaciers probably built morainic ridges similar to those formed by the later Wisconsin Episode glaciers, the Illinois Episode moraines apparently were not as numerous and have been exposed to weathering and erosion for approximately 280,000 years longer than their younger counterparts. For these reasons, Illinoian glacial features generally are not as conspicuous as the younger Wisconsinan features.

Overlying the glacial deposits is a thin cover of material called *loess* (pronounced "luss"). These sediments were deposited by the wind during all of the glacial episodes, from the earliest pre-Illinois Glacial Episode (approximately 1.6 million years ago) to the last glacial episode, the Wisconsin Episode (which occurred approximately 25,000 to 12,500 years ago. These loess deposits mantle the Mississippian, Cretaceous, Tertiary, and glacial outwash deposits throughout the field trip area. (See *Ancient Dust Storms in Illinois* at the back of the guidebook.)

GEOMORPHOLOGY

Physiography The field trip area is located near the junction of, and influenced by, four prominent physiographic provinces (fig. 11). These include the southern portion of the Shawnee Hills Section (Interior Low Plateaus Province), the northern portion of the Mississippi Embayment Section (Coastal Plain Province), the southeastern portions of the Salem Plateau Section (Ozark Plateaus Province), and the southern portion of the Till Plains Section (Central Lowland Province). A major influence on the geomorphology of the field trip area was established by Pleistocene meltwaters (glacio-fluvial features). Oddly enough, the physiographic boundary for the most influential physiographic province (Central Lowland Province-Till Plains Section) is 25 miles to the north, and although very nearby, is farther away than the other three major physiographic provinces. Although the area of this field trip was not glaciated, the present landforms and courses of the Ohio and Mississippi Rivers were significantly modified during the Wisconsin Episode (the last major glaciation). Subsequent erosion by wind and rain has continued to modify the landscape.

The convergence of four or more major physiographic provinces is a rare geologic phenomenon, which only occurs in five other places in the United States. Of the six areas in the country where four or more physiographic regions overlap, the Cache River basin of the Mississippi Embayment, is thought to be the most diverse. Specifically, it is bounded on the west by the Ozark Hills, on the north and east by the Shawnee Hills, and on the south (ignoring low lines of hills that, strictly speaking, define the watershed) by the Mississippi and Ohio Rivers. The result is an unusually diverse assemblage of species and natural communities in close proximity to one another.

Drainage Within the field trip area, drainage is controlled by the Cache River and its tributaries.

Relief The highest land surface on the field trip route is located north of Wildcat Bluff (Stop 5), where the surface elevation is 600 feet above mean sea level (msl). The lowest elevation is about 290 feet above msl along the Ohio River at Stops 2 and 3 near Olmstead. The surface relief of the field trip area, calculated as the difference between the highest and lowest points, is 310 feet. *Local relief* is most pronounced along Wildcat Bluff where the Mississippian Hardinsburg Sandstone forms vertical bluffs that reach more than 190 feet above the Cache River valley.

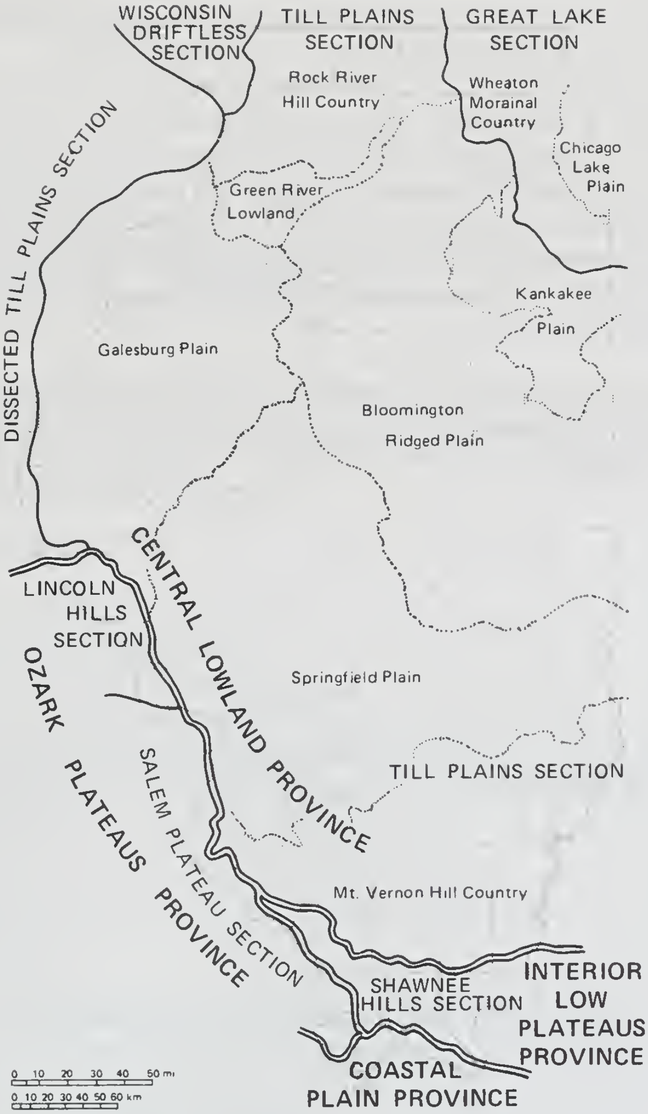


Figure 11 Physiographic divisions of Illinois.

NATURAL RESOURCES

Mineral production Of the 102 counties in Illinois, 98 reported *mineral* production during 1995, the last year for which complete records are available. The total value of all minerals extracted, processed, and manufactured in Illinois during 1995 was $2,202,300,000, which is 10.9% lower than the 1994 total. Minerals extracted accounted for 87.6% of this total; processed crude minerals and manufactured minerals accounted for the remaining 12.4%. Coal continued to be the leading commodity, accounting for 64% of the total. Illinois is the fifth largest producer of coal in the nation and is ranked 13th among the 31 oil-producing states, and 16th among the 50 states in total production of nonfuel minerals, but leads all other states in the production of sand and gravel, industrial sand, and tripoli (microcrystalline silica).

Economic minerals currently mined in Johnson County include crushed stone from limestone quarries. Although no active coal mines are operating in Johnson County, historical cumulative production equals 314,325 tons. Mining in Pulaski County includes crushed stone from limestone quarries, sand and gravel from alluvium deposits, and a specialized type of clay known as absorbent clay, most of which is processed to make pet litter and floor-sweeping compounds.

Groundwater Groundwater is a mineral resource frequently overlooked in assessments of an area's natural resource potential. The availability of this mineral resource is essential for orderly economic and community development. More than 35% of the state's 11.5 million citizens and 97% of those who live in rural areas depend on groundwater for their water supply. Groundwater is derived from underground formations called *aquifers*. The water-yielding capacity of an aquifer can only be evaluated by constructing wells into it. After construction, the wells are pumped to determine the quality and quantity of groundwater available for use.

Because fluvial-glacial outwash deposits occur in this area along the ancient course of the Ohio River, and alluvium deposits occur along the modern Ohio River, sand and gravel deposits are a significant source of groundwater.

GUIDE TO THE ROUTE

The starting point for the Cache River Area field trip is at the Shawnee Community College parking lot, which is located approximately 7 miles east of the Ullin exit at mile marker 18 of Interstate 57.

You must travel in the caravan Please drive with headlights on while in the caravan. Drive safely but stay as close as you can to the car in front of you. Please obey all traffic signs. If the road crossing is protected by an Illinois State Geological Survey (ISGS) vehicle with flashing lights and flags, please obey the signals of the ISGS staff directing traffic. When we stop, park as close as possible to the car in front of you and turn off your lights.

Private property Some stops on the field trip are on private property. The owners have graciously given us permission to visit on the day of the field trip only. Please conduct yourselves as guests and obey all instructions from the trip leaders. So that we may be welcome to return on future field trips, follow these simple rules of courtesy:

- Do not litter the area.
- Do not climb on fences.
- Leave all gates as you found them.
- Treat *public* property as if you were the owner—which you are!

When using this booklet for another field trip with your students, a youth group, or family, remember that *you must get permission from property owners or their agents before entering private property.* No trespassing please.

Miles to next point	Miles from start	
0.0	0.0	Entrance ramp of the Shawnee Community College. TURN RIGHT onto the Shawnee College Road to the east.
0.0	0.4	Road curves to the left.
0.1	0.5	Road curves to the right. Prepare to stop.
0.2	0.7	STOP (1-way). T-intersection (State Hwy. 37 1300E). TURN RIGHT onto State Hwy. 37.
0.3	1.0	Cemetery to the right. CONTINUE SOUTH.
0.8	1.8	T-intersection from the right (unmarked; no numbers or signs).
0.1	1.9	Entering the city limits of New Grand Chain.
0.1	2.0	T-intersection from the left.
0.1	2.1	T-intersection from the left (New Grand Chain Road). CONTINUE SOUTH on State Hwy. 37. Beginning to ascend a hill; road curves right.

0.9	3.0	Intersection (Brushy Road/1198N). Continue southwest on State Hwy. 37.
1.1	4.1	T-intersection from the left (Sunset Lane/1189E). CONTINUE AHEAD on State Hwy. 37 to the southwest.
1.25	5.35	Crossroad intersection (Olmsted Dam Road/ 1047N to the left, and Price Road/1047N to the right). CONTINUE AHEAD on State Hwy. 37 to the southeast.
1.45	6.8	Cross a small creek on a narrow bridge. CONTINUE AHEAD on State Hwy. 37.
0.4	7.2	T-intersection from the right (Bethlehem Road/998E). CONTINUE AHEAD on State Hwy. 37. Be prepared to left turn in approximately ¼ mile.
0.2	7.4	Crossroad intersection. Be careful; trucks enter road from the left. Be prepared to turn left on the same road. Vehicles should slow down.
0.3	7.7	Intersection with Feather Trail Road/972E). TURN LEFT on Feather Trail Road.
0.2	7.9	Cross bridge over small, unnamed creek.
0.1	8.0	To the left is the entrance road to the Golden Cat Clay Pit. CONTINUE AHEAD. T-intersection to the right with stop sign. This road goes into Olmsted (no signs to identify it). CONTINUE AHEAD uphill on Feather Trail Roadl.

0.2	8.2	**Stop 1 Golden Cat Clay Pit** Stop along shoulder of the road.

0.0	8.2	Leave Stop 1 and CONTINUE AHEAD.
0.15	8.35	Road jogs to the left. CONTINUE AHEAD on Feather Trail Road. Be prepared to stop ahead at T-intersection.
0.15	8.5	T-intersection (Winnebago Road). STOP and TURN LEFT on Fulton Street heading northeast out of Olmsted.
0.5	9.0	To the right through a gap in the trees, you can view the construction area for the new lock and dam which will be Stop 2. CONTINUE AHEAD on Olmsted Dam Road.
0.1	9.1	Masonic Cemetery to the left. CONTINUE AHEAD.
0.3	9.4	Water tower to the left. Prepare to turn right.
0.1	9.5	T-intersection from right (New Dam Lane/875N). TURN RIGHT onto New Dam Lane.

0.3	9.8	TURN RIGHT into Visitors Center. Immediately after this point, the road makes a sharp left turn into the project overlook (open daily sunrise to sunset). Offices are to the right. CONTINUE AHEAD on the new blacktop to the Visitors Overlook.

0.2	10.0	**Stop 2 New Locks and Dam at Olmstead: Visitors Overlook** The new lock and dam construction site for replacement of Locks and Dams 52 and 53.

0.0	10.0	Leave Stop 2. CONTINUE AHEAD and retrace route back to entrance.
0.2	10.2	TURN RIGHT out of the drive of the Visitors Parking Lot. TURN LEFT at the stop sign almost immediately after the jog. To the right is the employee parking lot. ***Do not enter***.
0.3	10.5	Prepare to stop and turn right.
0.1	10.6	T-intersection. STOP. (Olmsted Dam Road/1070E). TURN RIGHT (northeast) onto Olmsted Dam Road.
0.5	11.1	To the left is a large radio tower.
0.3	11.4	To the right is a very small, old cemetery. Road curves left.
0.3	11.7	T-intersection from right (Dam 53/1975N). TURN RIGHT on Dam 53 Road.
0.2	11.9	Road goes downhill at this point. A power plant is in the distance.
0.5	12.4	Road curves right. CONTINUE AHEAD.

0.3	12.7	**Stop 3 Old Locks and Dam 53 at Olmstead** LUNCH: Are you hungry?

0.0	12.7	Leave Stop 3. Continue out on the same road we entered. Head toward intersection with Olmsted Dam Road.
0.9	13.6	T-intersection (Olmsted Dam Road/1130E). TURN RIGHT onto Olmsted Dam Road.
0.5	14.1	T-intersection from the right (Rolling Hills Road/1020N). CONTINUE AHEAD on Olmsted Dam Road.
0.2	14.3	Prepare to stop ahead.
0.1	14.4	Crossroad intersection (Olmsted Dam Road/1047N and State Hwy. 37/1114E). STOP and TURN RIGHT (northeast) on State Hwy. 37. Past the intersection, Olmsted Dam Road changes to Price Road 1047N. Water tower for New Grand Chain City appears ahead in the distance.

1.2	15.6	T-intersection from the right (Sunset Lane/1198E). CONTINUE AHEAD on State Hwy. 37.
1.15	16.75	Crossroad intersection (Brushy Road/1198N). CONTINUE AHEAD on State Hwy. 37.
0.45	17.2	City limits of New Grand Chain. Population 250.
0.4	17.6	T-intersection from the right (New Grand Chain Road).
0.1	17.7	Road jogs to the left. CONTINUE AHEAD on State Hwy. 37.
0.3	18.0	T-intersection with county road to the left (unmarked). CONTINUE AHEAD.
0.7	18.7	Forest View Cemetery to the left. CONTINUE AHEAD on State Hwy. 37.
0.4	19.1	T-intersection to the left (Shawnee College Road/1408N). CONTINUE AHEAD on State Hwy. 37.
0.9	20.0	Crossroad intersection (State Hwy. 169 is to the right, and Normandy Road/1500N is to the left). CONTINUE AHEAD.
0.8	20.8	T-intersection from the right (Goines Lane/1572N). CONTINUE AHEAD.
0.2	21.0	Entering the Cache floodplain; cypress trees to the right and left.
0.1	21.1	Section 8 Woods Access. CONTINUE AHEAD on State Hwy. 37.
0.3	21.4	Cross the Cache River. Leaving Pulaski County and entering Johnson County.
0.1	21.5	Approaching T-intersection from the left. Prepare to turn left toward Perks.
0.1	21.6	T-intersection from left (Perks Road). TURN LEFT.
1.3	22.9	Cross Cypress Creek. Cypress Creek has been straightened and is a man-made controlled stream. Re-entering Pulaski County.
0.3	23.2	Prepare to turn left.
0.2	23.4	T-intersection from the left (Lower Cache River Access Road). TURN LEFT.

1.0	24.4	**Stop 4 Lower Cache River Access**

0.0	24.4	Leave parking lot of Lower Cache River Access.
0.2	24.6	Road jogs left; farm lane is to the right. CONTINUE AHEAD on road leaving Lower Cache River Access.
0.9	25.5	Prepare to stop.

0.1	25.6	Intersection (Perks Road/1700N). STOP and TURN RIGHT onto Perks Road, heading east.
1.6	27.2	Prepare to stop.
0.15	27.35	T-intersection (State Hwy. 37). STOP and TURN RIGHT (south) onto State Hwy. 37.
0.25	27.6	Cross the Cache River; entering Pulaski County and leaving Johnson County.
0.25	27.85	Section 8 Access Area to the left. CONTINUE AHEAD on State Hwy. 37.
0.35	28.2	T-intersection to left (Goines Lane/1572N). CONTINUE AHEAD on State Hwy. 37. Junction of State Hwy. 169 ahead. Prepare to turn left onto State Hwy. 169.
0.8	29.0	Crossroad intersection. State Hwy. 169/1501N is to the left; and Normandy Road/1500N is to the right. TURN LEFT on State Hwy. 169.
0.3	29.3	Ascending one of the many low hills in the area, somewhat similar to the one that Shawnee College is on. These low hills are composed of Mississippian bedrock capped by a mantle of loess.
0.9	30.2	Descending hill back into the flat of the Cache River Valley. Road curves sharply to the left. CONTINUE AHEAD on State Hwy. 169.
0.2	30.4	Cross a drainage ditch.
0.3	30.7	To the left in the distance is the Big Cypress Access Area. CONTINUE AHEAD on State Hwy. 169.
0.3	31.0	State Hwy. 169 curves to the right. CONTINUE AHEAD on State Hwy. 169.
0.2	31.2	T-intersection to the left (unmarked county gravel road).
0.3	31.5	Entering the city limits of Karnak. Population 650.
0.15	31.65	Crossroad intersection (East First). TURN LEFT onto East First.
0.15	31.8	Road bends sharply to the right. Cross old railroad tracks at the north edge of Karnak. To the right is an area of old factories and buildings that was the heart of part of the lumber industry at one time. Now they are all closed and abandoned.
0.2	32.0	Cross bridge over the Cache River. About a mile to the southeast, the Cache River was mostly diverted by the Post Creek cutoff. At this point, the Cache River looks more like a creek, which shows how much diversion has occurred.
0.7	32.7	Leave the woods around the Cache River Valley. Immediately ahead above the floodplain notice the low forested hills. Those hills are made up of Upper Mississippian bedrock (Chesterian) and consist of shale and limestone capped

		by sandstone (Cypress Sandstone). CONTINUE AHEAD on Karnack Road toward Belknap.
1.5	34.2	Enter the village of Belknap.
0.1	34.3	Intersection of Seminary Street. CONTINUE AHEAD on Karnak Road (called East Main Street in Belknap).
0.2	34.5	Crossroad and stop sign. CONTINUE AHEAD on Karnak Road. At this stop sign you can turn left and go to the Cache River Nature Area and the headquarters for Heron Pond.
0.1	34.6	Leave Belknap. To the left is a series of low forested hills mentioned earlier, which consists of Mississippian-age bedrock (i.e., limestone, shales, and sandstone of the Paint Creek Group). Belknap Road curves around the base of these hills heading toward U.S. Hwy. 45.
0.7	35.3	T-intersection to the right (Rose Farm Lane). CONTINUE AHEAD on Belknap Road.
0.3	35.6	Cross the Cache River.
0.7	36.3	Road curves slightly to the right. CONTINUE AHEAD.
0.3	36.6	CAUTION: single, unguarded railroad track crossing road. CONTINUE AHEAD.
0.2	36.8	Sharp curve to the right. A crossroads is near the middle of the curve (Foreman Lane to the right, and Heron Pond Lane to the left). Road to the left is the access to the Heron Pond Area. CONTINUE AHEAD on Belknap Road.
0.6	37.4	T-intersection to the right (Albritton Lane). CONTINUE AHEAD.
0.8	38.2	Sign marking a stop sign ahead. Be prepared to stop and turn left.
0.2	38.4	T-intersection (US Hwy. 45). STOP and TURN LEFT onto US Hwy. 45.
0.6	39.0	Road curves moderately to the left.
0.2	39.2	Cross Cave Creek.
0.1	39.3	To the immediate right, an opening in the trees forms a limestone glade. The habitat is based somewhat on an outcropping of Chesterian (Upper Mississippian) Haney and Beech Creek Limestones below the Hardinsburg Sandstone that caps these hills. Pass between a gap in these hills. CONTINUE AHEAD.
0.2	39.5	Road curves right and left at this point.
0.1	39.6	Road curves sharply to the right around the base of a hill.
0.1	39.7	Road curves to the left. Drive carefully here.

0.2	39.9	Road curves to the right again.
0.25	40.15	Road curves to the left.
0.5	40.2	Cross Dutchman's Creek.
0.1	40.3	Ascend a slight hill. Sign says Wildcat Bluff 3 miles. CAUTION and prepare to turn left. **NOTE:** Wildcat Bluff is 4.4 miles ahead.
0.2	40.5	T-intersection from left (Ballowe Church Road). TURN LEFT on Ballowe Church Road. CAUTION: watch for traffic.
0.15	40.65	Road ascends to the top of the hill. CONTINUE AHEAD on Ballowe Church Road.
0.05	40.7	Road now descends hill. CONTINUE AHEAD.
0.2	40.9	Road curves right and ascends hill again. CONTINUE AHEAD.
0.2	41.1	At the top of the hill, the road curves left back to the west. CONTINUE AHEAD.
0.3	41.4	T-intersection from left (Wildcat Cemetery Lane). CONTINUE AHEAD on Ballowe Church Road. Small brown sign indicates Wildcat Bluff ahead. Cross small, single lane bridge. Exposed to the immediate left is some of the Hardinsburg Sandstone that we will see at Wildcat Bluff. This rock is Chesterian (Upper Mississippian) in age.
0.1	41.5	Road curves right. CONTINUE AHEAD on Ballowe Church Road. Soils in ditches and fields in the area are made up of the loess that mantles all the bedrock in this area. The loess is exposed by construction of ponds and plowing of fields.
0.35	41.85	To the left is Ballowe Church (hence the name of this road).
0.5	42.35	T-intersection from the left (Hockins Road). TURN LEFT on Hockins Road and follow sign indicating direction to Wildcat Bluff.
0.45	42.8	Hockins Road makes a sharp left and ascends hill again. Follow curve to the left. We are ascending the back side of the cuesta made up of Upper Mississippian sandstones and limestones. Road goes up and down the hollows on the back (or north side) of this cuesta.
0.4	43.2	Continue to ascend hill higher up onto the cuesta.
0.2	43.4	We are now on the top of the cuesta, which is made up of Mississippian bedrock. Sharp curve to the left.
0.1	43.5	Sharp curve to the right.
0.2	43.7	Road curves sharply right.
0.1	43.8	Moderate curve to the left (heading back west).

0.2	44.0	T-intersection (Wildcat Bluff Road). STOP and TURN LEFT onto Wildcat Bluff Road.
0.1	44.1	Descend into a steep valley.
0.2	44.3	Reach bottom of valley and ascend hill again.
0.3	44.6	Reach top of hill. Approaching Stop 5. Prepare to turn left into parking lot.
0.1	44.7	**Stop 5 Wildcat Bluff** TURN LEFT and circle into parking lot for Wildcat Bluff.
0.0	44.7	Leave Stop 5
0.1	44.8	Begin descent into the valley north of Wildcat Bluff.
0.2	45.0	Partway down the slope where the road dips, located in the small ravine to the left is an exposure of Mississippian bedrock, probably the Hardinsburg Sandstone.
0.2	45.2	Bottom of the valley; begin climb out of the valley on Wildcat Bluff Road (heading north).
0.2	45.4	T-intersection from right (Hockins Road). CONTINUE AHEAD on Wildcat Bluff Road.
0.55	45.95	T-intersection to the left (Oak Grove Road). TURN LEFT onto Oak Grove Road.
0.45	46.4	T-intersection from right (Jenkins Road/700N). CONTINUE AHEAD on Oak Grove Road.
0.1	46.5	To the immediate right is a large radio or TV tower on top of the hill. CONTINUE AHEAD on Oak Grove Road.
0.3	46.8	Oak Grove Road turns sharply right.
0.2	47.0	Sharp left turn and a sharp turn back to the right.
0.3	47.3	Moderate curve to the left. CONTINUE AHEAD.
0.15	47.45	Road descends hill and curves sharply right to the north. CONTINUE AHEAD.
0.35	47.8	T-intersection (Old Cypress Road). TURN LEFT onto Old Cypress Road (heading west).
0.5	48.3	Sharp turn to the left.
0.3	48.6	Sharp turn to the right. CONTINUE AHEAD.

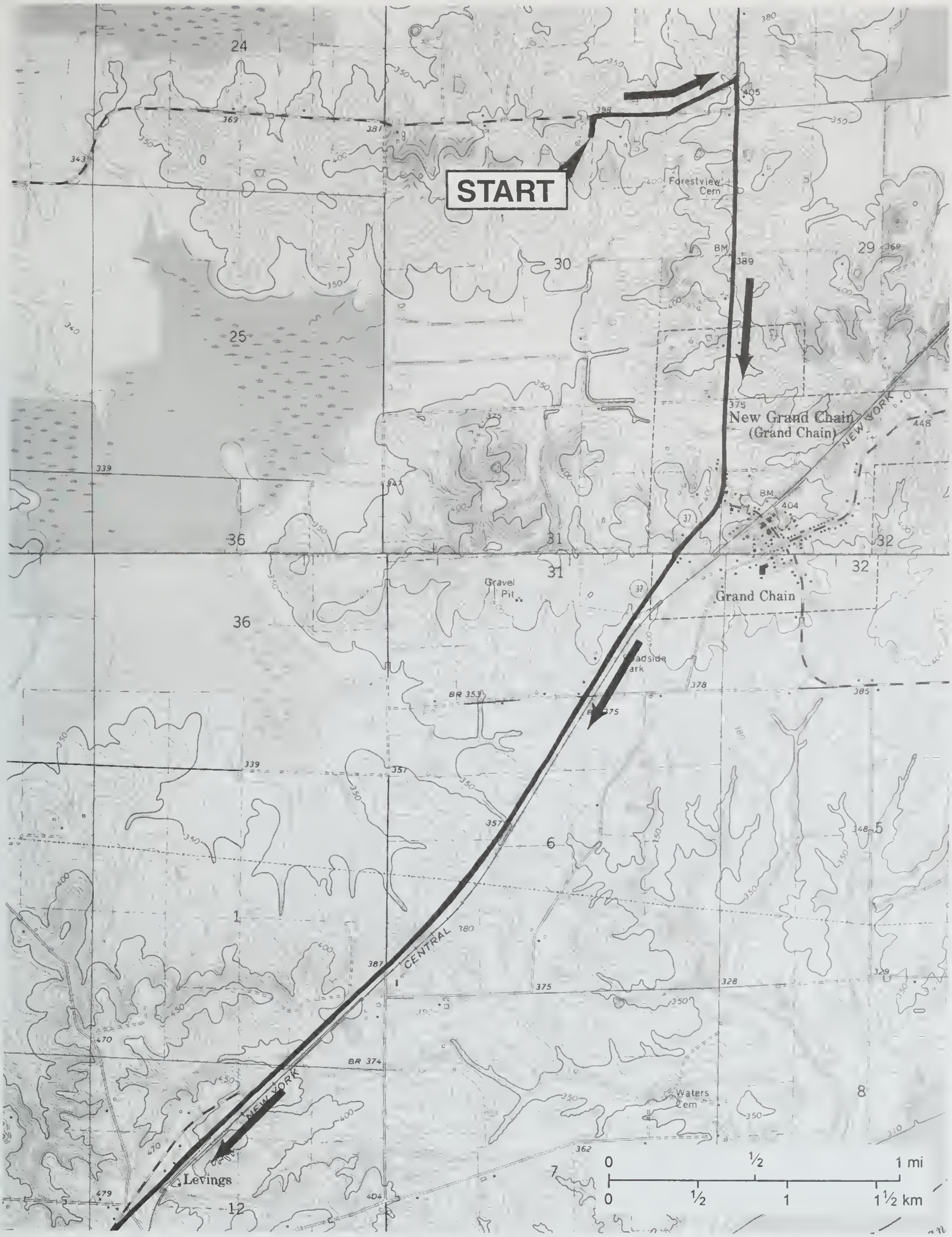
0.6	49.2	Crosses a single, unguarded railroad track. Use caution. CONTINUE AHEAD to the west.
0.1	49.3	Sharp jog to the left. CONTINUE AHEAD; road now heads south.
0.25	49.55	Curve to the right.
0.05	49.6	Cross the Cache River. CONTINUE AHEAD.
0.1	49.7	Road sharply jogs to the right uphill. Some Mississippian bedrock is exposed in the ditch to the right as we ascend the hill.
0.3	50.0	To the right is the Fain Cemetery. CONTINUE AHEAD on road.
0.2	50.2	Moderate curve to left (south). CONTINUE AHEAD (south) on Old Cypress Road.
0.65	50.85	T-intersection (Old Cypress Road and Snake Hole Lane). The road ahead becomes Snake Hole Lane. TURN RIGHT (west) on the continuation of Old Cypress Road.
1.0	51.85	Sharp left turn.
0.1	51.95	Sharp right turn (heading west again).
0.25	52.2	T-intersection from right (Bear Branch Road). TURN RIGHT onto Bear Branch Road.
0.15	52.35	On the left, in the old hog lot is an exposure of loess, which also caps the hills. Down in the gullies, weathered Mississippian bedrock is exposed. Road turns sharply left.
0.15	52.5	Sharp curve to the right. CONTINUE AHEAD.
0.4	52.9	Old railroad grade to the left exposes loess, which is largely grassed over. Crossroad intersection (Bear Branch Road and State Hwy. 37 South). TURN LEFT onto State Hwy. 37 South. CAUTION: moderate traffic on this highway.
0.2	53.1	Road curves left. CONTINUE AHEAD on State Hwy. 37 South.
0.4	53.5	T-intersection from right (Campbell Hill Road). CONTINUE AHEAD.
0.1	53.6	Ascend hill approaching water tower for Cypress.
0.3	53.9	Water tower for Cypress to the left. To the right is a T-intersection with Meredith Street, which leads into Cypress. CONTINUE AHEAD. Beginning descent down hill. We are now on top of a Mississippian bedrock cuesta capped by the Cypress Sandstone, which is named for the town of Cypress, at the bottom of the hill.
0.3	54.2	Entering the city limits of Cypress. Population 300.
0.3	54.5	Leaving Cypress. Road gently curves right.

0.4	54.9	Moderate curve to the left. CONTINUE AHEAD on State Hwy. 37.
0.2	55.1	Old railroad viaduct.
0.1	55.2	Masonic Cemetery to the left and right. Road curves left and then right through the middle of the cemetery.
0.3	55.5	Crossroad intersection (Dongola Road is to the west, and West Eden Road is to the east). CONTINUE AHEAD on State Hwy. 37.
0.2	55.7	Road gently curves left.
0.1	55.8	T-intersection to the left (Pontiac Lane). CONTINUE AHEAD on State Hwy. 37.
0.2	56.0	Road cut to the right and left through the hill. Exposures of Mississippian limestones (some of the same material we will see in the quarry).
0.65	56.65	Crossroad (Annabelle Road to the left, and Luther Chapel Road to the right). CONTINUE AHEAD on State Hwy. 37.
0.55	57.2	T-intersection from the right (West White Hill Road). CONTINUE AHEAD.
0.1	57.3	Entering community of White Hill. To the left are spoils from the White Hill Quarry. Prepare to turn left.

0.2 57.5 **STOP 6 White Hill Quarry** TURN LEFT into entrance area. This is the end of the trip. We hope everyone had a good time. Drive safely on your way home. See you next spring for the Warsaw-Hamilton trip in western Illinois.

This is the end of the trip, hope everyone had a good time, drive safely. See you next spring for the Warsaw-Hamilton trip in western Illinois. To reach I-57, go south on State Highway 37 about 3 miles to Shawnee Community College Road. Turn right (west) and follow Shawnee Community College Road about 7 miles to Exit 18 of I-57.

You can also go north on State Highway 37 about 8 miles to the intersection with State Highway 146 at West Vienna. Turn left on Highway 146 and go about 9 miles to the intersection with I-57 at Exit 30. You can also go east on Highway 146 about 6 miles (through the town of Vienna) to get on I-24 east bound toward Paducah, or westbound toward I-57 and Marion.


START
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Forestview Cem
New Grand Chain
(Grand Chain)
Grand Chain
Gravel Pit
Roadside Park
NEW YORK
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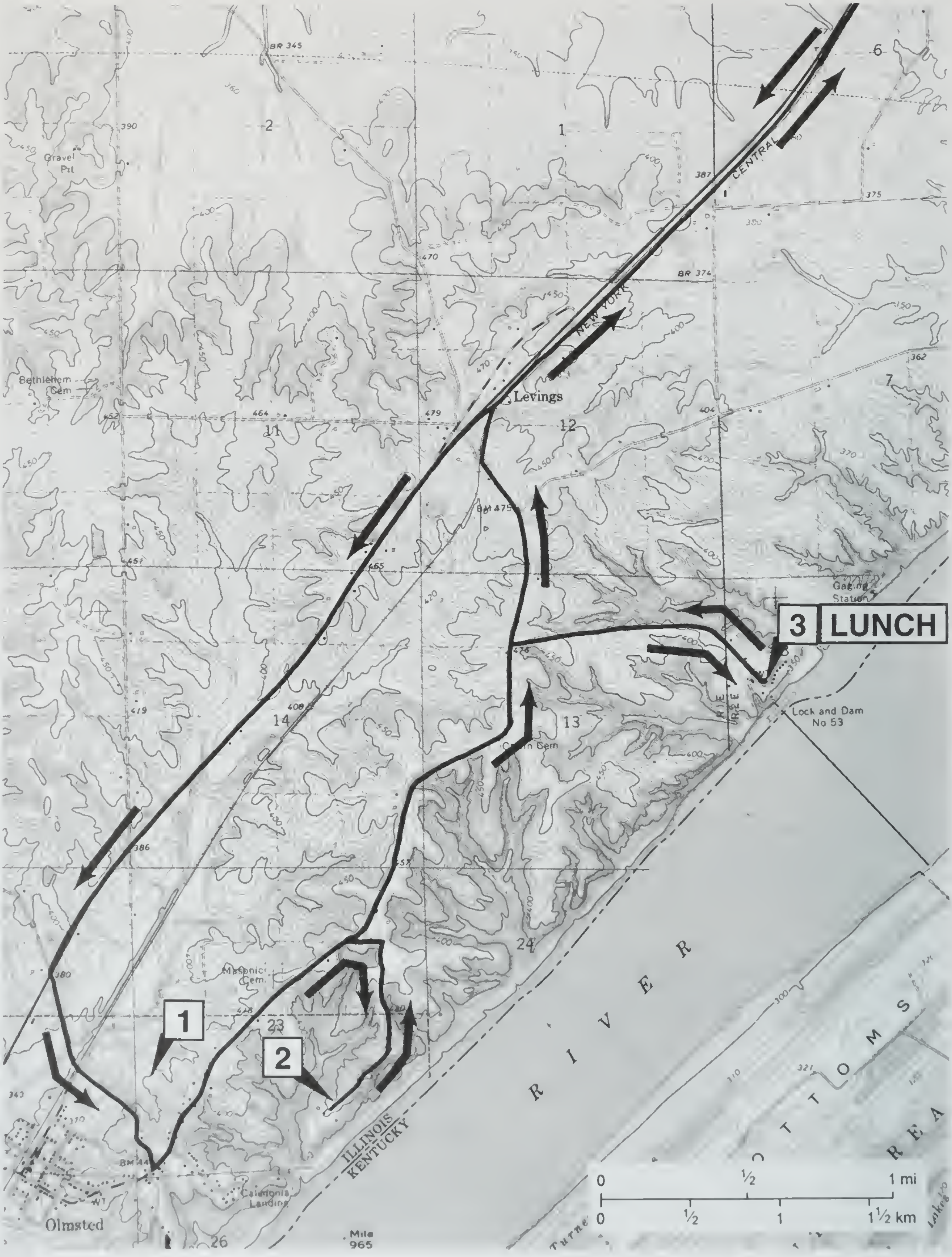
3 LUNCH
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Lock and Dam No 53
Gaging Station
Bethlehem Cem
Gravel Pit
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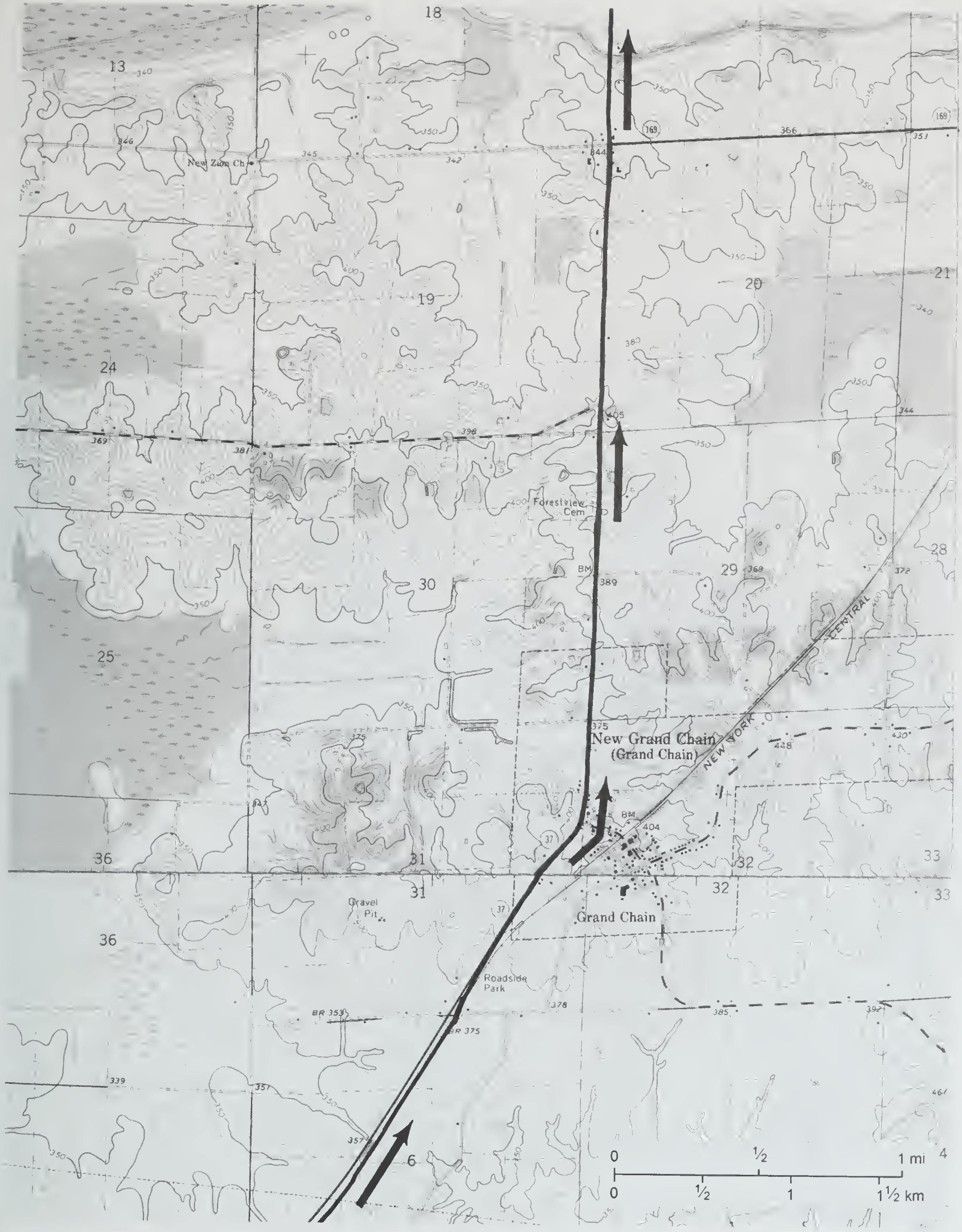
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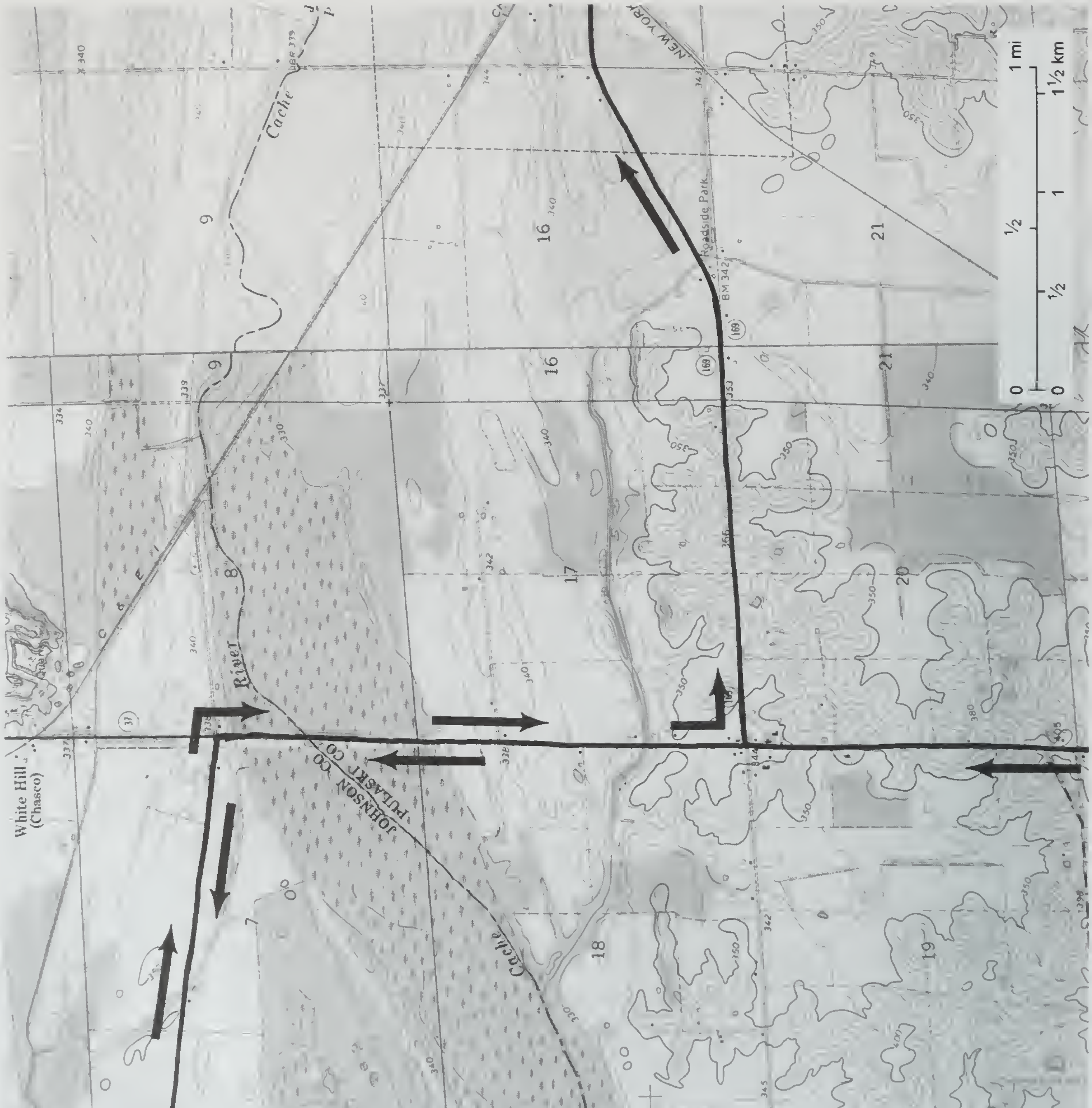

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Karnak
JOHNSON CO
MASSAC CO
PULASKI CO
JOHNSON CO
PULASKI CO
River
DITCH
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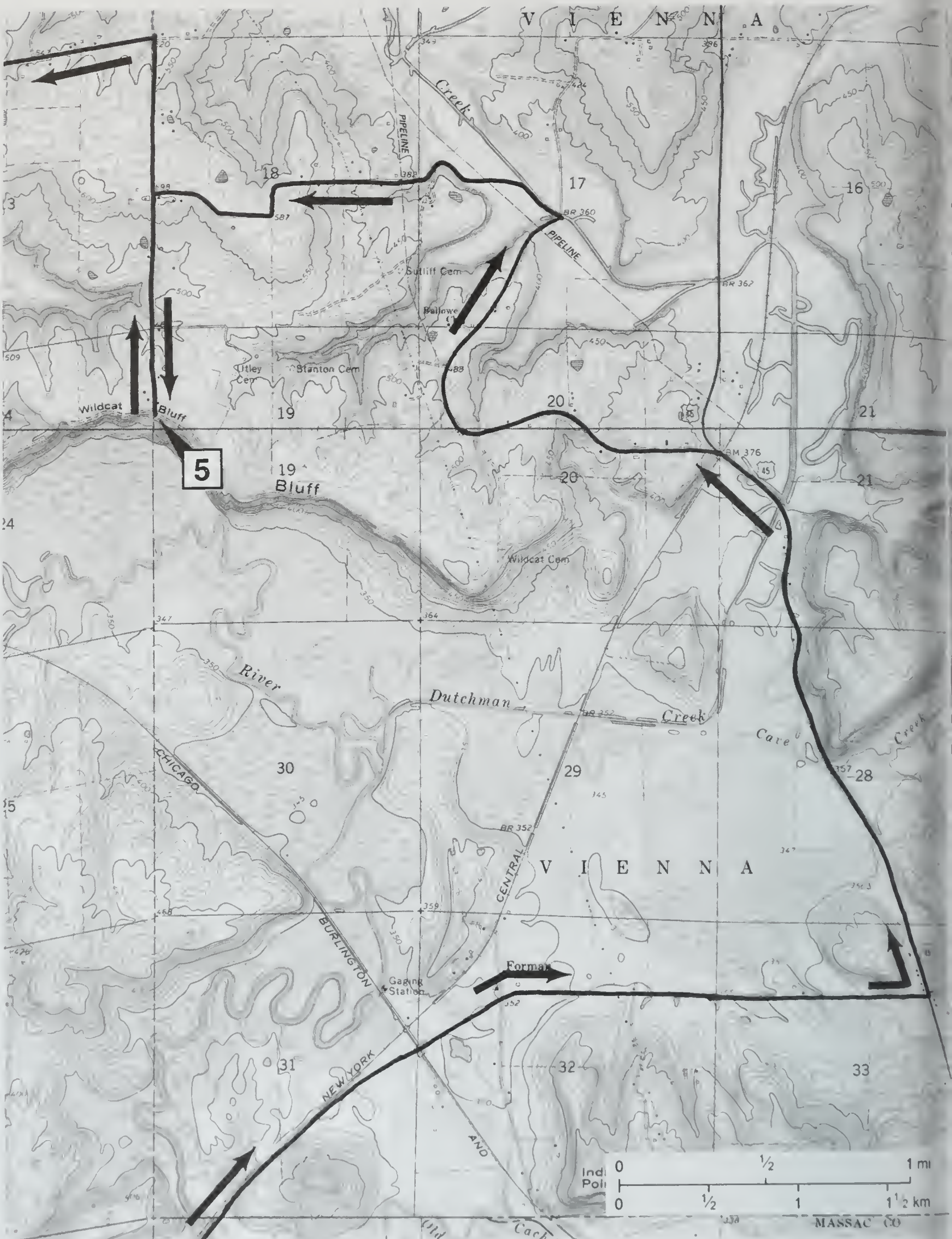
169


VIENNA
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River
Dutchman
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BURLINGTON
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Cache
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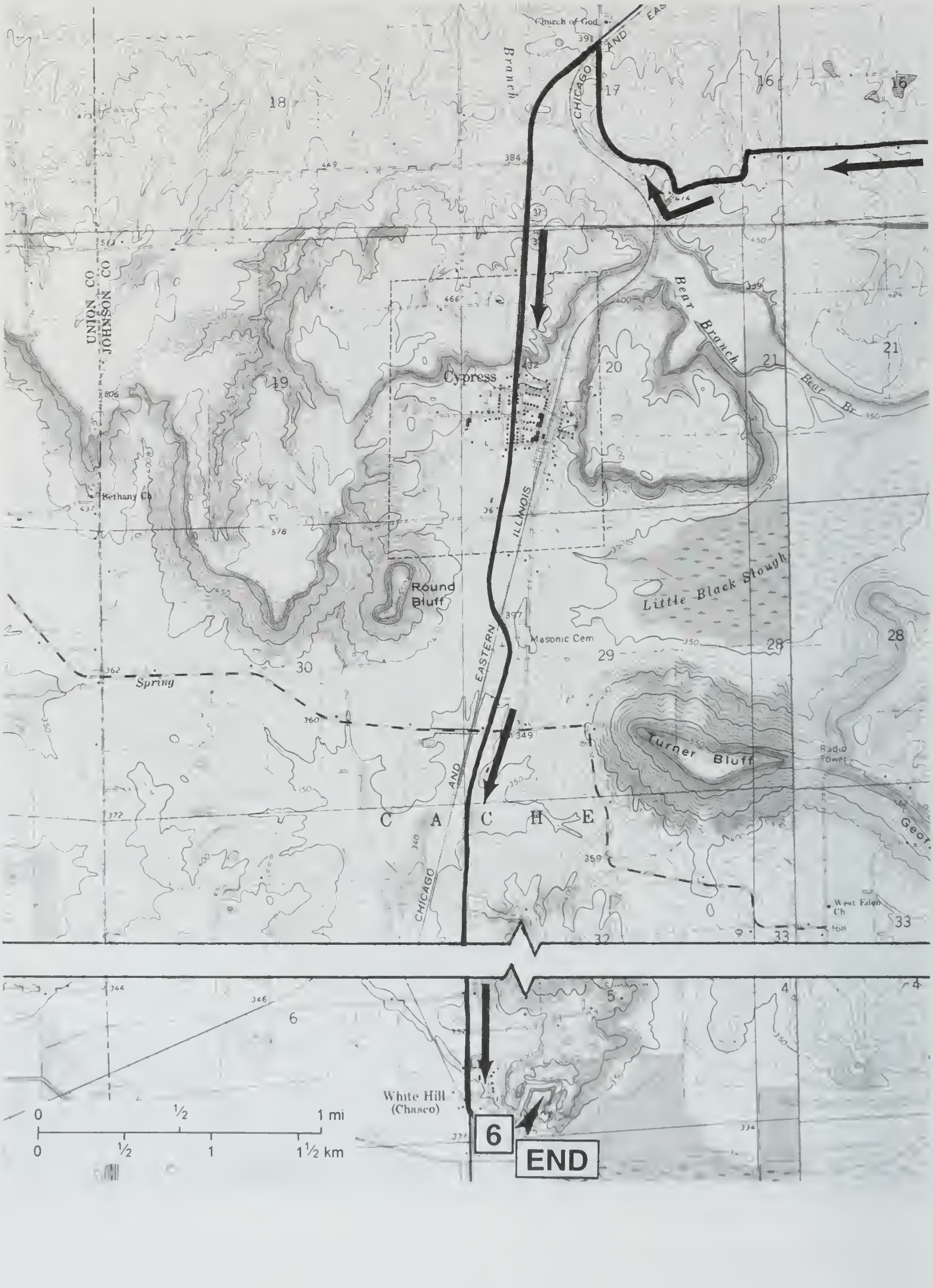
Church of God
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STOP DESCRIPTIONS

STOP 1 Golden Cat Clay Pit (NE NW SW Section 23, T15S, R1E, 3rd P.M., Pulaski County; Olmsted 7.5-Minute Quadrangle) (fig. 12)

The geologic section exposed at the Golden Cat Company's pit includes Pleistocene loess (wind-blown silt) with alluvium and colluvium deposits at the base, which overlie the Pliocene–Pleistocene Mounds Gravel. The Mounds Gravel in turn rests on the Paleocene Porters Creek and Clayton Formations. Near the bottom of the pit, the Paleocene sediments overlie the Cretaceous Owl Creek and McNairy Formations (fig. 7). The company is mining absorbent clay from the Porters Creek and the upper part of the Clayton. This clay is a valuable natural resource that has been mined in this area since about 1920. Early use was mainly as an oil clarifier. Today it is mainly used to make odor and moisture absorbent pet litter, marketed under the brand name Tidy Cat..

The Clayton Formation in southernmost Illinois is up to 20 feet thick. The lower part contains macrofossils, and is generally greenish gray silty clay interbedded with bioturbated glauconitic, micaceous, fine to medium quartz sand and silty clay. The upper part is mainly dark greenish gray sandy, glauconitic clay with occasional thin glauconitic sand beds. Sedimentation occurred in an open marine environment in water depths less than 70 feet (Fluegeman and Masters 1988). The sediments and fossils in the Clayton, as well as the overlying Porters Creek, indicate that sea level rose (transgressed) during the Paleocene and ocean waters spread inland across the Gulf Coastal Plain and Mississippi Embayment, extending into southern Illinois (figs. 8 and 11). The full extent of this marine transgression is unknown due to later erosion of the sediments deposited at that time.
The Paleocene and Cretaceous sediments of southern Illinois are found in what is called the Mississippi Embayment (fig. 5). This embayment is a structural trough in the form of a wedge-shaped inland

Figure 12 Golden Cat Company's pit. Top of the hill is Pleistocene loess over Mounds Gravel, upper bench near top of Porters Creek, and lower bench near top of McNairy (photo by Wayne T. Frankie).

extension of the Gulf Costal Plain. It is both a physiographic and structural feature. The northern limit of the Mississippi Embayment is generally marked by the erosional limit of the Cretaceous to Tertiary age deposits. The late Cretaceous and Paleocene deposits represent the shoreline, open to marine sedimentation, when the waters of the Gulf of Mexico reached inland to the southern tip of Illinois.

Previous research on the Cretaceous-Paleocene section in southernmost Illinois included obtaining two potassium-argon dates on the pelletal glauconite above and below the Cretaceous–Tertiary (K/T) boundary. The uppermost Owl Creek Formation (Cretaceous) was dated at 65.7 ±1.4 million years B.P., and the lowermost Clayton Formation (Paleocene) was dated at 60.6 ±1.3 million years B.P. (Reed et al. 1977).

Scientists at the ISGS , Ball State University, and SIU at Carbondale are currently studying a fossiliferous zone near the base of the Clayton that contains marine microfossils, called foraminifera, and macrofossils that include clams, snails, bryozoans, crab shells, and the bones and teeth of fish, sharks, turtles, crocodiles, and other vertebrates remains. This fossil assemblage indicates that the paleoenvironment of the lower Paleocene sediments is very similar to that of deposits of the same age in the Gulf Coastal Plain from Georgia to Texas. This fauna lived in a shallow near-shore marine environment, as suggested by the presence of thick-shelled clams. The presence of phosphatic nodules and abundant pelletal glauconite indicates at least periodic reducing conditions and slow sedimentation rates on this sea floor. Conditions may have been occasionally brackish because of the presence of a brackish-water form of bryozoan (Mitchell et al. 1997).

Some of these scientists are also currently studying the K/T boundary to determine if the boundary is conformable, and if any evidence exists of the famous metorite impact theorized to have wiped out dinosaurs and other Cretaceous life. The scientists are currently looking for evidence of the tsunami (or tidal wave) from the impact that occured in the Yucatan Peninsula. Evidence of massive tidal waves has been found in the embayment sediments in the Gulf states. In addition, the sediments are being analyzed for the iridium layer that apparently is a signature of this event.

STOP 2 New Lock and Dam at Olmsted (SE SE Section 23, T15S, R1E, 3rd P.M., Pulaski County; Olmsted 7.5-Minute Quadrangle) (fig. 13)

The Olmsted Project

The following information is adapted from the U.S. Army Corps of Engineers pamphlet, *Olmsted Locks & Dam, Ohio River, Under Construction.*

The continuing growth in barge traffic on the Ohio River requires periodic improvements in the waterways transportation infrastructure. Locks and Dams No. 52 and 53, located on the Ohio River between Paducah, Kentucky, and Cairo, Illinois, were completed in 1929. The original locks at Dams No. 52 and 53 were 110 feet wide and 600 feet long. Temporary 110-foot-wide and 1,200-foot-long lock chambers were added later. The antiquated design and age of these structures make it impossible to meet current traffic demands without significant delays.

This strategic reach of the Ohio River provides a connection between the Ohio, Tennessee, Cumberland, and Mississippi Rivers. The area has been described as the "hub" of the Ohio and Mississippi Rivers waterway system. Barge traffic moving between the Mississippi River system and the Ohio,

Figure 13 Lock cofferdam at the Olmsted Locks and Dam Project. The cofferdam is used to hold back the Ohio River during construction of the locks. Approximately 41 acres are within the coffered area (photo by Wayne T. Frankie).

Tennessee, and Cumberland rivers must pass through this stretch of river. More tonnage passes this point than any other place in America's inland navigation system.

In 1995, 97 million tons of goods were shipped through this reach of the Ohio River. The U.S. Army Corps of Engineers and the navigation industry, in a continuing effort to provide for the nation's future navigation needs, is in the process of replacing these aged facilities with one of the largest civil works projects ever undertaken by the Corps.

Construction of the Olmsted Locks and Dam Project, located at river mile 964.4, was authorized by the U.S. Congress on Nov. 17, 1988, by passage of the Water Resources Development Act of 1988 (Public Law 100-676).

The cost of this project is being equally shared by congressional appropriation and the navigation industry. Industry pays a tax on diesel fuel, which goes to the Inland Waterways Trust Fund. The trust fund then pays 50% of the project cost, which is estimated to be over $1 billion.

The Olmsted project will consist of two 110-by-1,200-foot lock chambers located along the Illinois shoreline. The dam will consist of tainter gates, a navigable pass section, and a fixed weir (fig. 14).

In a raised position, the wickets (gates) will maintain the required navigable depths from the Olmsted project upstream to Smithland Locks and Dam. When river flows are sufficient, the wickets can be lowered to lie flat on the river bottom and allow traffic to navigate over the dam without passing through the locks. This arrangement reduces delays experienced when locking through the system is necessary.

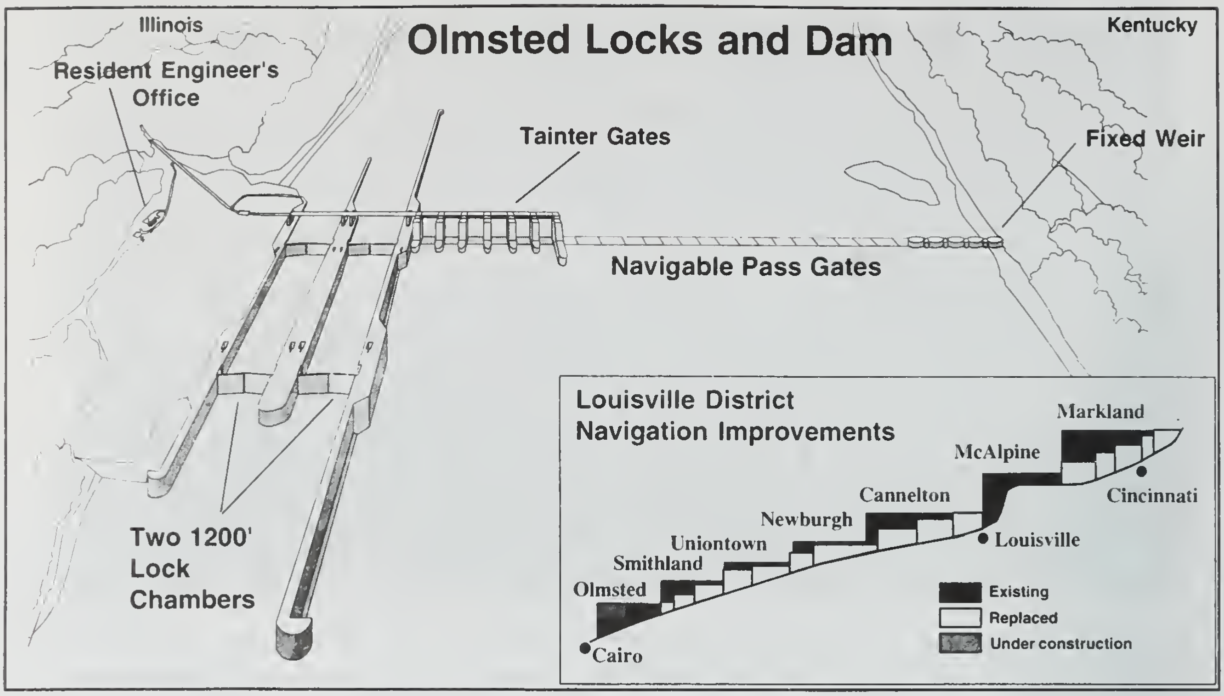


Figure 14 Artist's rendition of the New Locks and Dam at Olmsted (modified from U.S. Army Corps of Engineers).

Benefit The Corps of Engineers estimates that this project will produce an average annual economic benefits to the nation of more than $600 million. Operation and maintenance costs will be reduced. The new locks will operate more efficiently and will pass tows with fewer delays. Delays ultimately raise the price of commodities that move on the waterways. Total lockage time will be reduced from 5 hours through Locks and Dams 52 and 53 to less than 1 hour in the new project. Without the new locks, the Corps estimates lockage wait times of 150 hours per tow by the year 2005 at Lock and Dam 52.

Statistical Information

Dam	
Type	Tainter gates and wickets
Length	2,626 feet
Type of Fixed Weir	Sheet pile cells
Number of Navigable Pass Gates	To be determined
Height of Gates	22.5 feet
Length of Gates	26 feet
Upper Pool Elevation (mean sea level)	302 feet
Tailwater Elevation	Uncontrolled
Locks	
Location	Along Illinois bank
Number of Chambers	2
Size	110 feet by 1,200 feet
Elevation of Lock, Wall Top	310 feet
Lock Sill Elevation	261 feet
Type of Lock Gates	Mitering
Height of Lock Gates	62 feet

Navigational Locks Figure 15 illustrates the mechanics involved in moving a vessel through a lock from the upriver to the downriver level. The process is reversed for a vessel going upstream.

History of Navigation Improvements In 1885, the first Corps-built lock and movable dam project on the Ohio River was completed at Davis Island near Pittsburgh, Pennsylvania. In 1910, by passage of the Rivers and Harbors Act, Congress authorized the Corps of Engineers to upgrade, improve, and maintain locks and dams on the nation's navigable waterways. This general authority was used to construct a system of 50 locks and dams on the Ohio River plus improvements to Lock and Dam 41 at Louisville, Kentucky. That system was completed in 1929 at a cost of about $125 million. It provided a minimum 9-foot channel depth for year-round navigation. Locks and Dams 52 and 53 were the last two of these projects completed.

The original dams were made of wooden wickets that were manually raised to hold back water during periods of low flow and dropped to the river bottom during high water. The adjoining 600-foot locks were adequate until after World War II, when longer tows came into use with diesel-powered towboats. These towboats, which were capable of pushing 25,000-ton loads, soon could not operate efficiently through a system designed for the less powerful steamboats. The system, completed in 1929, was obsolete, and by the 1950s, the Corps of Engineers began replacing these structures with a new system of modern high-lift locks and dams. The new system featured 110-by-1,200-foot lock chambers and made water-borne transportation more efficient by creating longer pools with fewer lockages. For example, the Markland Locks and Dam project at river mile 531.5 replaced five of the older structures.

The first modern structure was Greenup Locks and Dam at Ohio River mile 341, with the locks becoming operational in 1959. It is important to note that these "modern" locks and dams are aging. As these projects age, necessary repairs become more frequent and more extensive and, therefore, more costly.

Contrary to popular belief, these structures have no effect on flood levels. They neither reduce nor increase flood levels but are solely intended to create navigation pools to provide required navigable depths. Flood control is provided through a system of reservoirs on Ohio River tributaries and with levees and flood walls protecting urban and agricultural areas.

Water-borne transportation is the most economical mode for transporting bulk commodities such as coal, grain, aggregates, petroleum products, and chemicals. The Ohio River navigation system saves American consumers millions of dollars each year, while helping to conserve energy resources.

STOP 3 Old Locks and Dam 53, at Olmstead (SW NW Section 18, T15S,R2E, 3rd P.M., Pulaski County; Olmsted 7.5-Minute Quadrangle) (fig. 16)

Locks and Dam 53

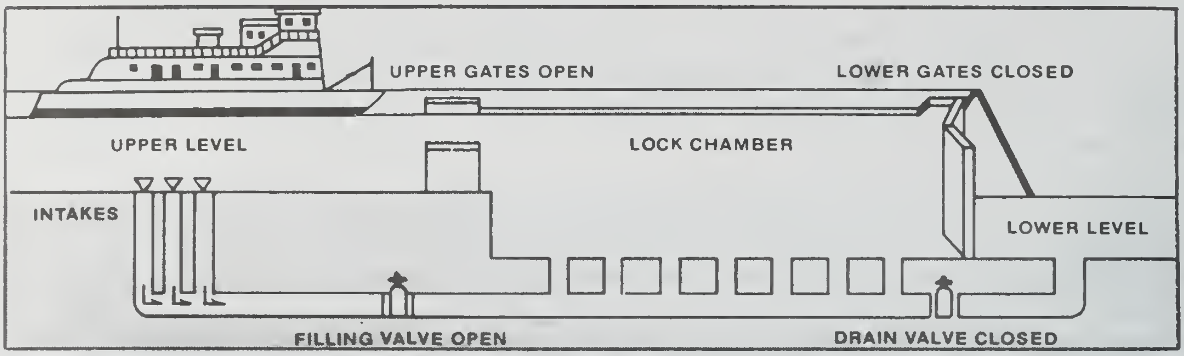
The following information is adapted from the U.S. Army Corps of Engineers pamphlet, *Locks & Dam 53: The Ohio River ... Artery of Development.*

The rivers of this country have long been recognized as vital links in a transportation network—water highways—carrying goods and raw material necessary to the commerce of the nation.

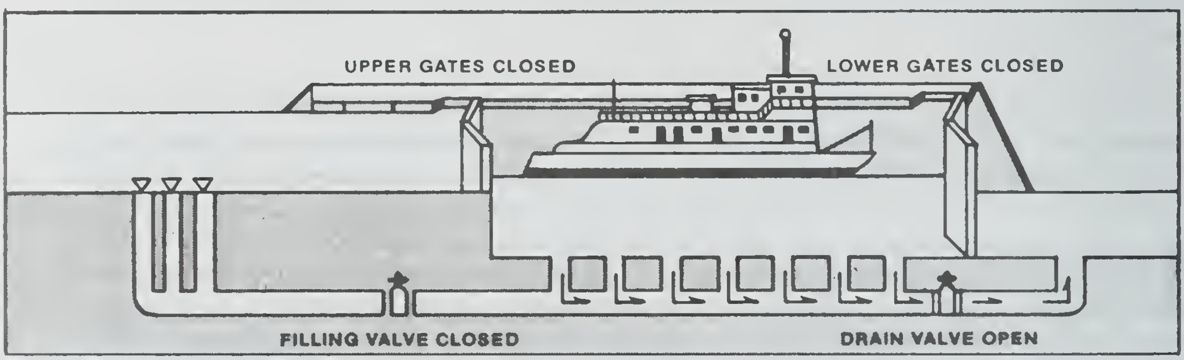
How Navigation Locks Work

To provide adequate depth for navigation at all seasons, the Ohio River and major tributaries have been improved through the building of locks and dams. Each dam impounds a pool for navigation. The locks provide the means by which vessels are raised or lowered from one pool to the next.

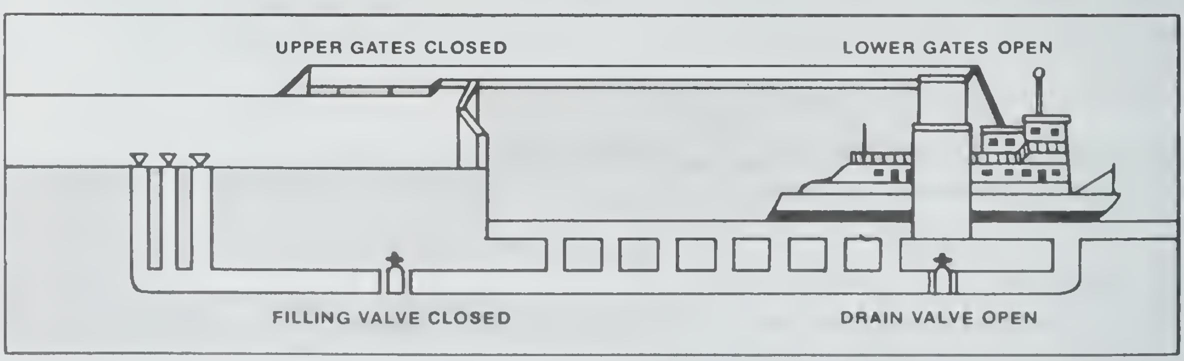
The accompanying diagrams show how locks function. A towboat is here being passed from the upriver to the downriver level.



The lower lock gates are closed; the drain valve is closed; the filling valve is open; the lock has filled to the level of the upriver pool; and the upper lock gates have been opened to allow the towboat to enter the lock



Now the towboat is in the lock; the upper lock gates have been closed; the filling valve is closed; the drain valve is open, allowing water to drain into the downriver pool. The towboat is lowered as the water level lowers



The water in the lock has here reached the level of the downriver pool. The lower lock gates have been opened and the towboat is leaving the lock to proceed on its way downriver

Figure 15 Operation of navigation locks (modified from U.S. Army Corps of Engineers, Ohio Division pamphlet 1979).

Figure 16 Locks and Dam 53, near Olmsted at river mile 962 (photo by Wayne T. Frankie).

The Congress of the United States foresaw and recognized this when it gave the Corps of Engineers its first Civil Works Mission in 1824. Congress authorized the Corps to spend $75,000 removing the snags—dead trees—and dredging the river bottom on both the lower Ohio River and part of the Mississippi River.

By 1929, additions and modifications to the original plan resulted in a navigation system of 50 locks and dams (later modifications reduced this number to 46). Each of the dams on the Ohio had a lock chamber that measured 600 feet by 110 feet. With the year-round capability and the 9-foot depth, the Ohio River churned with activity.

The advent of diesel-powered towboats coupled with the demand for increased tonnage, produced tows that often surpassed the 600-foot capacity of the existing lock chambers. When this occurred, it was necessary to break the tow and lock it through in two sections, using cables and winches to move the first section out of the chamber. The tow was then reassembled to proceed to the next lock, where the process would be repeated. This procedure, called “double locking,” was a hazardous operation and often required 2 to 3 hours to complete. The result was a 5-o’clock rush hour, 24 hours a day.

To relieve this congestion on the river, in the early 1950s Congress authorized the Corps of Engineers to begin replacing the old structures with 19 modern dams. The new structures were to feature at least one 1,200-foot lock for the larger tows in addition to an auxiliary lock, usually 600 feet long.

Locks and Dam 53, the navigation structure nearest the mouth of the river at Cairo, Illinois, is actually a remnant of the original 1929 system. A temporary 1,200-foot lock has been built at this project to handle the traffic that moves in this area. Construction on this lock began in August 1974, with the lock being fully operational by November 1980.

This is a low-cost structure that provides an immediate relief to the traffic jam (as much as 3-day waits) that was occurring.

The temporary 1,200-foot lock at Locks and Dam 53 was designed similar to an earlier structure built at Locks and Dam 52, Ohio River. The Locks and Dam 52 structure, designed and constructed in just over a year, won a Chief of Engineer's Award for its many innovative technical features.

Location Locks and Dam 53 is located on the Ohio River approximately 11 miles upstream of Mound City, Illinois. The navigation locks are located on the Illinois side of the river approximately 962 miles downstream from Pittsburgh, Pennsylvania. The upper pool above the dam extends upstream for a distance of 23 miles to Locks and Dam 52.

Statistical Information The dam is a wicket type with an overall length of 3,662 feet. It has a navigable pass of 932 feet, 340 feet of chanoine weir, 160 feet of bebout weir, two 91-foot beartraps with piers, 102 feet of fixed weir, and 1,894 feet of core wall. The upper pool elevation is 290 feet above msl and the lower pool elevation is 276 feet above msl

The two adjacent parallel lock chambers are located on the Illinois bank of the Ohio River. The original lock measures 110 x 600 feet. The new lock is 110 feet wide x 1,200 feet long. Gates are of mitering type and are operated by hydraulic cylinders. Filling and emptying time is about 20 minutes.

Geology

At this stop, exposures of Pleistocene deposits (consisting of loess and reworked Mounds Gravel deposits, and underlying Late Cretaceous McNairy strata) (fig. 7) occur in the bluff and along the bank of the Ohio River, south of the locks and dam.

The following geologic section was compiled from various outcrops in the vicinity of Locks and Dam 53 by Pryor and Ross (1962).

Cretaceous System	**Thickness (ft)**
Gulfian Series	
McNairy Formation	
Sand, red at top grading down to buff, very micaceous, fine to medium, cross-stratified.	30.0
Levings Member: Silt, white to light gray, very micaceous, clayey, structureless except in lower part where it is interlaminated with underlying material.	27.5
Silt, dark brownish gray, very micaceous, very clayey, slightly lignitic, abundant pyrite nodules, leaf-bearing, well laminated.	10.0
Silt, light brown, very micaceous, very clayey, slightly lignitic.	3.5
Silt, black to grayish brown, very micaceous, very clayey, very lignitic; abundant pyrite nodules, abundant leaf fossils; well laminated.	2.5
Silt, black, very micaceous, slightly clayey, very carbonaceous, slightly lignitic; abundant pyrite nodules; well laminated.	3.0
Lignite, dark brown.	0.25
Silt, black, clayey, micaceous, carbonaceous with rootlets at top, structureless.	2.75

Silt, black, clay, black, interlaminated, very micaceous, very lignitic in upper 1 foot, very pyritic.	5.0
Lignite, black to dark brown, very silty.	0.2
Silt, black, very carbonaceous, slightly micaceous, very pyritic, slightly laminated at base grading upward into massive structure with plant rootlets.	2.0
Clay, black to grayish black, very silty, very micaceous; abundant pyrite nodules.	3.0
Base: concealed at river level	

In southern Illinois, the late Cretaceous rocks (fig. 7) include the Tuscaloosa, McNairy, and Owl Creek formations. At the base of the Tuscaloosa is a soil stratigraphic unit named the Little Bear Soil. This soil, developed in the weathered zone at the top of the Mississippian or older Paleozoic bedrock, is overlain by Cretaceous age sediments. It is thought to be early Cretaceous in age, although Jurassic-aged material may have been discovered recently within this ancient soil unit. Overlying the McNairy in a small area of Pulaski County near the Ohio River, is an interval of glauconitic, micaceous sandy, silty clay up to 10 feet thick. This unit is the Owl Creek Formation, also of late Cretaceous age. It conformably overlies the McNairy and is thought to represent a brief advance of the Gulf sea waters over the deltaic sediments of the McNairy. The Owl Creek is not present at this stop.

The McNairy Formation is composed of nonmarine, fine, cross-stratified, micaceous sands, with numerous thin beds of lignitic silt and clay from 25 to 450 feet thick. The lower part of the formation consists of fine, white to light gray, cross-bedded, micaceous sand. Locally in the upper part of the formation, there is a distinct facies, consisting of gray to black silt with beds of lignite, named the Levings Member. (This is likely what we see here in the bank of the Ohio River.) The upper part of the McNairy, seen in the bluff at this stop, is similar to the lower McNairy and consists of white to light gray, cross-bedded, micaceous sand. In the areas where the McNairy is overlain by the Mounds Gravel (Pliocene to Pleistocene in age), such as at this stop, red iron oxide may stain the McNairy downward for about 50 feet. These stains are part of the colloidal clay and iron-oxide accumulation zone of an ancient (early Pliestocene or late Tertiary) soil.

The Tuscaloosa sediments are quite discontinuous and, in many areas, the McNairy directly overlies the older Paleozoic rocks. The Tuscaloosa sediments were deposited in a nonmarine fluvial environment. The McNairy Formation is the result of deltaic deposition in the northern end of the Mississippi Embayment (fig. 5). The sands represent fluvial (river) or long-shore beach deposits, whereas the lignitic clays and silts were deposited in the floodplain of the delta between the distributary channels of the river.

STOP 4 Lower Cache River Access Area (NW NW NE Section 13, T14S,R1E, 3rd P.M., Pulaski County; Cypress 7.5-Minute Quadrangle) (fig. 17)

Cypress Creek National Wildlife Refuge—*by Elizabeth Jones, U.S. Fish and Wildlife Service*
A valuable natural resource exists in southernmost Illinois. It is abundant with water-tolerant trees—bald cypress and tupelo gum, carpets of duckweed, and sounds of life. A visitor would not be a bit surprised to see the snout of an alligator protruding from the murky shadows of this swampy landscape.

Figure 17 Tall bald cypress trees and buttonbushes in the Buttonland Swamp at the Lower Cache River Access Area (photo by Wayne T. Frankie).

Well, alligators might not exist in this "bayou," but lots of other animals do. This resource, reminiscent of places much farther south, is the Cache River Wetlands.

Cradled in the arms of the Ohio and Mississippi Rivers, the Cache River Wetlands is one of the largest remaining wetlands in the state; it protects 1,000—year-old trees and provides a safe haven for over 50 state-threatened and endangered species. To some people's disbelief, a visit to the Cache River Wetlands, does not require tall boots, bug nets, and a machete. The Cache River Wetlands offers a peaceful experience, and a variety of opportunities to view wildlife in a natural setting—a setting that has existed for thousands of years.

The area is managed by the Cache River Wetlands Joint Venture which includes three organizations: Cypress Creek National Wildlife Refuge (Refuge), The Nature Conservancy (TNC), and the Illinois Department of Natural Resources (which includes Cache River State Natural Area, Mermet Lake, and Horsehoe Lake).

Public events, guided tours and hikes are offered throughout the year. Trails, boardwalks, and canoes provide access into the heart of the Cache River Wetlands. Public lands within the Refuge, the Cache River State Natural Area (SNA), and TNC are accessible year round for hiking, hunting, fishing, canoeing, birdwatching, and wildlife observation. Areas within the Cache River Wetlands are also available for educational use.

Opportunities include:

- Hunting and Fishing – Hunting and fishing are permitted throughout the area (except in dedicated Nature Preserves). Information and specific regulations are available at the Refuge Headquarters.
- Wildlife Observation – Waterfowl, barn owls, wild turkeys, song birds, egrets, great blue herons, bald eagles, river otter, bobcats, coyotes, fox, and white tail deer are a few of the species found within the Cache River Wetlands. Wildlife viewing opportunities exist throughout the area; you may contact the Refuge or SNA Headquarters for specific observation sites.
- Hiking – Over 20 miles of hiking trails offer the best way to experience the rich diversity of the Cache River Wetlands. Limekiln Springs, Heron Pond, Wildcat Bluff, and a variety of other natural sites along the Cache offer scenic hiking opportunities. Many trails are found within the SNA. Currently, other trail access sites are planned for development on the Refuge over the next several years.
- Canoeing and Boat Access – Boating the Cache River offers opportunities to hunt, fish, and observe wildlife. The Refuge and SNA provide boating accesses along the Cache.
- Education – Field trip opportunities and environmental education programs are currently available to schools and other special interest groups.

Future plans for the Refuge call for a Wetland Education Center. The Centers, associated programs, and exhibits will provide people with a greater understanding of our dependence upon natural resources (clean air, water, soil, plants and wildlife), provide a central location for area information, immerse visitors in a wetland world through interactive exhibits and educational experiences, and help generate public support for the Cache River Wetlands and surrounding area. Whether or not individuals (students or visitors) hike or canoe the area first-hand, this facility will provide visitors with a memorable experience, as well as spark a tourist economy and new rural development.

A crucial component of the Joint Venture's stewardship role is to provide educational and recreational opportunities for citizens. These efforts will help increase understanding of this internationally significant resource in order to protect the Cache River Wetlands on a long-term basis.

Now, you should know a lot more about the opportunities within the Cache River Wetlands. Hopefully, you agree it is an exciting place to learn about and explore. So, what are you waiting for? For more information regarding educational or recreation opportunities or special public events in the Cache River Wetlands, contact Cypress Creek National Wildlife Refuge at 618-634-2231.

Cache River Wetlands

The following is adapted from the U.S. Department of Interior's pamphlet *Cypress Creek National Wildlife Refuge.*

This unique area is a diverse and complex web of life comprised of bald cypress and tupelo swamps, bottomland forests, and rolling upland. The Cache River Wetlands harbors over 250 species of migratory waterfowl, wading birds, and neotropical migrant songbirds. This richness and diversity of life is a result of four converging regions (or physiographic divisions, see fig. 11) of differing climate and topography. One of the regions is the Gulf Coastal Plain; it extends into the southern tip of Illinois and provides conditions that support tupelo and cypress swamps and wildlife associated with areas much farther south, such as Louisiana and Florida.

This "Illinois bayou"

- is the largest remaining wetland in the state,
- shelters over 50 state endangered and threatened species,
- includes two National Natural Landmarks,
- protects 1,000 year old cypress trees (claiming a number of state champion trees), and
- is designated a wetland of international importance by the RAMSAR Convention.

Bringing it Back During the past 90 years, 230,000 acres, more than half of the former wetlands in southern Illinois, have been drastically destroyed and changed. Native Americans found the Cache River Valley rich with resources and did very well trapping, hunting, and fishing. The first European settlers arrived in 1803 and brought sawmills, farming, and finally drainage and land clearing to the region. Although bottomland soils were rich, they were too wet for farming, eventually turning many settlers' efforts to harvesting timber.

In the early nineteenth century, market hunting and sawmills fueled the local economy. Pilings were cut from huge cypress trees to rebuild Chicago after its devastating fire in the late 1800s. In the early 1900s, the Cache River was straightened and ditched, diverting the natural river's path into separate directions. New technology and equipment of the 1920s brought extensive land clearing, and newly drained wetlands were converted to croplands. Today, after nearly a century of intensive use, the tide of wetland destruction is being reversed.

Cache River Wetlands Project—Working Together! A cooperative preservation and restoration effort called the Cache River Wetlands Joint Venture is working to protect and restore a 60,000-acre wetland corridor along 50 miles of the Cache River. Partners in this effort include the Cypress Creek National Wildlife Refuge (Refuge), the Illinois Department of Natural Resources (IDNR), The Nature Conservancy (TNC), and Ducks Unlimited, with support from the Citizens Committee to Save the Cache River. These efforts will repair natural ecosystems and provide hunting, fishing, hiking, canoeing, and other recreational experiences while expanding the region's economic diversity. Through this Joint Venture and citizen involvement, restoration and protection of the Cache River Wetlands is well under way.

Cypress Creek National Wildlife Refuge (U.S. Fish and Wildlife Service) Cypress Creek National Wildlife Refuge established in 1990, is one of over 500 refuges across the nation. The Refuge will eventually encompass 35,000 acres of the Cache River Wetlands. It consists of valuable forests and wetlands, along the Cache River and Cypress Creek. The emphasis at the Refuge is on land acquisition, restoration, and the construction of a wetlands education center.

U.S. Fish & Wildlife Service
Cypress Creek National Wildlife Refuge
Rt. 1, Box 53D
Ullin, IL 62992
(618) 634-2231

The Nature Conservancy The Nature Conservancy (TNC) is an international conservation organization which strives to protect habitat for native plants and animals. The Illinois Chapter of TNC has been active in preservation and restoration efforts along the Cache River since 1970. The organization shares a headquarters with the Refuge, and owns and manages Limekiln Springs Preservation.

The Nature Conservancy
Rt. 1, Box 53E
Ullin, IL 62992
(618) 634-2524

Ducks Unlimited Once the owner of 1,000 acres within the Joint Venture area, Ducks Unlimited developed shallow water areas on the Frank Bellrose Waterfowl Reserve. The organization no longer owns land within the project, but remains a strong supporter of the Cache River Wetlands.

Ducks Unlimited, Inc.
1 Waterfowl Way
Long Grove, IL 60047
(708) 438-4300

Citizens Committee to Save the Cache River The Citizens Committee, a community-based organization, was established in 1979 to promote conservation practices in the Cache River drainage basin. The Joint Venture exists due to their efforts over the past 25 years.

Cache River State Natural Area (Illinois DNR) (fig. 18)
The following information is adapted from the Illinois Department of Natural Resources pamphlet *Cache River State Natural Area*.

This large state-owned and managed area contains 10,430 acres, and is composed of two distinct management units that include the Little Black Slough and the Lower Cache, situated on the Cache River in Johnson and Pulaski Counties. Little Black Slough lies on the Upper Cache River north of Belknap, while Lower Cache is along the stretch of the Lower Cache River from Karnak to Perks.

Lower Cache is best known for its remnant examples of high-quality wetland natural communities, which once were so prominent in the Cache River valley. The most striking examples of these wetlands include bald cypress and tupelo gum swamps with trees more than 1,000 years old. Native oak and hickory trees grow in the flatwoods and wet forests next to the swamps. Little Black Slough also is well known for its cypress and tupelo swamps and rich mixed hardwood floodplain forests as well as upland woods with small patches of limestone barrens (prairie-like communities). In these unique wetland and upland natural communities, the visitor can expect to see many of the plants and animals native to southern Illinois, including a blending of northern and southern species.

The Cache River State Natural Area has three dedicated nature preserves. Two preserves, the Heron Pond-Wildcat Bluff Preserve and the Little Black Slough Preserve are located within the Little Black Slough unit, while the Section 8 Woods Preserve is located east of Illinois Route 37 on the Lower Cache unit.

The National Park Service has registered two National Natural Landmarks within the Cache River State Natural Area. The Cache River State Natural Area is nationally significant because it contains true southern swamps at the northern part of their range. At last count, this area contained 39 state-threatened or endangered plant and animal species and eleven state champion trees.

Site objectives The main objective at Cache River State Natural Area is to preserve, protect and enhance the natural resources while providing the opportunity for quality outdoor recreation. Critical habitat is managed to preserve and protect endangered, threatened and rare plants and animals.

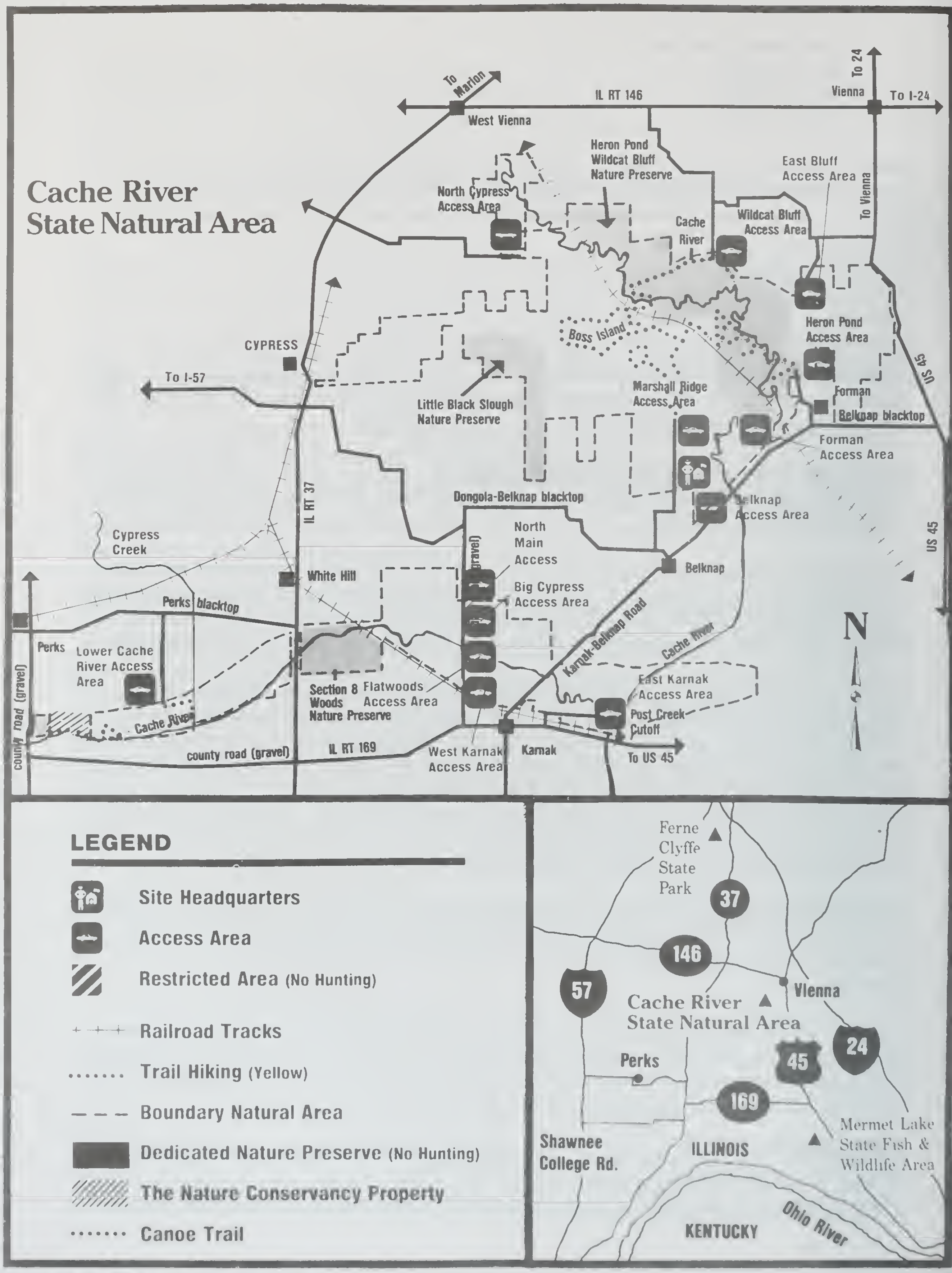


Figure 18 Cache River State Natural Area

In addition, three areas have been dedicated as Illinois Nature Preserves to ensure permanent protection of examples of some of the outstanding natural communities characteristic of deep southern Illinois. Compatible outdoor recreational uses include sightseeing, birding, hiking, hunting, fishing, and canoeing. The area is also available for scientific research and educational use by permit.

History Early uses of the Cache River valley include the activities of Native Americans: sustenance trapping, hunting and fishing. Later settlers of European descent brought sawmills, farming, and finally drainage and land clearing to the region.

Native Americans found the area rich in wildlife and did well in their trapping, hunting, and fishing efforts. During 1803, the first European settlers came to the Cache River basin and began clearing small patches for farming. Although the bottomland soils were rich, they were too wet for farming, and the settlers eventually turned their efforts toward harvesting the timber. The Bell Company, the Main Brothers Box and Lumber Company, and others built sawmills around 1870 and began to harvest large quantities of timber for lumber, veneer for manufacturing baskets and boxes, railroad ties, mine timbers, and charcoal. Large-scale drainage and land clearing efforts began in the early 1900s.

Since then, thousands of acres of bottomland in the Cache River valley were brought under cultivation. In 1970, the State of Illinois began land acquisition efforts in the Little Black Slough unit and purchased 1,123 acres that now make up the Heron Pond-Wildcat Bluff Preserve. In 1973, the Main Brothers sold their holdings to Westvaco Corporation. With the assistance of the Nature Conservancy, the Westvaco land was acquired by the State of Illinois in 1975. Today, almost one-quarter of the Little Black Slough unit is dedicated as an Illinois Nature Preserve. In 1982, the State of Illinois bought the first tract of land on the Lower Cache unit. Since that time, the Lower Cache unit has grown to more than 3,000 acres, including the Section 8 Woods Nature Preserve.

The acquisition and establishment of the Cache River State Natural Area was due to successful cooperation between private, governmental, and commercial groups working together to protect this unique natural resource. All plants, animals, and natural features of the area are protected by law to ensure their existence for future generations. Scientific and educational use of the area is allowed by permit, issued by the Illinois Department of Natural Resources. Hunting and fishing are allowed in designated areas outside of the nature preserves.

For information about the area, contact Site Superintendent, Cache River State Natural Area, 930 Sunflower Lane, Belknap, IL 62908 (618) 634-9678. For more information on other Department of Natural Resources areas, write the Illinois Department of Natural Resources, Office of Resource Management, 524 South Second Street, Springfield, IL 62701-1787.

Wetlands

Groundwater Like windows in the watertable, wetlands are low-lying areas where the ground surface is below the water table (the top of the saturated zone) and are wet for at least part of the year. The waterlevel in a wetland marks the elevation of the watertable.

Wetland types include swamps, marshes, bogs, and fens. Wetlands not only depend on their existance for periodic groundwater discharge, but they may also provide critical recharge areas for groundwater when the water table is low.

Illinois' abundant wetlands play many important ecological roles; these include reducing the risk of flooding by storing water; improving water quality by filtering sediments, and absorbing nutrients, and contaminants; reducing erosion; and providing unique habitats for numerous plants and animals. Changes in either the quality or quantity of their groundwater supply can severely affect the health of wetlands, which in turn are critical for maintaining the health of groundwater and ecological systems.

Defining Wetlands—*by Nancy L. Rorick, Illinois State Geological Survey*

The U.S. Army Corps of Engineers (1987) designates an area a jurisdictional wetland on the basis of hydrology, soils, and vegetation. A jurisdictional wetland is subject to regulation under the U.S. Army Corps of Engineers 404 permit. A wetland delineation is the classification of an area as a jurisdictional wetland by a trained scientist.

Hydrology The water level in a jurisdictional wetland can range from a maximum of 6.6 feet of standing water to no standing water, if the soil is saturated to the land surface. To meet the hydrology qualification, the soil must be saturated continuously for at least 5% of the growing season during 1 out of 2 years. Obviously, the area covered by water in Buttonland Swamp is a wetland; but if the delineation is done in late summer, there may be no standing water in a wetland. For example, the wetland boundary for Buttonland Swamp extends beyond the low-water level observed in the fall. A wetland expert would look for other signs that an area is inundated, such as watermarks on trees, debris lines, sediment deposits, and silt-coated vegetation. If standing water is absent, soil saturation can be determined by digging a 16-inch-deep hole. If the soil is saturated, water will seep into the hole. Another source of hydrologic information is records from stream gages. Figure 19 shows a hydrograph of water-level elevation over time in Buttonland Swamp.

Soils *Soils developed in wetlands are hydric soils* that have developed special characteristics (*redoximorphic features)* from being saturated for long periods. Hydric soils lack oxygen and are anaerobic due to prolonged wetness. Decay of plant debris under anaerobic conditions is very slow. This allows plant material to accumulate as deposits of peat and muck. Soils composed primarily of peat or muck are *organic soils* and are considered hydric soils. Soils composed primarily of nonorganic materials are *mineral soils.* Color is a major indicator of redoximorphic features in mineral soils. In the presence of oxygen, iron is oxidized and is brown or red in color; in the absence of oxygen, the iron is reduced and is bluish, greenish, or grayish in color. These reduced colors are called gleyed. If saturation is less frequent, the soils lack color (have a low chroma) and are dull grey, brown, or black. Frequently, these soils have bright *mottles (*reddish brown spots) where the iron is oxidized. In hydric soils, brightly colored aureoles (*oxidized rhizospheres*) frequently develop around live roots (Mitsch and Gosselink 1993). Other indicators of hydric soils are manganese and iron oxide nodules. The Natural Resource Conservation Service has published a list of hydric soils that is available on the Web at: http://www.statlab.iastate.edu:80/soils-info/

A note of caution: redoximorphic features can persist after a wetland is drained. These former wetland soils are *relic hydric soils.*

Vegetation The prevalent vegetation in a jurisdictional wetland is species that are adapted to living in wet conditions. The cypress tree has adapted to saturated conditions by developing buttressed trunks for stability and knees for respiration.

Buttonland Swamp

Soils The soil that covers most of Buttonland Swamp is the Karnak Series (United States Department of Agriculture 1968). The Karnak Series is included on the state hydric soil list (United States

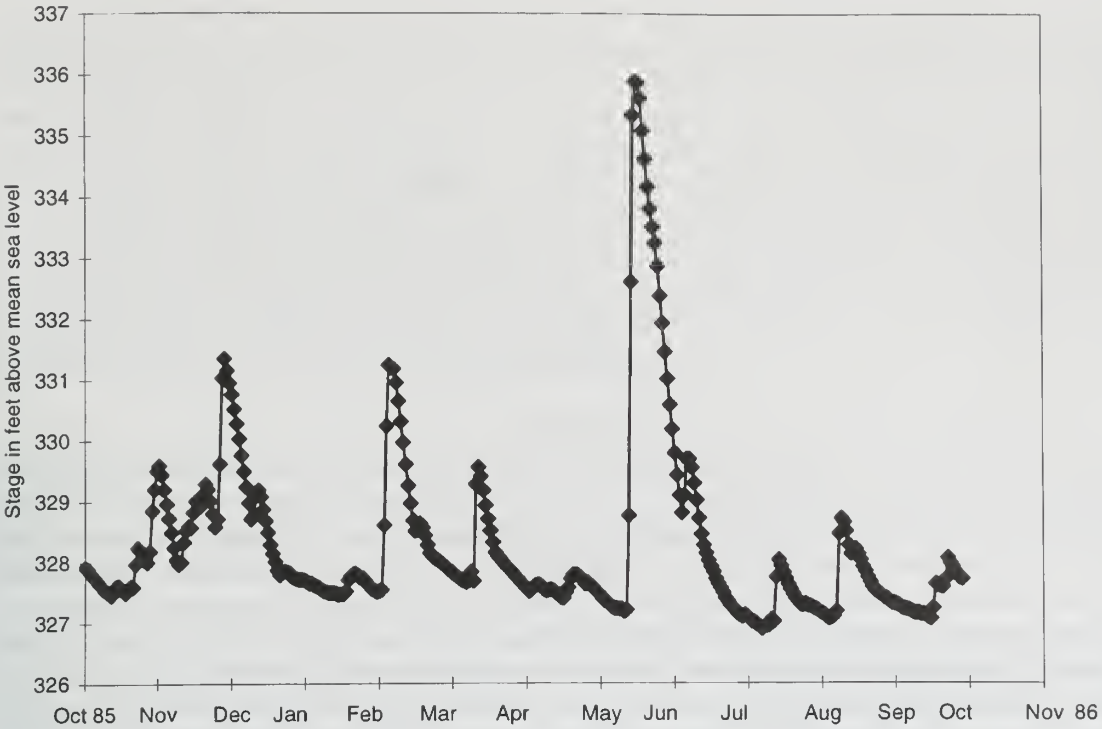


Figure 19 Water-level elevation in Buttonland Swamp recorded at the IL 137 bridge by the Illinois State Water Survey (modified from Demissie et al. 1990b).

Department of Agriculture 1995) and is recognized as hydric because of its dark gray color and prominent mottles. It is very poorly drained and is formed in fine-grained slack water deposits. North and up slope of the boat dock at the Lower Cache Access Area, the Karnak grades into the Sciotoville and Wheeling soil series. Both soils are developed in alluvial material deposited by the Ohio River; the Sciotoville on low ridges, and the Wheeling on terraces. Both soils are silt loams, brownish colored, and non-hydric.

Hydrology The Lower Cache River was channelized in the 1930's (Demissie et al. 1990). This channel still forms a well-defined passage through Buttonland Swamp. Further dredging and clearing occurred in Buttonland Swamp during the 1960s. Today, the swamp is permanently flooded due to the construction of the Diel Dam west of the Perks Bridge in 1982. A second rock dam was constructed in 1995 just west of the IL 37 bridge.

Figure 20 is a profile of the channel thalweg (the deepest part of the channel) from the Cache Chapel Road Bridge east to the Cache River Levee. The figure illustrates the influence of beaver dams on the water level in the swamp. The Lower Cache River is unusual in that water flows both east and west. Water leaves the Lower Cache River at the east end through culverts in the Cache River Levee and at the west end through the Cache River Diversion Channel into the Mississippi River (Demissie et al. 1990a). The channel profile (fig. 20), shows that the highest point in the Lower Cache River occurs between the two water outlets, which explains how the two-directional flow can occur. The location of the east–west flow divide is not fixed, but is dependent on the water level in the swamp and the amount of water entering the swamp from its tributaries (Allgire 1991).

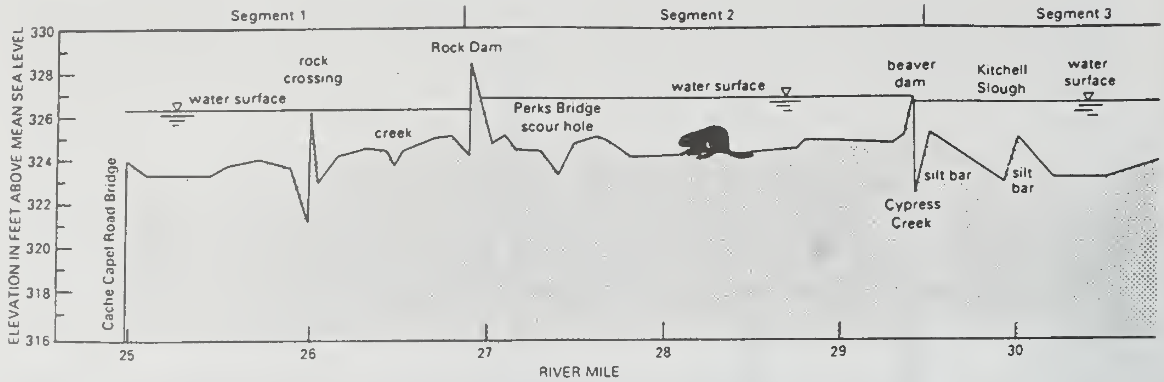


Figure 20 Bed profile of the Lower Cache River, October–November 1989 (modified from Allgire 1991).

Although Buttonland Swamp is permanently flooded, figure 19 shows that water-level fluctuations still occur. These water-level fluctuations are extremely important to cypress regeneration (Middleton, unpublished). Cypress seeds are typically viable for only 1 year. To regenerate, cypresses require high water in the winter followed by dry conditions in the summer. The seeds float and are dispersed by winter floods. Germination can only occur in the absence of standing water, so a period of drawdown is necessary. The period of drawdown must be prolonged because seedlings will die if they are submerged for more than 2 weeks during the growing season. The impoundment of Buttonland Swamp limits cypress regeneration to a narrow ring around the perimeter of the swamp (Middleton *unpublished*).

Changes in the watershed have also altered Buttonland Swamp by causing a large influx of sediment. In 1986, an estimated 131,600 tons of sediment was deposited in Buttonland Swamp (Demissie et al. 1992). Much of the sediment entering Buttonland Swamp is deposited behind beaver dams and log jams (Allgire 1991). The excessive sediment entering the swamp has eroded from stream banks and cleared and cultivated land (Demissie et al. 1990a).

Formerly meandering stream channels, including Cypress Creek just east of the Lower Cache Access Area, have been straightened or channelized. This straightening, by increasing the gradient and shortening the stream length, allows water in the stream to flow at a faster rate than it did before channelization. The fast flowing water is more erosive and can carry more sediment than the slow flowing water in the previously meandering channel. Channelized streams tend to downcut and are lower in elevation than the previous meandering stream and the surrounding land surface. Cleared, cultivated, and urban lands generate more runoff and sediment than unaltered landscapes. Channelized streams in developed watersheds are efficient transporters of water and sediment, which can lead to both enhanced flooding and sedimentation in downstream areas.

Wetland Vegetation—*by Alicia Admiraal, Illinois Natural History Survey*

The prevalent plant species in a jurisdictional wetland are hydrophytic; that is, they typically occur in areas permanently flooded or periodically saturated. Many of these species have developed physiological and physical mechanisms to deal with inundation and anaerobic soils. Some adaptations include specialized tissue with large air spaces to aerate underwater roots (for example, arrowhead), buttressed trunks for stability (for example, bald cypress), and adventitious roots that grow from stems or branches (for example, willows).

Cache River vegetation The Cache River basin contains an unusual Illinois natural community—the swamp. A swamp is a forested, permanent or semi-permanent body of water. Shrub swamps have a similar hydrologic regime but are characterized by greater than 50% areal cover of shrubs and less than 20% tree cover (White and Madany 1978). Presently, the canopy vegetation in deep water areas is dominated by tupelo (*Nyssa aquatica*), bald cypress (*Taxodium distichum*), and red maple (*Acer rubrum* var. *drummondii*). These species, especially cypress, are known for their ability to withstand long periods of inundation. Shrubs include buttonbush (*Cephalanthus occidentalis*), named for its button-shaped flower heads and fruits. Buttonbush is the major species in buttonland swamp. Historically, the region of the Lower Cache River had a more diverse plant species community. Clearing, logging, and hydrologic alterations all contributed to changes in species composition, abundance, and distribution (Taft and Mankowski 1997).

Two shrubs, swamp rose (*Rosa palustris)* and Virginia willow (*Itea virginica*), are typically found growing on floating logs and buttressed trunks in deeper water. Other species that thrive in this moss-covered habitat include common beggar-ticks (*Bidens frondosa*), marsh St. John'swort (*Triadenum walteri*), mad-dog skullcap (*Scutellaria lateriflora*), and stalked water horehound (*Lycopus rubellus*) (Taft and Mankowski 1997).

Diminuitive floating aquatic plants are often very abundant in the swamp. These plants can form a blanket across the surface. Close examination reveals that several species are present, including duckweeds (*Lemna minor*, *Spirodela punctata*, *S. polyrhiza*) and water meal (*Wolffia braziliensis*) (Taft and Mankowski 1997).

A "Cache" of Macroinvertebrates—*by Michael R. Jeffords and Susan L. Post, Illinois Natural History Survey*

Although most of us are unacquainted with the invertebrates—the least conspicuous but most abundant animals in any wetland habitat—they play an essential role in transferring energy up the food chain. Among the invertebrates present in the Cache River wetlands are protozoa, sponges, flatworms, worms, crustaceans, mollusks (clams and snails), spiders, and insects. While most of the insects are terrestrial, a significant number (about 10%) are adapted for living in water. Among the fairly common but uncelebrated insects of wetlands are various water beetles, giant water bugs, water scorpions, dragonflies, and mayflies See figs. 21a and 21b *An Aquatic Macroinvertabrates Sampling* at the back of this section.

Adaptations for Living in Water The adaptations of these organisms for living in water are very diverse and are the basis for many so-called human inventions.

Locomotion The water strider, sometimes called a pond skater, does not float on water like a piece of wood. Instead, it skates along on the surface. Its body is so light that its six legs do not break through the water's thin surface. Each of its skating legs has a large number of hydrophobic (water-repelling) hairs that actually repel water. Thus, the water strider can often be seen riding on a series of dimples in the water's surface.

Another remarkable form of water locomotion is used by the immature dragonfly, or nymph. Although the adult dragonfly relies on its wings to get about, the nymph lives underwater and depends on a form of jet propulsion. It sucks water through the rear of its body into a chamber in its abdomen and then squirts it out with enough force to propel itself forward through the water.

Diving beetles swim underwater searching for aquatic insects and tiny fish to eat. Their hairy rear legs act like paddles to move them through the water.

Feeding The adult dragonfly catches mosquitoes and other small insects while in flight, but the wingless immature nymph develops entirely under water and must find another method of feeding. Nymphal mouthparts are hinged underneath the head and swing out like a retractable lower "lip" to snatch such prey as an aquatic insect, a small fish, or even a tiny tadpole.

The slender water scorpion uses its front legs to capture prey—just about any small underwater creature. With its needlelike mouthparts, the water scorpion pierces its prey, injects a digestive enzyme into its victum, and then sucks the juices from inside its victim.

Breathing Many aquatic insects rely on gills for breathing—caddisflies and mayflies, for example. The water scorpion, however, has no gills and must poke its breathing tube up through the surface film of the water to get air.

The gill-less diving beetle must go to the surface to get a bubble of air, which it holds under its wing covers as it re-enters the water. Other diving beetles rely on waxy hairs to trap air next to their bodies. The dragonfly nymph gets oxygen by pumping water into a chamber in its abdomen (the same water its expels for jet propulsion.).

Reproduction The females of some species of water bugs arrange for a baby sitter by gluing their eggs to the back of a male. He carries them until they hatch.

Damselflies and dragonflies mate while in flight. The male grasps the female behind her head with the tip of his abdomen. The female collects sperm by placing the tip of her abdomen near the male's sex organs on the anterior (front) end of his abdomen. This adaptation helps the highly predaceous dragonflies to reproduce with only a minimum of canabalism!

Wetland Habitats The surface of a quiet marsh or pond presents no barrier to a raccoon searching for crayfish or a heron attempting to spear an elusive tadpole. To the small creatures of the world, however, the water's surface presents a firm, but flexible, surface and many plants and animals are well adapted for living at or near this surface. Surface tension results because water molecules are more strongly attracted to each other than to the air above. The surface of the water—held in place from each side and from below—results in a dense surface film of water molecules. Each of the invertebrates described here is adapted in some way for living at or near the water's surface.

Fishing spiders occur along the shores of many wetlands and move about on the water's surface with considerable agility. They feed primarily on animals that have fallen into the water and become trapped in the surface film. Even though these spiders do not spin silken webs, the surface film of the water functions as a web.

Marsh treaders, also called water measurers, are slender, stick-like predators or scavengers that live in vegetation found around the edges of ponds and marshes. Unlike their fast cousins, the water striders, marsh treaders can walk very slowly on the water's surface. As a result, they seem to hunt in slow motion.

The gyrating, spinning whirligig beetles are familiar inhabitants of most quiet waters in the Midwest. Adults are specially adapted for living on the surface film. Their eyes are divided into upper and lower halves—the upper portion sees the world above the water, while the lower portion keeps tabs on what's happening below the surface! Whirligigs often congregate in large schools, where they catch small prey or feed on dead organisms. Only the upper half of the beetle is water repellent; thus it swims half above and half below the surface.

For most small animals, the surface film is a barrier between two entirely different worlds. Although some species regularly pass back and forth between the air and the water, others spend their entire lives submerged. Even in the deepest parts of the marsh, life abounds. The group of animals described here are adapted in some way to living under the water's surface.

Houses of sand, houses of rock, houses of sticks, and even fishing nets are used by caddisfly larvae. Unlike the airborne adult, the larvae live on the marsh bottom, where they feed on small food particles, scavenge dead organisms, or are predaceous. One group of caddisfly larvae constructs silken nets that trap food particles, which the larvae then remove and eat.

Another group uses silk from its abdomen to glue objects together to make cases in which the larvae live. Caddisfly larvae use various materials to construct cases that serve many functions, including protection, camouflage, and respiration.

STOP 5 Wildcat Bluff (NW Section 19, T13S, R3E, & NE Section 24, T13S, R2E, 3rd P.M., Johnson County; Vienna 7.5-Minute Quadrangle) (fig. 22)

Bedrock Geology

Wildcat Bluff, located north of Heron Pond, forms the northem limit of the Cache Valley. The bluff consists of Mississippian-age (Lower Chesterian) strata of the Golconda Formation and the more resistant overlying Hardinsburg Sandstone (fig. 2). The elevation at the top of the bluff is slightly more than 500 feet above mean sea level, and the elevation of Heron Pond is approximately 350 feet above mean sea level. Local relief, calculated as the difference between the lowest and highest elevations, is slightly more than 150 feet.

These alternating fluvial (sandstone, shale, and siltstone) and marine (limestones and shales) rocks were formed along the shore of a shallow sea that repeatedly covered the area throughout the Mississippian as well as the Pennsylvanian (see *Mississippian Rocks in Illinois* in the back of this guidebook). In the Golconda limestones and shales, are a number of fossils from marine organisms that tell us about the environment of deposition for these strata. The fossils include brachiopods, bryozoans, corals, blastoids, crinoids, and other marine animals.

Generalized Geologic Section of Rocks Exposed at Wildcat Bluff	**Unit Thickness (ft)**
Mississippian	
Lower Chesterian	
Hardinsburg Sandstone: fine to medium grained, friable sandstone, massive, and crossbedded in all but lower 15 feet. Lower 15 feet are thin and wavy (ripple) bedded; rests unconformably on top of unit below.	Up to 53 feet

Golconda Formation: limestone, shaley limestone, and calcareous shale, interbedded; fossiliferous, contains brachiopods, bryozoans, crinoid and blastoid remains and other marine fossils. Limestones are argillaceous (shaley) and thick-bedded near top, but are mostly thin-bedded and interbedded with calcareous gray, fossiliferous shales toward the base.	Approx. 15 feet exposed
Base: covered by talus and vegetation.	

The Cache Valley is carved into portions of the Golconda Formation and the underlying Cypress Sandstone. All of the bedrock units in the bluff belong to the Chesterian Series and dip northward into the Illinois Basin at an angle of 1° to 2°.

The bedrock south of the bluff consists of the Cypress Sandstone. It is overlain by the Cretaceous and Tertiary units discussed at stops 1 and 3. These unconsolidated sediments consist of clays, sands, and gravels, some of which are partly cemented with hematite and limonite. The Cache Valley, an old abandoned course of the Ohio River, is filled with glacial outwash deposits, and the modern Cache River valley is filled with modern alluvium.

Cypress Sandstone In the eastern portion of the Cache Valley, the Cypress Sandstone is the most persistent thick, massive-bedded sandstone of the Chesterian. It forms an escarpment that extends from central Union County southeast to the bottomlands that connect the valleys of the Cache River and Bay Creek. Other bluffs formed by the Cypress are present both north and south of Bay Creek

Figure 22 Rock shelter in the Hardinsburg Sandstone at Wildcat Bluff (photo by Wayne T. Frankie).

at the eastern end of the Cache Valley. The thickness of the Cypress Sandstone is difficult to estimat, but it probably exceeds 100 feet almost everywhere. The following lithologic descriptions are from Weller and Krey (1939).

> The Cypress consists of gray to yellowish medium grained sand that weathers brown. The main central part of the formation is very massive, but thin-bedded strata are present in both the lower and upper parts. Cross-bedding is common.
>
> **Golconda Formation** The Golconda Formation consists of interbedded limestones and shales. At most places, limestone appears to dominate the upper part and also to be relatively abundant in the lower part, but the middle part consists almost exclusively of shale. The limestones are generally more or less crystalline and vary from light gray to bluish gray in color. Some oolitic limestone is locally present. The shales vary from nearly black to light gray or greenish, and some are vary calcareous. A little reddish shale is locally present. The Golconda Formation is generally more than 100 feet thick and attains its greatest thickness of about 150 feet south of Vienna; but in southeastern Johnson County south and west of Ganntown, it thins to no more than 40 feet.
>
> **Hardinsburg Sandstone** The Hardinsburg Sandstone forms a well-marked escarpment north of and parallel to the series of ridges capped by the Cypress Sandstone in the eastern portion of the Cache Valley. It is most massive in its lower part and is separated from the Golconda Formation by an erosional unconformity that accounts for the variable thickness of the underlying rocks. The Hardinsburg Sandstone is thickest to the east and thins to the west. It is 100 feet thick where it is well exposed in the Ohio River bluffs above Golconda. This thickness continues into Johnson County, where the formation thins irregularly and locally is apparently no more than 30 feet thick; in Union County it is probably not more than 50 feet thick. As it thins westward, the Hardinsburg Sandstone becomes somewhat more thin-bedded and shaly, and locally it includes dark shale.

History of the Cache Valley

The view to the south from Wildcat Bluff overlooks a portion of the Cache Valley, one of the most impressive physiographic features in Illinois (fig. 23). The valley stretches east to west for nearly 45 miles from the Ohio River to the Mississippi River, across all or parts of Pope, Massac, Johnson, Union, Pulaski, and Alexander Counties.

The Cache Valley is an abandoned segment of the trunk portion of a major drainage system and is one of the best exposed and most widely recognized landforms in Illinois. Physiographically, it forms the northern most edge of that part of the Coastal Plain Province (fig. 11) known as the Mississippi Embayment. Here the embayment abuts against the Shawnee Hills Section of the Interior Low Plateaus Province.

The valley extends nearly 45 miles westward from its sharp angular junction with the Ohio River at Ropers Bluff (located about 5 miles south of Golconda). The relatively flat alluvial floor of the Cache Valley ranges from about 1.5 to nearly 4 miles wide.

The valley walls are cut into resistant Paleozoic rocks in the eastern one-quarter and along the entire north side of the valley and, in places, follow fault zones. Where resistant Paleozoic strata are exposed, the north valley walls are much steeper, 150 to 250 feet high, and better defined than the south side, where all but the eastern one-quarter was eroded in softer, relatively unconsolidated Cretaceous and Tertiary sediments (fig. 7). The eastern part of the valley is now occupied by Bay

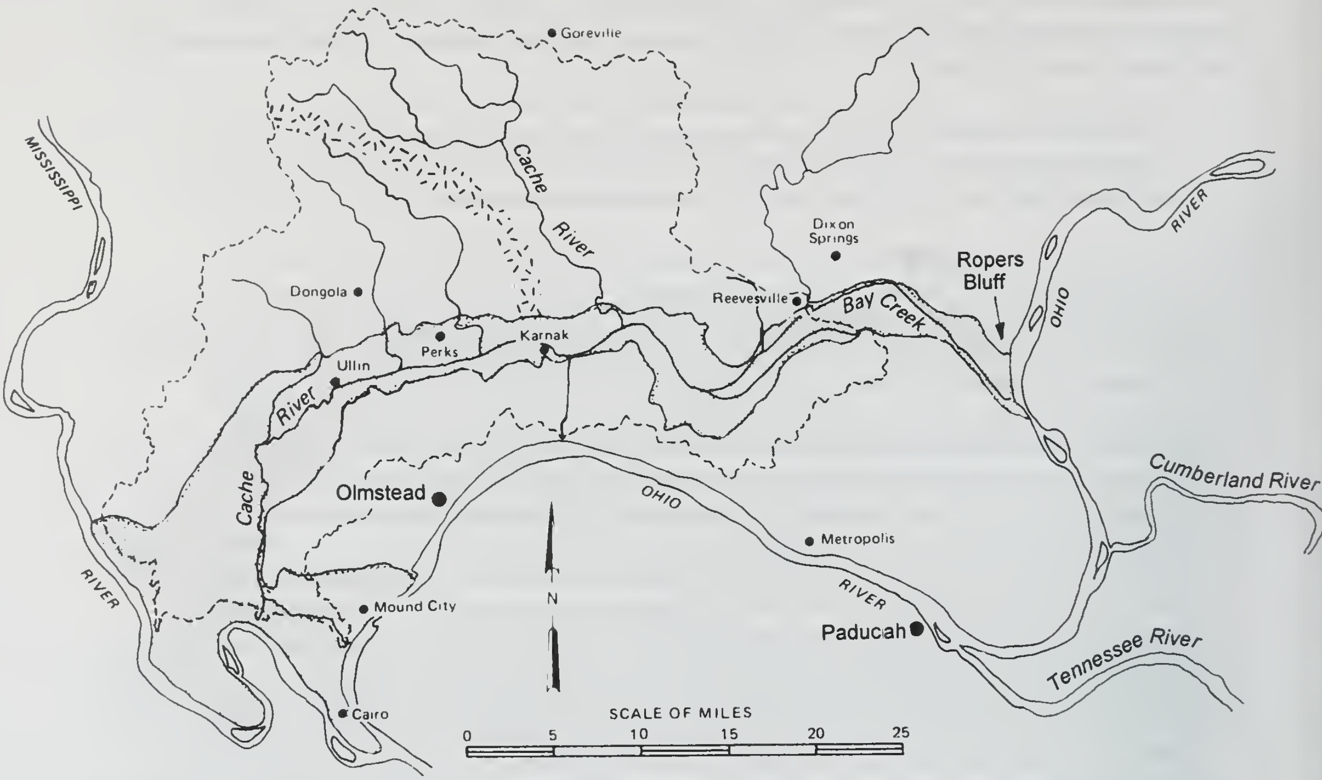


Figure 23 The Cache Valley (modified from Demissie et al. 1990b).

Creek, and the western part by the Cache River; both are underfit streams, too small to have eroded such an enormous valley. In the subsurface, the deepest part of the valley is incised into Paleozoic strata throughout its extent. The origin of the Cache Valley and its history have remained matters for research and discussion for more than 55 years.

The earliest *fluvial* system to occupy the position of the Cache Valley is unknown, but it is reasonable to believe its beginning dates back to the Paleozoic/Mesozoic erosional unconformity. During part of that time, the Little Bear Soil was developed, and the Cretaceous Tuscaloosa Gravel was deposited in the vicinity of the Cache Valley. The deposition of the Tuscaloosa chert gravel and the overlying fluvial-deltaic McNairy Formation reflect the northward extension of the Mississippi Embayment into southernmost Illinois.

During the early part of the late Cretaceous, the northern part of the Mississippi Embayment was on the north flank of an upland known as the Pascola Arch (fig. 5), with possibly as much as 500 feet of relief. Streams beginning in the uplands flowed northeast and east across the embayment into a trunk stream that drained southward around the periphery of the arch. The Tuscaloosa Gravel was deposited in part by this fluvial system. It is not known for certain if any part of the trunk stream occupied the position of the Cache Valley because no deposits of the Tuscaloosa have been identified in the Cache Valley. The strong curvilinear alignment of the Cache Valley with the eastern edge of the Mississippian Embayment and the Cumberland and Tennessee River valleys suggests that its origin may be related to the Cretaceous fluvial system, even though during the time of Tuscaloosa deposition, drainage flowed east and south, opposite to the modern drainage direction.

In the mid-Tertiary, the northeastern part of the Mississippi Embayment, including most of the area of the Cache Valley, was relatively near sea level in elevation, and the surrounding Paleozoic bedrock regions were also low and of subdued relief.

During the Pliocene, continental tectonic uplift initiated a new erosion cycle. Chert-rich residuum was eroded from the Paleozoic uplands and deposited in the form of alluvial fans in the northeastern Mississippi Embayment by high-velocity braided streams. The ancestral Tennessee and Cumberland were the dominant rivers along the east side of the embayment, building their alluvial fans from the southeast toward the northwest where the Cumberland was joined by the relatively small, preglacial Ohio River near the present upstream (east) end of the Cache Valley.

These low-gradient alluvial fans apparently filled the northeastern part of the low-lying embayment and overlapped onto the east flank of the Paleozoic uplands. The fans were deposited on an erosional surface that is now at an elevation of 450 to 500 feet above mean sea level in the embayment area, and extend upward to 600 to 650 feet on the upland rim areas. Erosion has subsequently dissected the fans and underlying deposits. Northward progradation of these alluvial fans may well have forced the main Cumberland-Ohio, and probably the Tennessee River channels northward into the position of the Cache Valley. Erosion and redistribution of the chert gravels began in the Late Pliocene and probably continued into the early Pleistocene. Deep entrenchment of the major valleys in the mid-continent may well have begun with the onset of the Pliocene.

There are few, if any, deposits in the Cache Valley and vicinity to provide evidence of the effect of pre-Illinoian glacial and interglacial stages on the area. Although this area was not glaciated, Illinoian ice did extend southward to within about 25 miles of the Cache Valley. Deep weathering and erosion appear to have progressed at variable rates during the early Pleistocene in this area. Early Pleistocene glaciations blocked other drainage systems from Indiana to Pennsylvania and eventually diverted them into the Ohio. This large increase in the size of its drainage basin, coupled with the addition of vast quantities of meltwater, converted the Ohio into a major river. This conversion, accompanied by eustatic lowering of sea level during each pre-Illinoian glaciation (at least two) and probably by continental tectonic uplift, ultimately resulted in the deep entrenchment of the ancestral Ohio River channel into bedrock beneath the Cache Valley.

The bottom of this deep valley follows the Ohio, then down the Cache Valley at an elevation of about 120 feet above mean sea level (msl). Drill hole records show that the present Ohio Valley is not entrenched much below the present river channel of about 220 feet above msl. However, a deep valley appears to extend from the mouth of the Tennessee River northeastward within the present Ohio River valley to the upstream end of the Cache Valley. Thus, it seems most plausible that during the early Pleistocene, the Ohio-Cumberland-Tennessee rivers did meet near the sharp bend between Golconda and Bay City, Illinois, to flow westward, carving and entrenching the Cache Valley. The absence of an equally deep channel in the present Ohio River valley between Paducah and Olmsted is also strong evidence that the pre-Illinoian Ohio River did not flow through its present channel, but rather through the Cache Valley.

It appears more likely that the present course of the Ohio River formed in the late Wisconsinan time. During a period of extremely high meltwater volume and alluviation of the valleys, a large slackwater lake formed in the Tennessee River valley, backing up a tributary of the Tennessee toward Metropolis, Illinois. A low divide separating this northeast-flowing drainage from another steep-gradient system flowing westward was eventually topped, and rapidly cut down by the steep-gradient stream. The volume of meltwater was large enough and was sustained long enough to establish a permanent channel southwestward to a juncture with the Mississippi River. Both the Cache Valley channel and the new Ohio River channel were probably used by the Ohio on into the Holocene, especially during times of exceptionally high flooding. By studying slack water lake deposits associated with the Cache Valley, Graham (1985) determined, however, that the diversion of the Ohio was essentially completed by about 8,200 radiocarbon years B.P. Backwaters of the Ohio most recently spilled through the Cache Valley during the record flood of 1937.

In summary, the geologic history of the deeply entrenched Cache Valley extends back into the Cretaceous Period and is related to the origin of the northern part of the Mississippi Embayment. A stream flowing east to southeast may have occupied all or a part of the location of the Cache Valley during the erosion of the Pascola Arch. Alternating subsidence and uplift in the embayment resulted in the deposition of shallow marine and fluvial-deltaic sediments in most of the area of the Cache Valley, followed by periods of erosion. Chert gravel deposition in the late Tertiary filled the northeastem portion of the embayment, concentrating the major west- to southwest-draining rivers of the time into the present location of the Cache Valley. The valley was superimposed onto the bedrock by early Pleistocene (pre-Illinoian) deep entrenchment of the major glacial drainage systems. With each glacial cycle, the Cache Valley was alternately scoured out and refilled with sediment to varying heights and thicknesses. The shallowest sediments underlying the Cache Valley are mostly late Wisconsinan and Holocene in age (12,600 to 8,2000 years ago), bracketing the time of the diversion of the Ohio, Cumberland, and Tennessee rivers from the Cache Valley into the present Ohio valley.

STOP 6 White Hill Quarry (Southern half SW Section 5, T14S, R2E, Johnson County; Cypress 7.5-Minute Quadrangle) (fig. 24)

This quarry exposes strata of the basal Chesterian Series (Mississippian Period) deposited along and in the shallow Mississippian seas that repeatedly covered much of area. These rocks are especially interesting because during this interval of Mississippian time we see a transition from largely marine carbonate deposition to a depositional system dominated by terrestrial siliciclastic (sandstone-shale-siltstone) rocks (fig. 2). The quarry operates in one of the last thick Mississippian carbonate units (the Ste. Genevieve Formation), which is in turn overlain by the Aux Vases Sandstone (fig. 24). From this time on in the Mississippian, the shifting back and forth of shorelines (see *Mississippian Rocks in Illinois* at the back of the guidebook) led to the deposition of alternating sandstones, shales and siltstones, and only limited amounts of marine carbonate rock. Prior to this, deposition was dominated by marine carbonates, with little deposition of nonmarine sands, silts, and clays.

The Ste. Genevieve is quite fossiliferous, but its deposition in wave-dominated environments led to the fragmentation of the shells of marine organisms; so essentially much of the carbonate is a shell-fragment "sandstone"—called wackestone, packstone, or grainstone, depending on the amount of carbonate mud versus calcite shell fragments, making up the rock. Grainstones consist almost entirely of sand size or coarser grains (oolites or fossil skeletal material), and the absence of lime mud indicates deposition in a high-energy (that is, wave-dominated) near-shore marine environment. Wackestones are basically mud-supported and have carbonate mud as the primary matrix, with the grains floating in this matrix. Packstones have abundant skeletal grains (enough so that they touch each other), but the pores between the larger grains are filled with lime mud.

Many of the beds in the Ste. Genevieve are skeletal oolitic to oolitic grainstones. Oolites are sand-sized spheres formed by the accretion of layers of calcite precipitated from the seawater as the

Figure 24 Ste. Genevieve limestone and overlying Aux Vases Sandstone at White Hill Quarry (photo by Wayne T. Frankie).

shell fragments were rolled back and forth in the waves. In the high wall of the quarry we can see some of the lighter colored, oolitic, grainstone limestones thickening and thinning. These layers represent "sand" bars of oolites and fossil shell fragments piled up by the waves in this shallow near-shore environment.

The best fossils are found in the parts of the St. Genevieve where the wave action was lessened at times (and the shell fragments were not broken as much). During these quieter times, fine clays carried seaward from nearby land settled and preserved these delicate marine organisms. Hence, the best fossil collecting can be found in the gray to greenish gray shale partings on limestone blocks that represent these quieter times in the deposition of these marine rocks.

According to one of our carbonate workers at the ISGS (Zakaria Lasemi, personal communication) the basal part of this quarry may actually be in the St. Louis Formation, where chert nodules increase in abundance. The contact between the Ste. Genevieve and Ste. Louis, however, is gradational so this determination requires some judgment on the part of geologists.

The Aux Vases Formation exposed near the top of the quarry is made up primarily of sandstone (silica grains) with some shales. This formation contains a number of interesting sedimentary features: rip-up clasts, mud cracks (or desiccation cracks in shaley intervals), and load casts in the contacts with shales. Oolite lenses are found in the lower part of the unit.

The following measured section is from ISGS field notes by W. John Nelson and Taury Smith, and has been slightly modified by R.J. Jacobson.

Geologic Section at White Hill Quarry	Unit Thickness (ft)
Quaternary	
Loess: light yellowish brown, compact silt with modern roots, probably Peoria Loess.	10
Silty clay: brown with strong red and orange mottling, blocky, black root traces, probably Sangamon Soil developed in Illinoian Loess.	5
Mississippian	
Aux Vases Formation	
Sandstone: light brownish gray, noncalcareous, quartz arenite. Upper 1 foot: ripple cross-laminated, very fine and silty; middle 2 feet: fine grained, mostly planar beds 2–8 inches separated by thin siltstone layers. Bottom 2 feet: very fine sandstone with flaser bedding. Occasional green shale rip-up clasts.	5
Sandstone: light gray, very fine to fine quartz arenite, some layers calcareous, tabular bedding. Cross-bedded layers up to 2 feet thick are separated by thin intervals of thin-bedded, planar to ripple laminated sandstone interlaminated with greenish gray shale. Cross-bedded sandstones contain occasional shale rip-up clasts. Desiccation cracks are common in the thin bedded shaley intervals. Small load casts occur in interbedded shale and siltstone. Lenses of oolites found in lower part. Sharp contact with underlying unit.	18
Ste. Genevieve Limestone	
Limestone: medium light gray, coarsely crystalline crinoidal grainstone, glauconitic.	
Limestone: medium gray skeletal wackestone, poorly exposed, argillaceous; contains whole brachiopods.	1
Covered.	2
Limestone: similar to last unit; yellowish gray shaley partings that contain numerous whole brachiopods are spaced 4–18 inches apart. Becomes coarser near the base, grading to a packstone. Lower contact is sharp, undulates.	14.5
Parting with apparent karst filling of fine-rounded chert and quartz gravel at the base (most pebbles. dark gray) overlain by reddish brown silt. (Note: karst is common in upper part of quarry.)	0–.75
Limestone: medium gray crinoidal packstone to grainstone, with brachiopods.	3
Limestone: bryozoan-brachiopod wackestone, medium light gray, slightly argillaceous.	1
Limestone: oolitic-skeletal packstone, medium gray, coarse grained, whole brachiopods, argillaceous near base.	1.3
Limestone: skeletal-oolitic grainstone, medium gray, very coarse, crinoids and brachiopods, faint horizontal layering.	4
Limestone: oolitic grainstone, very light gray, medium grained. Readily traceable along highwall; pinches and swells at both top and bottom (one of oolite "sandstone" bars).	5
Limestone: bryozoan-brachiopod wackestone, medium gray, slightly argillaceous.	1

Limestone: skeletal grainstone, medium gray, very coarse, largely crinoidal fragments.	2.5
Note: next two units are grainstone "sand" bars	
Limestone: oolitic grainstone, very light gray, medium grained, partly laminated. This unit forms a series of saucer-shaped swales averaging about 100 feet wide, with narrow upturned edges (that is, this unit is draped across a series of narrow mounds about 100 feet across in the underlying unit).	2–10
Limestone: oolitic-skeletal grainstone, medium light gray, fossils largely echinoderm and brachiopod fragments, grades from medium grained at top to very coarse near base. Sharp contact. This unit varies inversely in thickness with overlying unit. The lowermost 2-3 feet is coarse skeletal grainstone without oolites.	5–15
Shale: olive gray, flaky, strongly calcareous; lower part grading to very argillaceous limestone.	1.5
Limestone: skeletal grainstone, medium light gray, coarse grained, mostly crinoids and brachiopods.	5
Limestone: skeletal wackestone, medium gray, brachiopods and bryozoans, lower part oolitic.	3.5
Limestone: oolitc grainstone, very light gray, medium grained, cross-bedded; appears tabular throughout pit and varies in thickness only slightly.	5.5
Limestone: oolitc-skeletal grainstone, light gray, fine grained, well sorted. The lower part has fine, dark planar to wavy laminations. No fossil fragments. Appears to an eolian deposit. Basal contact is sharp and planar; lenses of black chert that contain fluorite along the contact.	4
Dolomite: light gray to light brownish gray, silt-size grains, uniform and massive or nearly so. Lower contact sharp and undulating with 2–3 feet of relief. Lower part grading to dolomitic skeletal wackestone.	7
Limestone: crinoidal grainstone, medium light gray, coarse grained, massive, contains brachiopod fragments. Small chert lenses along upper contact.	5
Bench (there may be a slight gap or overlap in section here) Limestone: cherty skeletal wackestone, medium dark gray, more muddy toward base; bed of 4-inch-thick black chert nodules near top of bed. Argillaceous parting at base about 1–2 inches thick. Sharp contact with underlying unit.	3
Limestone: oolitic grainstone, coarse skeletal fragments throughout, medium grained oolites, cross-bedded, numerous styolites, lower contact gradational. Shrinks and swells laterally from 0 to 12 feet; overlying unit is thick where this unit is thin (another oolite "sand" bar unit).	0–12
Limestone: oolitic wackestone/packstone, medium light gray, fine grained, muddier downward. Lenses of fine lime mudstone near base, brachiopods, crinoids, restricted appearance. Sharp contact with underlying unit.	7

Limestone: oolitic-skeletal grainstone, white, coarse grained, brachiopods, echinoderms, cross-bedded, small lenses of oolitc wackestone. Sharp contact at base.	5.5

St. Louis Formation

Limestone: skeletal packstone/wackestone, ooilites common, could be micritized. Abundant (algal?) oncolites throughout top of unit, brachiopods and crinoids, no chert; 1-foot packstone bed near top is crossbedded, the rest is muddier. Lower contact is sharp.	12.5
Limestone: lime mudstone/pelletal limestone, olive gray, scattered echinoderm fragments, faintly laminated; 10%–70% chert nodules, dark gray, vitreous, 1–4 inches in diameter. Lower contact is gradational.	5
Limestone: skeletal grainstone, crinoidal, more of a packstone at top, coarser and grain supported downward; thin shale in middle of unit; cherty in top 1.5 feet. Lower contact is gradational.	7
Limestone: skeletal wackestone, olive gray, nodular chert, muddier downward. Sublithographic at base.	3
Floor of active quarry	

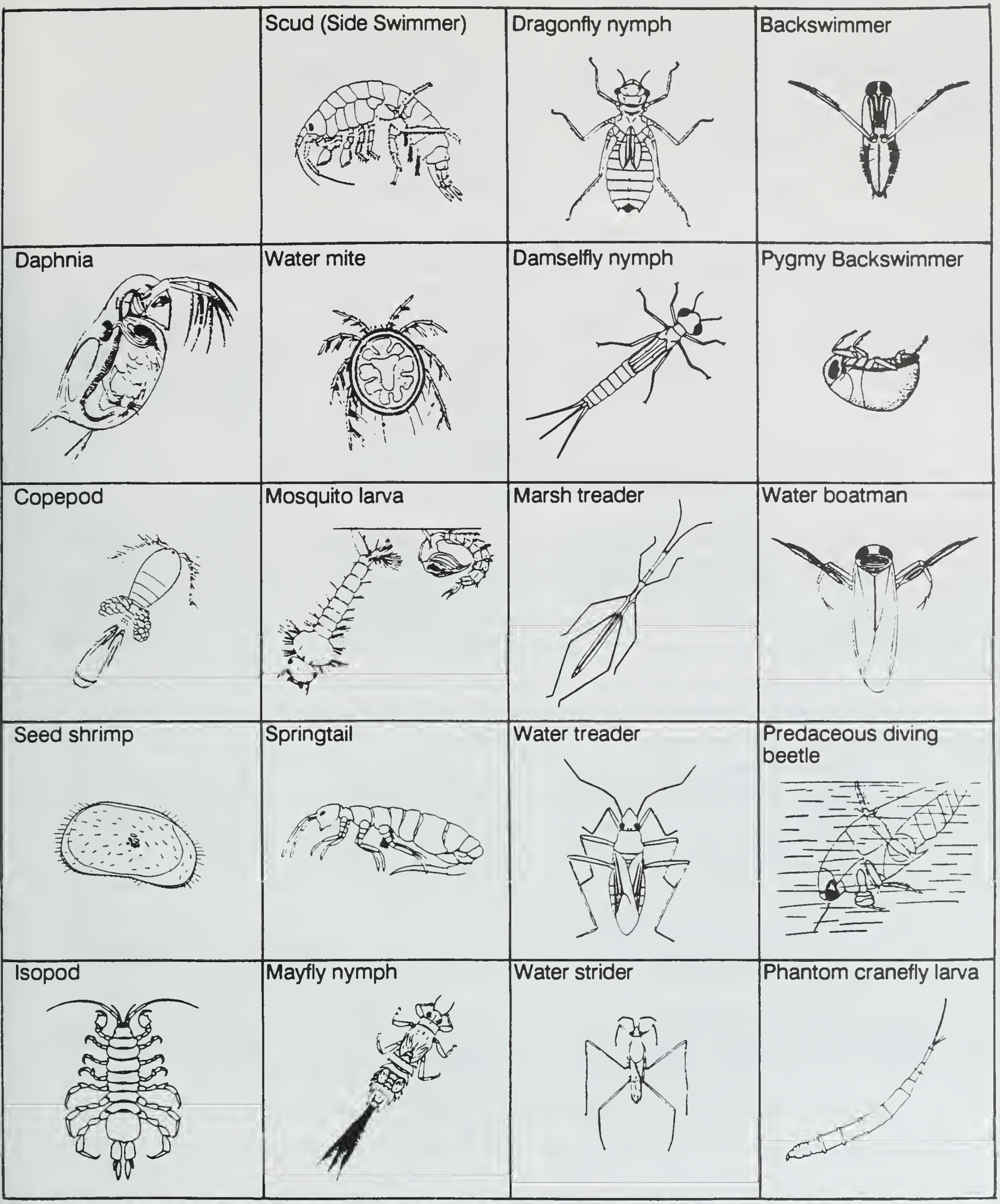


Figure 21a and 21b An aquatic macroinvertebrates sampling (used with permission from IDNR, Volo Bog State Natural Area).

Backswimmer True bugs with keeled back and paddle-like legs. Hind legs, longer than middle or front, are used as oars. Length to .5"	Dragonfly nymph Stocky, dull-colored, lack tail gills. Large chewing jaws shoot out to capture prey. Eat insect larvae, worms, crustaceans, small fish and even tadpoles. Usual size from < 1" - 2.5"	Scud (Side Swimmer) Crustaceans flattened sideways like fleas. Usually live close to bottom among debris. Some species in deep water. Avoid light. Scavenge on plant and animal debris. Length less than .5"	
Pygmy Backswimmer Live among vegetation, swimming short distances from plant to plant. Eat mainly small crustaceans. Length = .1"	Damselfly nymph Slim abdomen with three leaf-shaped gills at tip. Foods similar to dragonfly nymph. Both a food source for larger fish. Like dragonfly, transforms to adult on stem above water. Length to 1"	Water mite Arachnids; releated to spiders & ticks. Cephalothorax and abdomen completely fused. Many are red. Eat worms, small crustaceans and insects. A few are parasitic. A few swim; most crawl about vegetation. Must surface to breathe. Length to .2"	Daphnia Swim with enlarged second pair of antennae. Eat algae, microscopic animals and detritus swept into mouth on current of water created by legs. Preyed upon by small fish. Length ~ .02"
Water boatman Slender bugs with long hind legs flattened for swimming. Surfaces to gather air in silvery envelope surrounding body. Must cling to object to remain submerged. Eat plant material and detritus. Length to 1"	Marsh treader Slender true bugs creep along water surface, especially among vegetation. Spear prey with sharp beak then suck out body juices. Length to 1.5"	Mosquito larva Head and thorax larger than abdomen. Eat microscopic organisms and organic debris filtered through brushes around mouth. Breathe through gills at end of abdomen. Length to .2"	Copepod Small crustaceans of shallow water. May be found in damp debris above water line. Egg sacs visible on female during breeding season. Eat algae, bacteria and detritus. Length to .1"
Predaceous diving beetle Hind legs are oar-like and hairy. Voracious predators; eat insects and other small water animals including fish. Hang head-down with abdomen above surface to gather air beneath wings. Length to 1"	Water treader Small greenish true bugs live on surface near vegetation. Feed on small animals on or just below water's surface. Females lay eggs in plant stems. Length to .5"	Springtail Live on the surface of water and debris along water's edge; not truly aquatic. Primative wingless insects that jump by using spring-like device under abdomen. Less than .2" long.	Seed shrimp Bivalved (clamlike) crustaceans common in algae, other vegetation, mud, pond bottoms. Eat detritus. Length to .1"
Phantom cranefly larva Has respiratory tube projecting from rear. Lives in decaying vegetation - its main food source. Length to 1.3"	Water strider Not spiders! Count legs; four easily seen, front two held under head. Slender true bugs skate on water's surface in search of prey on or under surface. May be cannibalistic when food is scarce. Usually < 1"	Mayfly nymph Rows of leaf-like gills along abdomen along with three usually feathery "tail" appendages. Nymphs eat small organisms and organic debris. Adults do not eat; live only a few hours. Length to 1"	Isopod Related to pill bugs. Scavenge on decaying plants and animals. Length less than 1"

Figure 21b

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GLOSSARY

The following definitions are from several sources in total or in part, but the main reference is: Bates, R.L., and J.A. Jackson, editors, 1987, Glossary of Geology: American Geological Institute, Alexandria, VA, 3rd edition, 788 p.

Ablation Separation and removal of rock material and formation of deposits, especially by wind action or the washing away of loose and soluble materials.

Age An interval of geologic time; a division of an epoch.

Aggrading stream One that is actively building up its channel or floodplain by being supplied with more load than it can transport.

Alluviated valley One that has been at least partially filled with sand, silt, and mud by flowing water.

Alluvium A general term for clay, silt, sand, gravel, or similar unconsolidated detrital material deposited during comparatively recent time by a stream or other body of running water as a sorted or semisorted sediment in the bed of a stream or on its floodplain or delta, etc.

Anticline A convex upward rock fold in which strata have been bent into an arch; the strata on each side of the core of the arch are inclined in opposite directions away from the axis or crest; the core contains older rocks than does the perimeter of the structure.

Aquifer A body of rock or sediment that will yield water of useable quantity to a well or spring. Aquifers act as conduits bounded by less permeable materials.

Argillaceous Largely composed of clay-sized particles or clay minerals.

Arenite A relatively clean quartz sandstone that is well sorted and contains less than 10% argillaceous material.

Base level Lowest limit of subaerial erosion by running water, controlled locally and temporarily by water level at stream mouths into lakes or more generally and semipermanently into the ocean (mean sea level).

Basement complex Largely crystalline igneous and/or metamorphic rocks of complex structure and distribution that underlie a sedimentary sequence.

Basin A topographic or structural low area that generally receives thicker deposits of sediments than adjacent areas; the low areas tend to sink more readily, partly because of the weight of the thicker sediments; this also denotes an area of deeper water than found in adjacent shelf areas.

Bed A naturally occurring layer of Earth material of relatively greater horizontal than vertical extent that is characterized by a change in physical properties from those overlying and underlying materials. It also is the ground upon which any body of water rests or has rested, or the land covered by the waters of a stream, lake, or ocean; the bottom of a watercourse or of a stream channel.

Bedrock The solid rock underlying the unconsolidated (non-indurated) surface materials, such as, soil, sand, gravel, glacial till, etc.

Bedrock valley A drainageway eroded into the solid bedrock beneath the surface materials. It may be completely filled with unconsolidated (non-indurated) materials and hidden from view.

Braided stream A low gradient, low volume stream flowing through an intricate network of interlacing shallow channels that repeatedly merge and divide, and are separated from each other by branch islands or channel bars. Such a stream may be incapable of carrying all of its load.

Calcarenite Limestone composed of sand-sized grains consisting of more or less worn shell fragments or pieces of older limestone; a clastic limestone.

Calcareous Containing calcium carbonate ($CaCO_3$); limy.

Calcined The heating of limestone to its temperature of dissociation so that it loses its water of crystalization.

Calcite A common rock-forming mineral consisting of $CaCO_3$; it may be white, colorless, or pale shades of gray, yellow, and blue; it has perfect rhombohedral cleavage, appears vitreous, and has a hardness of 3 on Mohs' scale; it effervesces (fizzes) readily in cold dilute hydrochloric acid. It is the principal constituent of limestone.

Cave A cavity in the earth large enough for a human to enter. Caves can form as a result of physical and chemical weathering of rock. Physical weathering usually produces shelter-type caves that extend into the rock for only a few feet. Chemical weathering of rock can produce caves (solution channels along fractures and bedding planes) that extend for many miles into the rock.

Chert Silicon dioxide (SiO_2); a compact, massive rock composed of minute particles of quartz and/or chalcedony; it is similar to flint but lighter in color.

Clastic Fragmental rock composed of detritus, including broken organic hard parts as well as rock substances of any sort.

Closed depression A low, roughly concave topographic feature in a landscape. Rain falling within the boundaries of the depression would be channeled toward its lowest part (usually near its center).

Closure The difference in altitude between the crest of a dome or anticline and the lowest contour that completely surrounds it.

Columnar section A graphic representation in a vertical column of the sequence and stratigraphic relations of the rock units in a region.

Conformable Layers of strata deposited one upon another without interruption in accumulation of sediment; beds parallel.

Delta A low, nearly flat, alluvial land deposited at or near the mouth of a river where it enters a body of standing water; commonly a triangular or fan-shaped plain sometimes extending beyond the general trend of the coastline.

Detritus Material produced by mechanical disintegration.

Disconformity An unconformity marked by a distinct erosion-produced, irregular, uneven surface of appreciable relief between parallel strata below and above the break; sometimes represents a considerable interval of nondeposition.

Dolomite A mineral, calcium-magnesium carbonate ($Ca,Mg[CO_3]_2$); applied to those sedimentary rocks that are composed largely of the mineral dolomite; it also is precipitated directly from seawater. It is white, colorless, or tinged yellow, brown, pink, or gray; has perfect rhombohedral cleavage; appears pearly to vitreous; effervesces feebly in cold dilute hydrochloric acid.

Drift All rock material transported by a glacier and deposited either directly by the ice or reworked and deposited by meltwater streams and/or the wind.

Driftless Area A 10,000-square-mile area in northeastern Iowa, southwestern Wisconsin, and northwestern Illinois where the absence of glacial drift suggests that the area may not have been glaciated.

End moraine A ridge-like or series of ridge-like accumulations of drift built along the margin of an actively flowing glacier at any given time; a moraine that has been deposited at the lower or outer end of a glacier.

Epoch An interval of geologic time; a division of a period.

Era A unit of geologic time that is next in magnitude beneath an eon; consists of two or more periods.

Escarpment A long, more or less continuous cliff or steep slope facing in one general direction, generally marking the outcrop of a resistant layer of rocks.

Fault A fracture surface or zone in Earth materials along which there has been vertical and/or horizontal displacement or movement of the strata on both sides relative to one another.

Fissure A relatively wide planar opening in bedrock that originated as a fracture or fault. The opening may be partially or totally filled with soil or, if open, can act as a conduit for flowing water.

Flaggy Tending to split into layers of suitable thickness for use as flagstone.

Floodplain The surface or strip of relatively smooth land adjacent to a stream channel that has been produced by the stream's erosion and deposition actions; the area covered with water when the stream overflows its banks at times of high water; it is built of alluvium carried by the stream during floods and deposited in the sluggish water beyond the influence of the swiftest current.

Fluvial Of or pertaining to a river or rivers.

Formation The basic rock unit distinctive enough to be readily recognizable in the field and widespread and thick enough to be plotted on a map. It describes the strata, such as limestone, sandstone, shale, or combinations of these and other rock types; formations have formal names, such as Joliet Formation or St. Louis Limestone (Formation), usually derived from geographic localities.

Fossil Any remains or traces of an once living plant or animal specimens that are preserved in rocks (arbitrarily excludes Recent remains).

Friable Said of a rock or mineral that crumbles naturally or is easily broken, pulverized, or reduced to powder, such as a soft and poorly cemmented sandstone.

Geology The study of the planet Earth. It is concerned with the origin of the planet, the material and morphology of the Earth, and its history and the processes that acted (and act) upon it to affect its historic and present forms.

Geophysics Study of the Earth by quantitative physical methods.

Glaciation A collective term for the geologic processes of glacial activity, including erosion and deposition, and the resulting effects of such action on the Earth's surface.

Glacier A large, slow-moving mass of ice at least in part on land.

Gradient(s) A part of a surface feature of the Earth that slopes upward or downward; a slope, as of a stream channel or of a land surface.

Groundwater Water present below the water table in small, often microscopic, interconnected pore spaces between grains of soil, sand and/or gravel, and in open fractures and/or solution channels in rock.

Igneous Said of a rock or mineral that solidified from molten or partly molten material, i.e., from magma.

Indurated A compact rock or soil hardened by the action of pressure, cementation, and especially heat.

Joint A fracture or crack in rocks along which there has been no movement of the opposing sides.

Karst Area underlain by limestone having many sinkholes separated by steep ridges or irregular hills. Tunnels and caves resulting from solution by groundwater honeycomb the subsurface.

Karst aquifer An aquifer whose porosity and permeability is dominated by connected conduits (for example, joints, fractures, caves, tubes) that were enlarged by dissolution of rock. Karst aquifers have extremely rapid recharge and relatively large hydraulic conductivities (greater than 10-4 cm/s) and a turbulent groundwater flow regime (as opposed to laminar flow).

Karst terrain An area or region of the surface of the earth whose landscape is characterized by sinkholes, caves, springs, disrupted land drainage, and an underground drainage system. Karst terrains form in areas with carbonate rock (limestone and dolomite), and areas underlain by other types of soluble rock (for example, salt or gypsum).

Lacustrine Produced by or belonging to a lake.

Laurasia A combination of Laurentia, a paleogeographic term for the Canadian Shield and its surroundings, and Eurasia. It is the protocontinent of the Northern Hemisphere, corresponding to Gondwana in the Southern Hemisphere, from which the present continents of the Northern Hemisphere have been derived by separation and continental displacement. The hypothetical supercontinent from which both were derived is Pangea. The protocontinent included most of North America, Greenland, and most of Eurasia, excluding India. The main zone of separation was in the North Atlantic, with a branch in Hudson Bay, and geologic features on opposite sides of these zones are very similar.

Limestone A sedimentary rock consisting primarily of calcium carbonate (the mineral, calcite).

Lithify To change to stone, or to petrify; esp. to consolidate from a loose sediment to a solid rock.

Lithology The description of rocks on the basis of color, structures, mineral composition, and grain size; the physical character of a rock.

Local relief The vertical difference in elevation between the highest and lowest points of a land surface within a specified horizontal distance or in a limited area.

Loess A homogeneous, unstratified deposit of silt deposited by the wind.

Magma Naturally occurring mobile rock material or fluid, generated within Earth and capable of intrusion and extrusion, from which igneous rocks are thought to have been derived through solidification and related processes.

Meander One of a series of somewhat regular, sharp, sinuous curves, bends, loops, or turns produced by a stream, particularly in its lower course where it swings from side to side across its valley bottom.

Meander scars Crescent-shaped, concave marks along a river's floodplain that are abandoned meanders, frequently filled in with sediments and vegetation.

Metamorphic rock Any rock derived from pre-existing rocks by mineralogical, chemical, and structural changes, essentially in the solid state, in response to marked changes in temperature, pressure, shearing stress, and chemical environment at depth in Earth's crust (gneiss, schist, marble, quartzite, etc.).

Mineral A naturally formed chemical element or compound having a definite chemical composition and, usually, a characteristic crystal form.

Monolith (a) A piece of unfractured bedrock, generally more than a few meters across. (b) A large upstanding mass of rock.

Moraine A mound, ridge, or other distinct accumulation of glacial drift, predominantly till, deposited in a variety of topographic landforms that are independent of control by the surface on which the drift lies.

Morphology The scientific study of form, and of the structures and development that influence form; term used in most sciences.

Natural gamma log These logs are run in cased, uncased, air, or water-filled boreholes. Natural gamma radiation increases from the left to the right side of the log. In marine sediments, low radiation levels indicate non-argillaceous limestone, dolomite, and sandstone.

Nickpoint A place of abrupt inflection in a stream profile; A sharp angle cut by currents at base of a cliff.

Nonconformity An unconformity resulting from deposition of sedimentary strata on massive crystalline rock.

Outwash Stratified drift (clay, silt, sand, gravel) that was deposited by meltwater streams in channels, deltas, outwash plains, on floodplains, and in glacial lakes.

Outwash plain The surface of a broad body of outwash formed in front of a glacier.

Oxbow lake A crescent-shaped lake in an abandoned bend of a river channel.

Pangea A hypothetical supercontinent; supposed by many geologists to have existed at an early time in the geologic past, and to have combined all the continental crust of the Earth, from which the present continents were derived by fragmentation and movement away from each other by means of some form of continental displacement. During an intermediate stage of the fragmentation, between the existence of Pangea and that of the present widely separated continents, Pangea was supposed to have split into two large fragments, Laurasia on the north and Gondwana on the south. The proto-ocean around Pangea has been termed Panthalassa. Other geologists, while believing in the former existence of Laurasia and Gondwana, are reluctant to concede the existence of an original Pangea; in fact, the early (Paleozoic or older) history of continental displacement remains largely undeciphered.

Ped A naturally formed unit of soil structure, e.g., granule, block, crumb, or aggregate.

Peneplain A land surface of regional proportions worn down by erosion to a nearly flat or broadly undulating plain.

Period An interval of geologic time; a division of an era.

Physiography The study and classification of the surface features of Earth on the basis of similarities in geologic strucure and the history of geologic changes.

Physiographic province (or division) (a) A region, all parts of which are similar in geologic structure and climate and which has consequently had a unified geologic history. (b) A region whose pattern of relief features or landforms differs significantly from that of adjacent regions.

Point bar A low arcuate ridge of sand and gravel developed on the inside of a stream meander by slow accumulation of sediment as the stream channel migrates toward the outer bank.

Radioactivity logs Logs of bore holes obtained through the use of gamma logging, neutron logging, or combinations of the several radioactivity logging methods.

Relief (a) A term used loosely for the actual physical shape, configuration, or general unevenness of a part of Earth's surface, considered with reference to variations of height and slope or to irregularities of the land surface; the elevations or differences in elevation, considered collectively, of a land surface (frequently confused with topography). (b) The vertical difference in elevation between the hilltops or mountain summits and the lowlands or valleys of a given region; "high relief" has great variation; "low relief" has little variation.

Sediment Solid fragmental material, either inorganic or organic, that originates from weathering of rocks and is transported by, suspended in, or deposited by air, water, or ice, or that is accumulated by other natural agents, such as chemical precipitation from solution or secretion from organisms, and that forms in layers on Earth's surface at ordinary temperatures in a loose, unconsolidated form; e.g, sand, gravel, silt, mud, till, loess, alluvium.

Sedimentary rock A rock resulting from the consolidation of loose sediment that has accumulated in layers (e.g., sandstone, siltstone, limestone).

Shoaling The effect of a near-costal sea bottom on wave height; it describes the alteration of a wave as it proceeds from deep water into shallow water. The wave height increases as the wave arrives on shore.

Sinkholes Any closed depression in the land surface formed as a result of collapse of underlying soil or bedrock. Sinkholes are usually found in areas where bedrock is near the surface and are susceptible to dissolution by infiltrating surface water. Sinkhole is synonymous with "doline," which is used extensively in Europe. Sinkhole formation is usually initiated by soil piping or collapse of a subsurface cavity in bedrock. The essential component of a hydrologically active sinkhole is a drain that takes away water that flows into the sinkhole and, presumably, into a conduit.

Slip-off slope Long, low, gentle slope on the inside of a stream meander.

Soil piping The movement and entrainment of soil along an initially small pathway in the soil. As water moves along the pathway, the pathway enlarges and the velocity of the flow may increase proportionally, thus, entraining more soil. The result is the formation of an ever enlarging cavity along the flow path. At some point, structural support may be lost and the ground surface or structures on the surface may collapse into the cavity.

Stage, substage Geologic time-rock units; the strata formed during an age or subage, respectively.

Stratigraphy The study, definition, and description of major and minor natural divisions of rocks, especially the study of the form, arrangement, geographic distribution, chronologic succession, classification, correlation, and mutual relationships of rock strata.

Stratigraphic unit A stratum or body of strata recognized as a unit in the classification of the rocks of Earth's crust with respect to any specific rock character, property, or attribute or for any purpose such as description, mapping, and correlation.

Stratum A tabular or sheet-like mass, or a single and distinct layer, of homogeneous or gradational sedimentary material of any thickness, visually separable from other layers above and below by a discrete change in character of the material deposited or by a sharp physical break in deposition, or by both; a sedimentary *bed.*

Subage An interval of geologic time; a division of an age.

Syncline A downfold of strata which dip inward from the sides toward the axis; youngest rocks along the axis; the opposite of anticline.

System The largest and fundamental geologic time-rock unit; the strata of a system were deposited during a period of geologic time.

Tectonic Pertaining to the global forces involved in, or the resulting structures or features of Earth's movements.

Tectonics The branch of geology dealing with the broad architecture of the upper (outer) part of Earth's crust; a regional assembling of structural or deformational features, their origins, historical evolution, and mutual relations.

Temperature-resistance log This log, run only in water, portrays the earth's temperature and the quality of groundwater in the well.

Terrace An abandoned floodplain formed when a stream flowed at a level above the level of its present channel and floodplain.

Till Unconsolidated, nonsorted, unstratified drift deposited by and underneath a glacier and consisting of a heterogenous mixture of different sizes and kinds of rock fragments.

Till plain The undulating surface of low relief in the area underlain by ground moraine.

Topography The natural or physical surface features of a region, considered collectively as to form; the features revealed by the contour lines of a map.

Unconformable Having the relation of an unconformity to underlying rocks and separated from them by an interruption in sedimentation, with or without any accompanying erosion of older rocks.

Unconformity A surface of erosion or nondeposition that separates younger strata from older strata; most unconformities indicate intervals of time when former areas of the sea bottom were temporarily raised above sea level.

Valley trains The accumulations of outwash deposited by rivers in their valleys downstream from a glacier.

Water table That point in a shallow well or opening in the earth where groundwater begins.

Weathering The group of processes, chemical and physical, whereby rocks on exposure to the weather change in character, decay, and finally crumble into soil.

MISSISSIPPIAN ROCKS IN ILLINOIS

Janis D. Treworgy

AGE AND DISTRIBUTION

The Mississippian Period is the interval of earth's geologic history that lasted from about 360 to 320 million years ago (fig. 1). The term *Mississippian System* refers to the layers of sediment that were deposited during this period. Today, Mississippian-age rocks are present in the southern two-thirds of Illinois where they are over 3,200 feet thick (fig. 2). These rocks were more widely distributed over the midcontinent but were removed in places by erosion. Although these layers of rock were originally horizontal deposits, they were warped downward into the shape of a shallow basin because of stresses in the earth's crust. This large downwarped depression is called the Illinois Basin. At the deepest part of the basin in southeastern Illinois, the Mississippian rocks are as deep as 5,000 feet. In western and southernmost Illinois, Mississippian rocks are shallow and exposed at the surface around the edge of the the basin (see outcrop areas in fig. 2).

ECONOMIC SIGNIFICANCE

Mississippian rock resources have been important to the mineral industries and economy of Illinois since the early 1800s.

- Nearly 80% of the oil produced in Illinois has been pumped from Mississippian rocks (Howard 1991). This crude oil is refined to produce gasoline, fuel oil, asphalt, road oil, lubricants, and other petroleum products, including petrochemicals.

- Fluorite (fluorspar), sphalerite (zinc ore), and galena (lead ore) were mined from major mineral deposits in heavily faulted Mississippian rocks in Hardin and Pope Counties, southernmost Illinois, from the early 1800s until the last mine closed in 1995. Mining ceased because of cheaper sources from other countries, primarily China and Mexico. Additional research on the Mississippian rocks in southernmost Illinois may lead to the discovery of new economically minable fluorite or other mineral deposits.

  Fluorite (calcium fluoride), Illinois' state mineral, is used in a variety of manufacturing processes, for example, as a flux in refining iron ore to steel. Fluorite is primarily used to make hydrogen fluoride (hydrofluoric acid) and fluorine gas, an ingredient in making refrigerants, solvents, lubricants, and toothpaste.

- About one-third of the limestone and dolomite for crushed stone in Illinois is quarried from Mississippian rocks. Crushed stone, also called construction aggregate, is used for road construction, concrete structures, agricultural lime, sulfur-dioxide removal from coal-burning power plant flues, and production of Portland cement and various chemicals. Some Mississippian-age limestone was quarried as a building and decorative stone in southern Illinois until the 1960s. It is similar to the "Indiana Limestone," a building stone used nationwide that is quarried in south-central Indiana.

PALEOGEOGRAPHY

Continental plate movement *Paleogeography* means "ancient" geography. During the Mississippian, the area now called Illinois was located south of the equator (fig. 3). The equator has not moved during the history of the earth, but the "plates" that make up the earth's crust have slowly moved around during earth's life of 4.6 billion years. During the 40 million years of the Mississippian Period, what is now Illinois moved slowly northward from near 30° south latitude to just north of 10° south latitude. About 100 million years later, all the continental plates drifted together and formed the supercontinent Pangea. Since then, the continental plates have been slowly drifting apart.

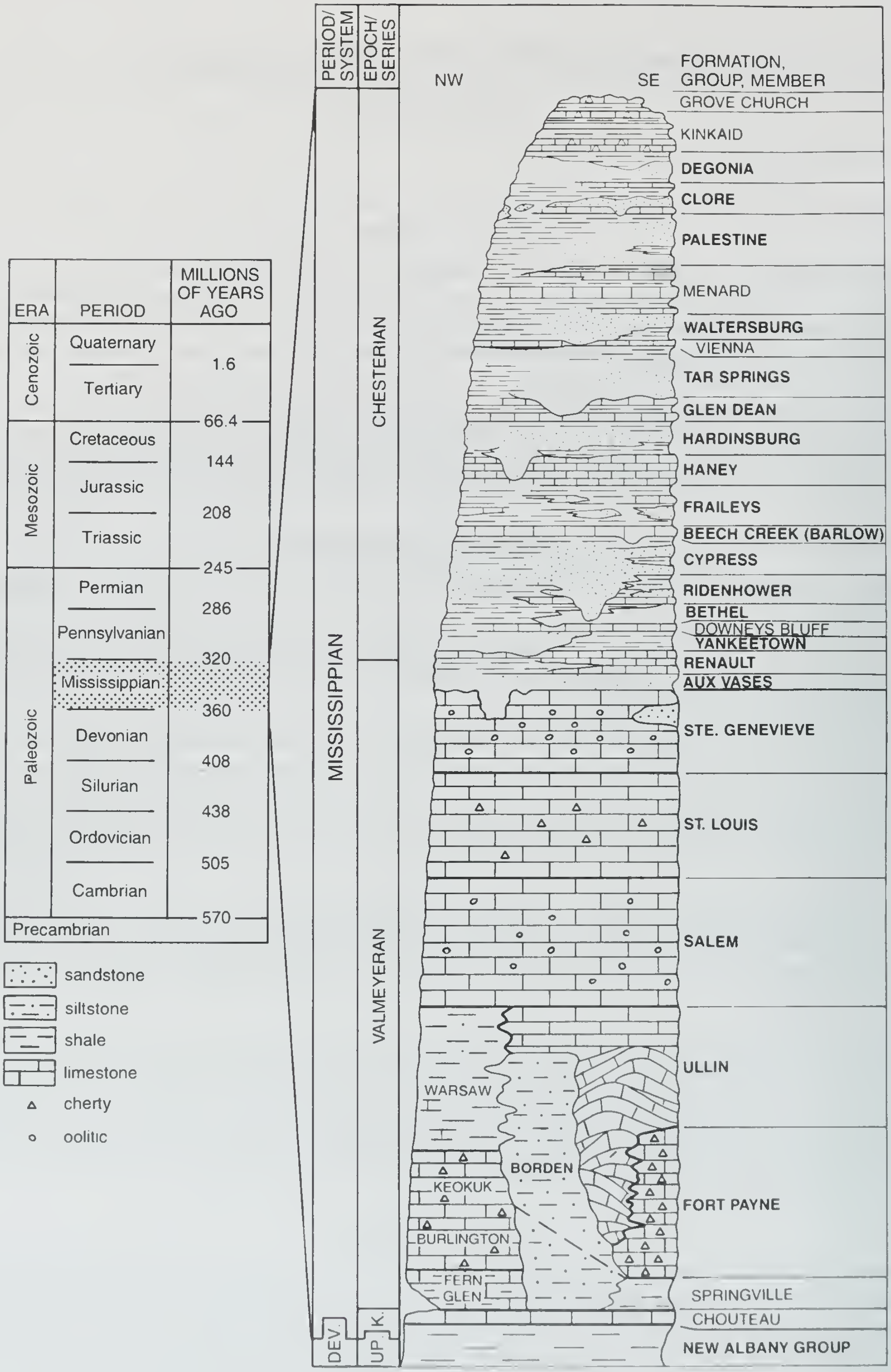

Figure 1 Mississippian rock units in Illinois. Units that have produced oil are shown in bold type. The base of the Fort Payne is approximately equivalent in time to the base of the Keokuk (dashed line). DEV = Devonian, UP = Upper Devonian, and K = Kinderhookian.

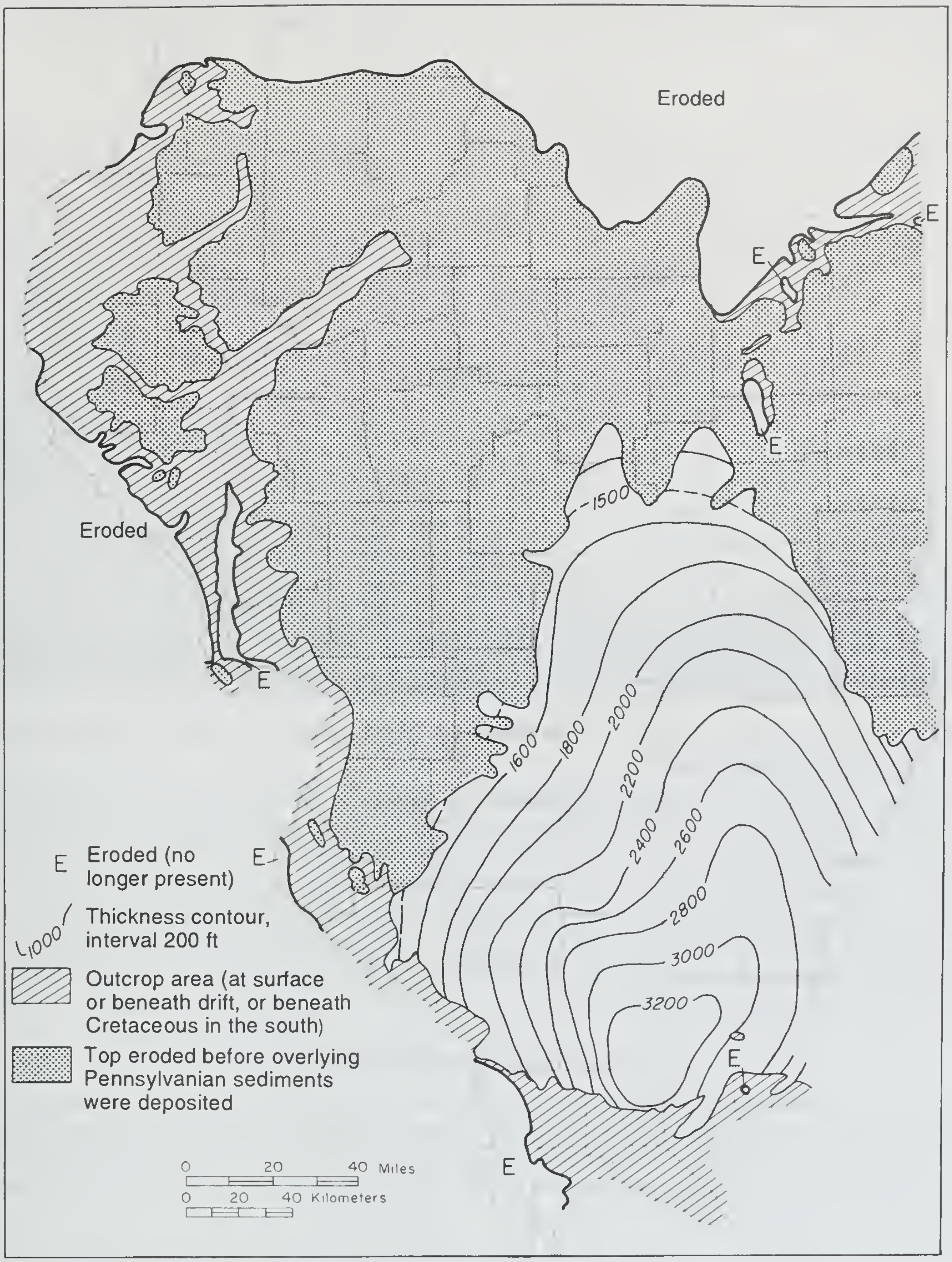

Figure 2 Distribution and thickness of the Mississippian rocks in Illinois. Thickness contours are shown where upper Chesterian rocks are present (modified from Atherton et al. 1975).

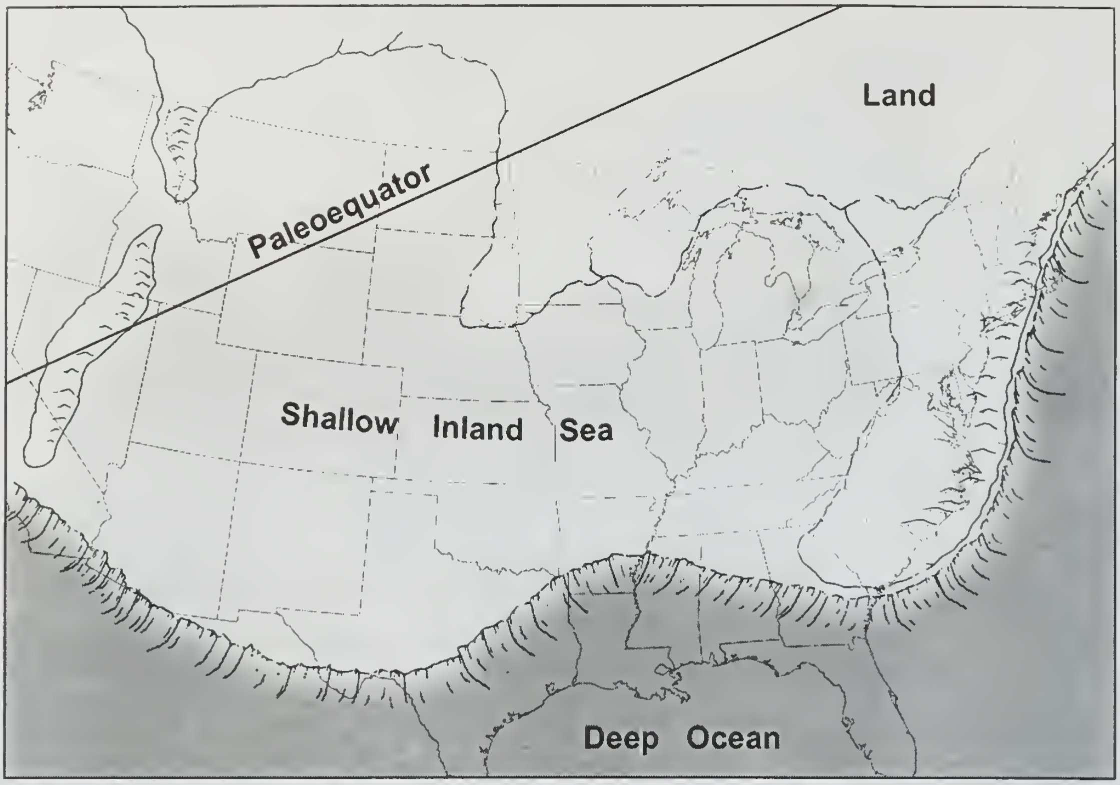

Figure 3 Position of much of the United States and general paleogeography during the Mississippian Period, approximately 350 million years ago.

Ancient seas Illinois and surrounding areas of the midcontinent were covered by a warm, shallow inland sea that extended inland from the deep ocean at the edge of the continental plate (fig. 3). During the early part of the Mississippian, this inland sea covered most of the midcontinent and was up to several hundred feet deep in the southern Illinois area. During the later part of the Mississippian, sea level dropped and exposed more land. As a result, the sea became shallower, just a few tens of feet deep in the Illinois Basin. Geologists can tell relative water depths from the type of sea life preserved as fossils in the rocks (plates A and B) and from sedimentary patterns or structures, such as ripple marks, that were formed in the sediment by currents generated by tides and waves.

COMMON MISSISSIPPIAN ROCKS

Common rocks of Mississippian age found in the Illinois area formed at the bottom of the shallow inland sea. Rivers and streams eroded sand, silt, and clay from the surrounding land and carried them into the sea where they were deposited on the bottom. *Shale* forms when mud (a mixture of fine clay and silt) collects at the bottom of the sea and is buried and compacted (lithified, or made rock-like). *Sandstone* and *siltstone* form similarly, but from coarser sand and silt particles.

Limestone, the most abundant Mississippian rock type in Illinois, formed differently. Limestone is primarily calcium carbonate (calcite, or $CaCO_3$) and can form in several ways. One of the most common ways begins with sea animals (such as crinoids, brachiopods, bryozoans, and molluscs) that secrete calcium carbonate to form their protective shells. When these animals die, their shells collect on the sea floor. Often the shells are broken by strong currents (due to storms and tides) near shore and carried seaward. When these shells become compacted and cemented on the sea floor (by calcite that precipitates from the sea water), limestone forms. Calcite-secreting animals are most abundant and prolific in clear, warm, relatively shallow water where there is little mud coming into the sea. Because these animals feed by filtering tiny floating plants and animals from the sea water, mud would choke them. Some limestones (for example, oolitic limestone) are a chemical precipitate from the sea water. Others (for example, micrite) form in part through precipitation caused by microbes, algae, or other organisms. In some cases, limestone is recrystallized to form a magnesium-rich carbonate rock called *dolostone* (or *dolomite*).

DEPOSITIONAL HISTORY

Various combinations of the rocks described above were deposited in Illinois during the 40 million years of the Mississippian Period. The oldest rocks were laid down first and are at the bottom of the sequence (fig. 1).

Pre-Mississippian Before Mississippian times, late in the Devonian Period (fig. 1), mud was being deposited in the sea that covered the area. This mud continued to enter the sea during the early Mississippian Period (Kinderhookian Epoch). As the mud was buried and compacted, it became shale. The sea during this time ranged from a few tens of feet deep near the shore to several hundred feet deep in southeastern Illinois, where the shale is thickest. Geologists call this shale unit the New Albany Group (fig.1). Today this shale is at the surface in western Illinois but is more than 5,000 feet deep in southeastern Illinois, where it is 450 feet thick.

This shale is rich in organic matter that was mostly derived from dead marine plants and animals that accumulated on the ancient sea floor. As the shale was buried progressively deeper in the earth's crust by overlying sediments, it became warmer. (The earth is hotter toward the center.) Eventually, about 250 to 150 million years ago, the shale became so hot (at least 125°F) that the organic matter "cooked" and released oil and gas. This oil and gas moved slowly upward along fractures and through pore spaces into and through overlying rock units. Some of this oil and gas became "trapped" in porous rock that is overlain by very dense rock. It is this trapped oil and gas that some geologists look for and that is pumped from the ground for our use.

Kinderhookian Epoch The amount of mud carried into the sea eventually diminished and allowed sea animals to dominate long enough for a thin limestone, the Chouteau Limestone, to be deposited over much of the southern half of Illinois. This limestone marked the end of the Kinderhookian Epoch (fig. 1).

Valmeyeran Epoch During Valmeyeran time (fig. 1), the sea continued to cover much of the midcontinent (fig. 3). In western Illinois, where the sea was now clear and shallow, more than 150 feet of limestone (Fern Glen, Burlington, and Keokuk Limestones, fig. 1) formed a bank with a fairly sharp eastern slope that dropped off into deeper water. Initially, while this limestone was forming in western Illinois, very little sediment (Springville Shale) was being deposited in the southeastern part of the state, where the sea was much deeper.

Later, silt, clay, and sand again entered the sea from the east and northeast, forming the rock unit called the Borden Siltstone (fig. 1). This clay and silt eventually spread into western Illinois and choked most of the calcite-secreting organisms, thereby ending limestone production. Where the shales and siltstones that developed from this clay and silt overlie the limestone in the west, geologists call them the Warsaw Shale (fig. 1). The Warsaw, well known for its geodes, is exposed at the surface in parts of western Illinois. The shales and siltstones of the Borden are present in central and southern Illinois and reach a maximum thickness of 700 feet thick in east-central Illinois.

While deposits of the Borden Siltstone were still accumulating along the center of what is now Illinois, limestone began to form again to the east and south. Initially, the Fort Payne Formation (fig. 1) was deposited in relatively deep water. Then, as the amount of silt and clay entering the area gradually diminished, the Ullin, Salem, St. Louis, and Ste. Genevieve Limestones (fig. 1) formed in the warm, clear, and progressively shallower water.

Today, these Valmeyeran-age limestones are up to 1,800 feet thick in southeastern Illinois where they are buried as deep as 5,000 feet. The limestones are present at the surface in western Illinois, most notably in the bluffs along the Mississippi River between Alton and Grafton, and in southern Illinois. Where shallow enough, the limestones are quarried in parts of southern and western Illinois. Oil is produced from some of the limestones in southeastern Illinois; about 18% of all Illinois oil production comes from porous zones in the Ste. Genevieve Limestone (Howard 1991). The deeper limestones can be as productive as the Ste. Genevieve, but they have not been fully explored.

Chesterian Epoch Near the end of Valmeyeran time, relative sea level gradually dropped, and the northern shoreline moved southward and exposed more land. This transition marked the end of the Valmeyeran Epoch and the beginning of the Chesterian Epoch (fig. 1). As sea level lowered, more mud and sand were carried by ancient rivers and streams from land areas to the north, northeast, and northwest into the sea in the Illinois area. The mud and sand carried into the sea were reworked by tidal currents and distributed over large areas of the sea floor, where they were buried and eventually formed shale and sandstone. Shell-forming organisms were relatively less common during Chesterian time because they were choked by this mud and sand in the water. Periodically during the Chesterian, the sea withdrew entirely from the area of Illinois for a time and then returned. Paleosols (ancient soils) and deeply eroded valleys that have since been filled with sediment are evidence of these periods of dry or exposed land.

Periodically, sea level rose, and the quantities of mud and sand flowing into the sea were reduced. During these times, shell-forming organisms prospered once again, and thin limestones formed in this inland sea. These limestones are commonly only 10 to 30 feet thick, unlike the thicker ones of Valmeyeran age.

These fluctuations in sea level during the Chesterian resulted in deposition of alternating units of shale, sandstone, and limestone, which geologists refer to as cyclic sedimentation.

Chesterian rocks are present in the southern half of Illinois. Although the rocks are at the land surface in parts of southwestern and southernmost Illinois, in southeastern Illinois they are as deep as 3,000 feet. They are as thick as 1,400 feet in southernmost Illinois. Sandstones of Chesterian age have produced about 60% of the oil found in Illinois (Howard 1991).

The Chesterian, the last epoch of the Mississippian Period, was a time of transition from the Valmeyeran Epoch, when the seas were clear and thick limestones formed, to the subsequent Pennsylvanian Period, when the seas shallowed and disappeared for longer periods of time, and shale, siltstone, sandstone, and coal were the major deposits formed.

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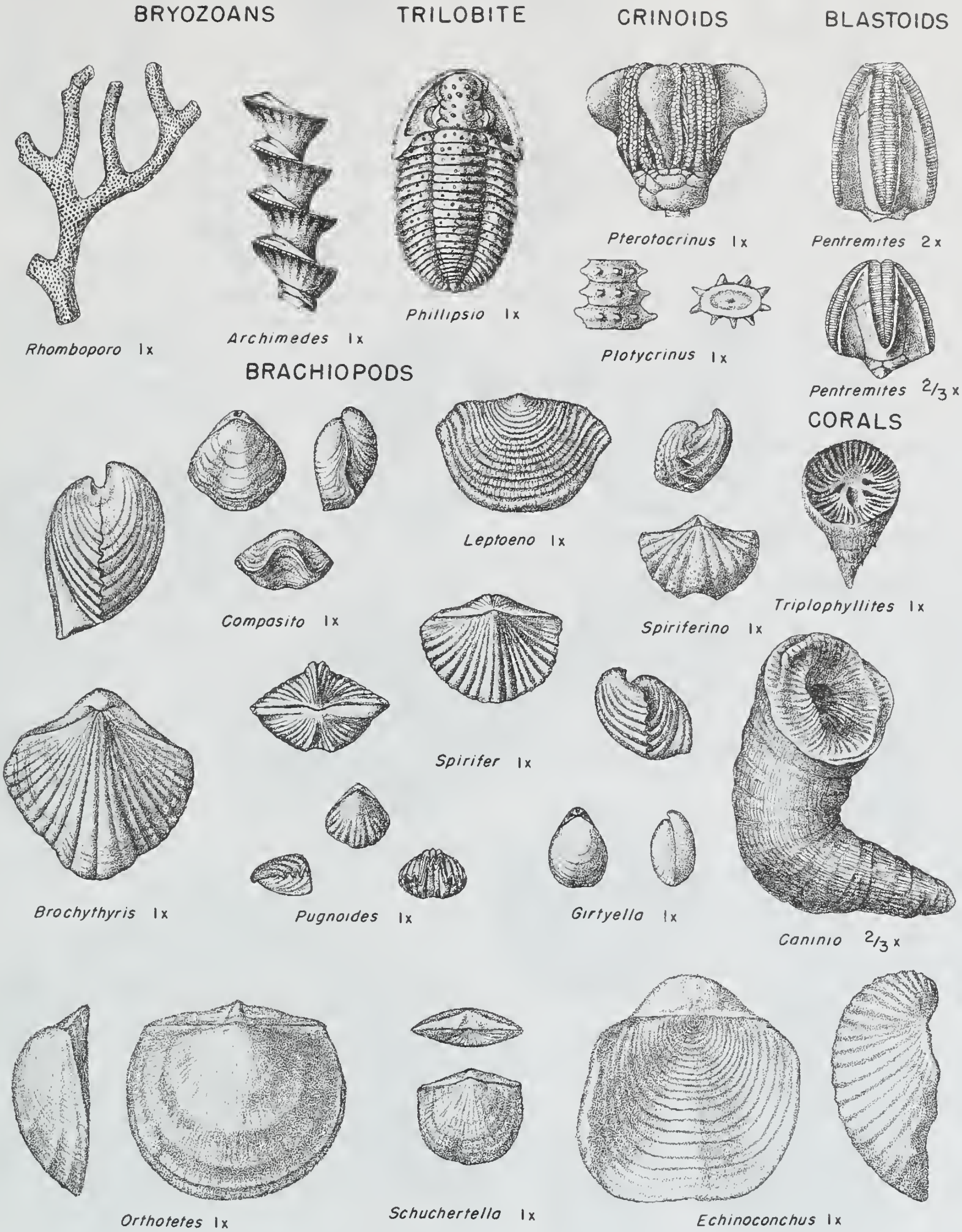


PLATE A Typical Mississippian fossils.

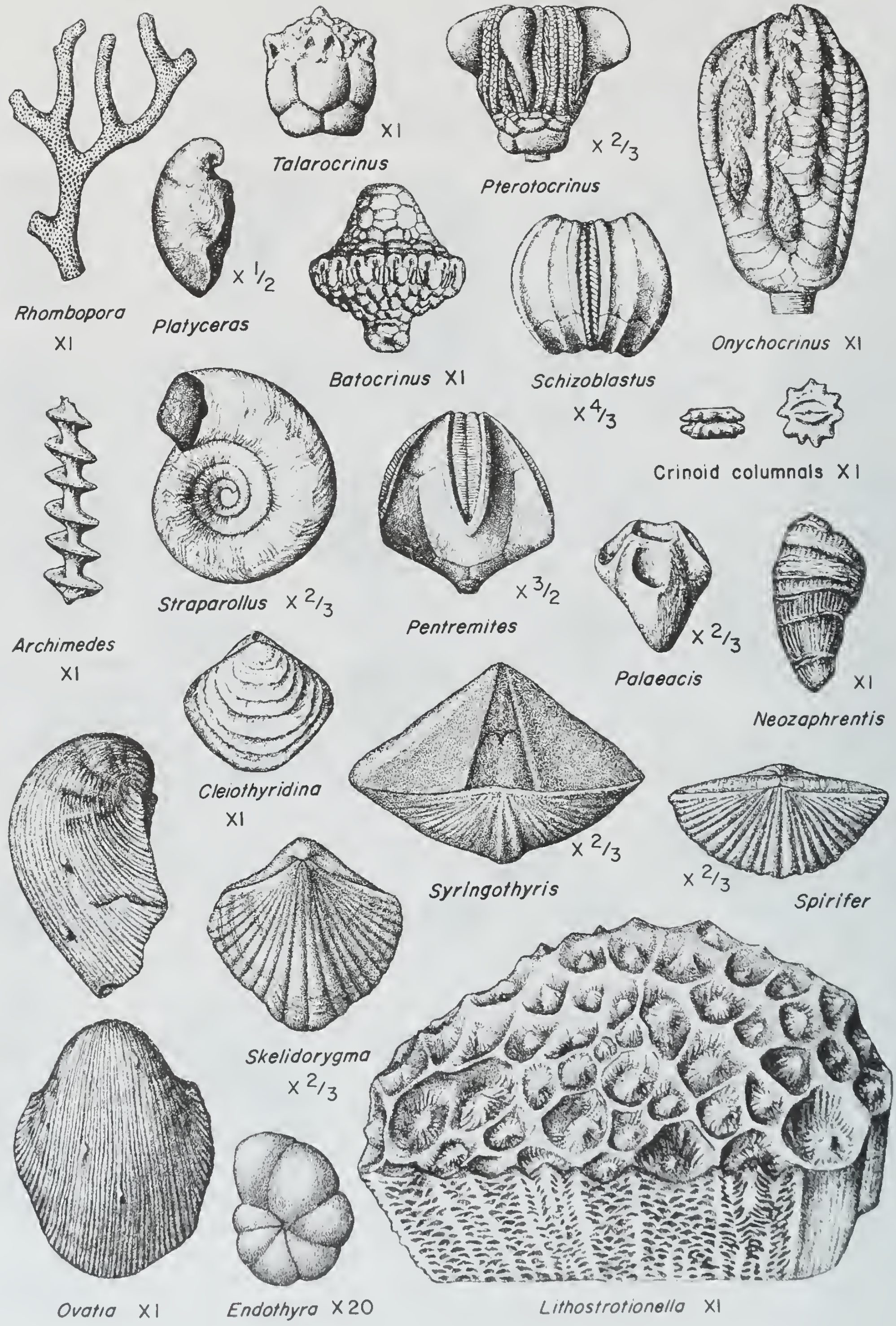


PLATE B Typical Mississippian fossils.

ILLINOIS STATE GEOLOGICAL SURVEY
Urbana, Illinois 61801

GEOGRAM 4
October 1975

WHEN THE EARTH SHAKES IN ILLINOIS

Myrna M. Killey

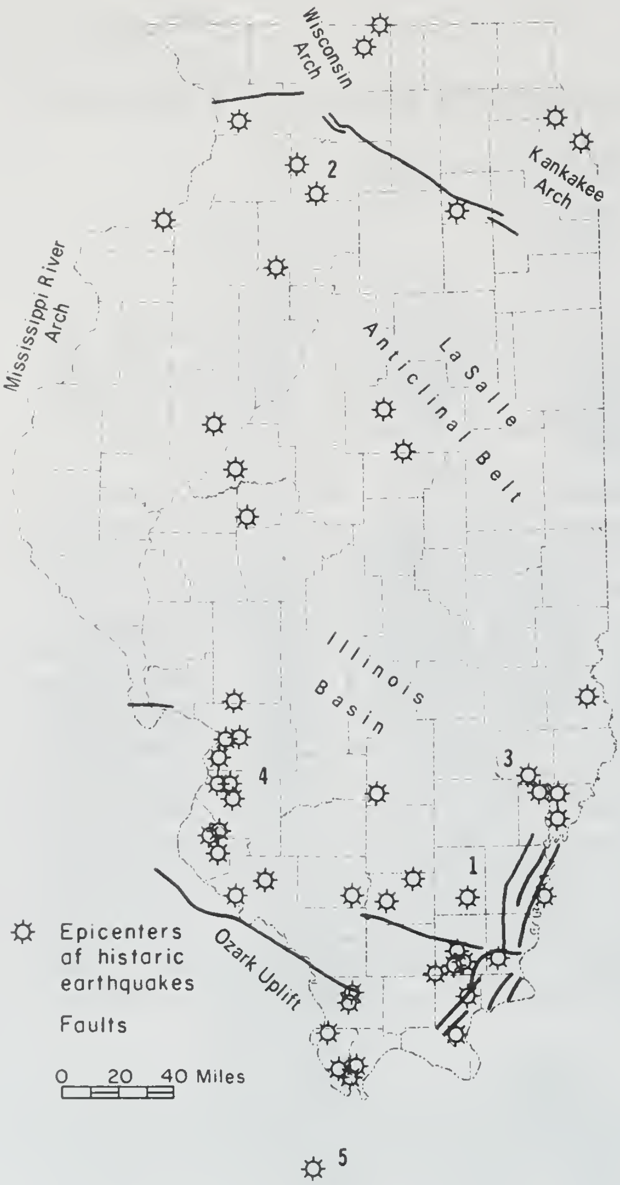
From time to time people in Illinois have reported feeling the earth shake. They may have heard rumbling noises like those made by heavy trucks passing by or have seen various objects mysteriously moving about—pictures swinging on the walls, dishes dancing on shelves, or parked cars rocking. People recognize these shakings as earthquakes and may wonder why earthquakes occur in Illinois.

The answer to that question is a complicated one. Essentially, earthquakes result from the build-up of great stresses in various parts of the earth. These stresses take the form of pulling, pushing, and shearing forces. Why such stresses build up is still not clearly understood and is the subject of much study and discussion among geologists and geophysicists. However, it is generally believed that these forces stretch the rocks and finally cause them to break. The breaks are called *faults* when the blocks of rock on either side of the break are displaced in relation to each other. In Illinois, the amount of displacement along faults observed in rocks near the surface is from a few inches to more than 3,000 feet. The faulting relieves the stress in the rocks and is the immediate cause of earthquakes. Sometimes faulting takes place at the earth's surface, but more often it occurs at great depth and cannot be seen on the land surface. In either case, faulting occurs where the rocks are weakest and offer the least resistance to stress. By noting places where faults can be seen at the surface and where long arches (*anticlines*) and troughs (*synclines*) occur in the rocks near the surface, geologists can pinpoint past zones of weakness in the rocks. These zones are the most likely places for future earthquakes to take place. They may extend for hundreds of miles.

When faulting takes place, the great amount of strain that had built up in the rocks is released suddenly and a series of vibrations, called seismic waves, radiates away from the fault. Although the release of stress is sudden, shaking may occur for some distance and has been known to last for hours. The nature of the rocks and the complicated paths along which seismic waves travel determine the extent and duration of the shaking.

The point at which faulting starts and from which seismic-wave energy radiates is called the *focus* of an earthquake. The *epicenter* is the point on the earth's surface directly above the focus. The map (turn page) shows epicenters of earthquakes that have occurred during historical times in Illinois. It also shows some geologic structures that indicate possible zones of weakness in rocks near the land surface.

You may remember some of the more recent earth tremors in Illinois. On the morning of November 9, 1968, an earthquake, centered near Broughton (1 on map) in Hamilton County, shook a large area of the central and southeastern United States. A less powerful quake was felt over a seven-state area in the central United States shortly after midnight on September 15, 1972. It was centered just south of Amboy in Lee County (2 on map) in northern Illinois. A third quake, felt



at 6 o'clock on April 3, 1974, was centered near Olney in Richland County (3 on map). Still another quake occurred early in the morning of June 5, 1974, in the Belleville area near St. Louis (4 on map).

As alarming as these quakes might have been, they by no means compare with the series of earthquakes that shook Illinois and the central United States from December 1811 through February 1812. The area around New Madrid, Missouri (5 on map), just south of Illinois along the Mississippi River, was the site of three consecutive quakes, each much larger than any other recorded earthquake in Illinois. A repeat of such events today would cause great loss of property and, possibly, life.

At the present time, geologists are working to find ways to predict when, where, and how large any future earthquakes will be. This information is vitally important to engineers, architects, and planners who design and build homes, hospitals, highways, dams, office buildings, factories, and other important structures. Although we cannot yet predict when and where the next earthquake will occur in Illinois, we can design structures to withstand the damaging effects of the earthquakes.

ILLINOIS STATE GEOLOGICAL SURVEY
Urbana, Illinois 61801

GEOGRAM 5
October 1975

ANCIENT DUST STORMS IN ILLINOIS

Myrna M. Killey

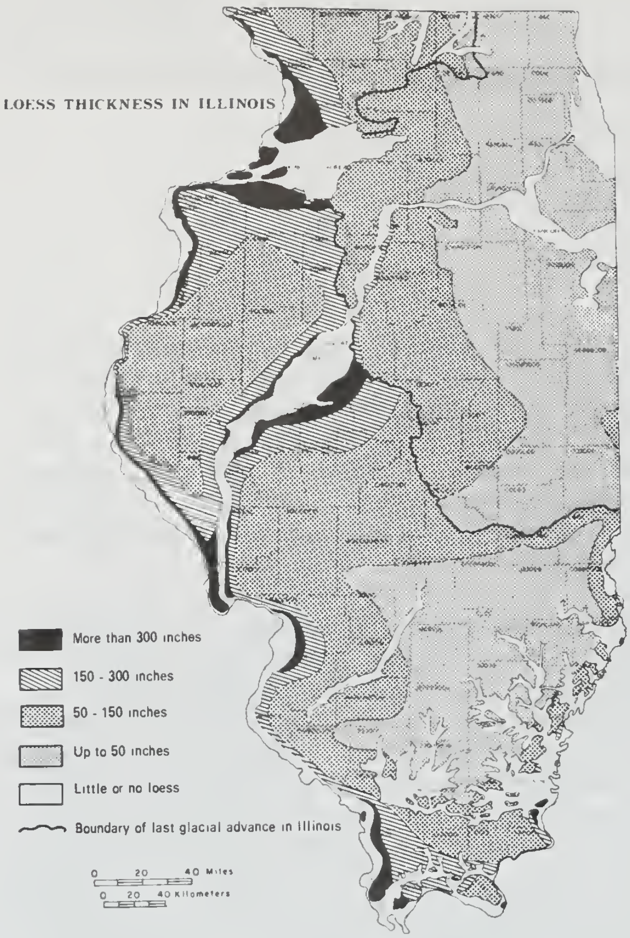
Fierce dust storms whirled across Illinois long before human beings were here to record them. Where did all the dust come from? Geologists have carefully put together clues from the earth itself to get the story. As the glaciers of the Great Ice Age scraped and scoured their way southward across the landscape from Canada, they moved colossal amounts of rock and earth. Much of the rock ground from the surface was kneaded into the ice and carried along, often for hundreds of miles. The glaciers acted as giant grist mills, grinding much of the rock and earth to "flour"—very fine dust-sized particles.

During the warm seasons, water from the melting ice poured from the glacier front, laden with this rock flour, called silt. In the cold months the meltwater stopped flowing and the silt was left along the channels the water had followed, where it dried out and became dust. Strong winds picked up the dust, swept it from the floodplains, and carried it to adjacent uplands. There the forests along the river valleys trapped the dust, which became part of the moist forest soil. With each storm more material accumulated until the high bluffs adjacent to major rivers were formed. The dust deposits are thicker along the eastern sides of the valleys than they are on the western sides, a fact from which geologists deduce that the prevailing winds of that time blew from west to east, the same direction as those of today. From such clues geologists conclude that the geologic processes of the past were much like those of today.

The deposits of windblown silt are called loess (rhymes with "bus"). Loess is found not only in the areas once covered by the glaciers but has been blown into the nonglaciated areas. The glaciers, therefore, influenced the present land surface well beyond the line of their farthest advance.

Loess has several interesting characteristics. Its texture is so fine and uniform that it can easily be identified in roadcuts—and because it blankets such a vast area many roads are cut through it. Even more noticeable is its tendency to stand in vertical walls. These steep walls develop as the loess drains and becomes tough, compact, and massive, much like a rock. Sometimes cracks develop in the loess, just as they do in massive limestones and sandstones. Loess makes good highway banks if it is cut vertically. A vertical cut permits maximum drainage because little surface is exposed to rain, and rainwater tends to drain straight down through it to the rock underneath. If the bank is cut at an angle more water soaks in, which causes the loess to slump down. Along Illinois roads the difference between a loess roadcut and one in ordinary glacial till is obvious. The loess has a very uniform texture, while the till is composed of a random mixture of rock debris, from clay and silt through cobbles and boulders.

Many loess deposits are worth a close look. Through a 10-power hand lens separate grains can be seen, among them many clear, glassy, quartz grains. Some loess deposits contain numerous rounded, lumpy stones called concretions. Their formation began when water percolating through the loess dissolved tiny



limestone grains. Some of the dissolved minerals later became solid again, gathering around a tiny nucleus or along roots to form the lumpy masses. A few such concretions are shaped roughly like small dolls and, from this resemblance, are called "loess kindchen," a German term meaning "loess children." They may be partly hollow and contain smaller lumps that make them rattle when shaken.

Fossil snails can be found in some loess deposits. The snails lived on the river bluffs while the loess was being deposited and were buried by the dust. When they are abundant, they are used to determine how old the loess is. The age is found by measuring the amount of radioactive carbon in the calcium carbonate of their shells.

Some of the early loess deposits were covered by new layers of loess following later glacial invasions. Many thousands of years passed between the major glacial periods, during which time the climate was as warm as that of today. During the warm intervals, the surface of the loess and other glacial deposits was exposed to weather. Soils developed on most of the terrain, altering the composition, color, and texture of the glacial material. During later advances of the ice, some of these soils were destroyed, but in many places they are preserved under the younger sediments. Such ancient buried soils can be used to determine when the materials above and below them were laid down by the ice and what changes in climate took place.

The blanket of loess deposited by the ancient dust storms forms the parent material of the rich, deep soils that today are basic to the state's agriculture. A soil made of loess crumbles easily and has great moisture-holding capacity. It also is free from rocks that might complicate cultivation. Those great dust storms that swirled over the land many thousands of years ago thus endowed Illinois with one of its greatest resources, its highly productive soil.

ILLINOIS STATE GEOLOGICAL SURVEY
Urbana, Illinois 61801

GEOGRAM 7
September 1976

HOW EARTHQUAKES ARE MEASURED

Myrna M. Killey

Photographs and films in news reports of earthquake damage show us in a vivid way how strong some earthquakes are. However, many earthquakes do not cause visible damage. Therefore, pictures are not the only means to describe the strength of an earthquake. In fact, most news accounts mention reports from scientists who refer to the severity of an earthquake by using measures of "magnitude" and "intensity." What do these terms mean?

The *magnitude* of an earthquake is computed from ground movement recorded at seismic stations by instruments called seismographs. Magnitude is the measure of the total seismic energy released by the earthquake. It was originally defined by Charles F. Richter, an American seismologist, to make it easier to compare the differences in amounts of energy released by earthquakes. Magnitude is not directly proportional to the amount of energy released. For example, an earthquake of magnitude 5 does not release only 25 percent more energy than an earthquake of magnitude 4. The earthquake of magnitude 5.5 that occurred in southern Illinois on November 9, 1968, released about 250 times the energy of the southern Illinois quake of magnitude 4.5 on April 3, 1974.

The *intensity* of an earthquake is a measurement of the effects of the shaking, as shown by the damage to property and by the earth deformation felt or observed by people in a particular part of the shaken area. Thus, for any earthquake there are many intensities (dependent upon the location of an observer in the earthquake area) but only one magnitude (measured by seismographs).

The most widely used intensity scale is the Modified Mercalli scale which was introduced in 1931. A Modified Mercalli scale of earthquake intensities and the approximately corresponding magnitudes on the Richter scale can be found in the table on the other side of this page. This table will help you to compare information between past earthquakes and future tremors about which you may read or hear in the news. Magnitudes and maximum intensities of some recent Illinois earthquakes are listed here. Maximum intensity is designated because an earthquake can produce several distinct shocks of different strengths.

	Magnitude	Maximum intensity
November 9, 1968	5.5	VII
September 15, 1972	4.63	VI
April 3, 1974	4.5	VI
June 5, 1974	4.0	V

The initial movements along a fault to relieve the buildup of stress may involve a relatively small area of the fault plane, but after a short interval of time a shift over a much larger area of the fault plane follows. Because tearing and displacement usually occur at great depths, shallower faults that can be seen at the earth's surface may or may not be affected. On the west coast, surface faults are highly active during earthquakes, but in Illinois, there is not yet evidence that recent earthquakes have caused shifts along the ancient fault lines intersecting the bedrock surface.

Sometimes the initial movements in the small area and the shifts in the much larger area of the fault plane occur almost at the same moment so that they cannot be distinguished. However, if the time interval between shocks is great enough to allow them to be distinguished, the first movements are called *foreshocks*. The shift of the rocks at the time of the principal break, or *main shock*, relieves the main stress in the rocks. Following the main shock, a series of adjustments in the rocks results in a sequence of *aftershocks* of gradually decreasing magnitude and frequency.

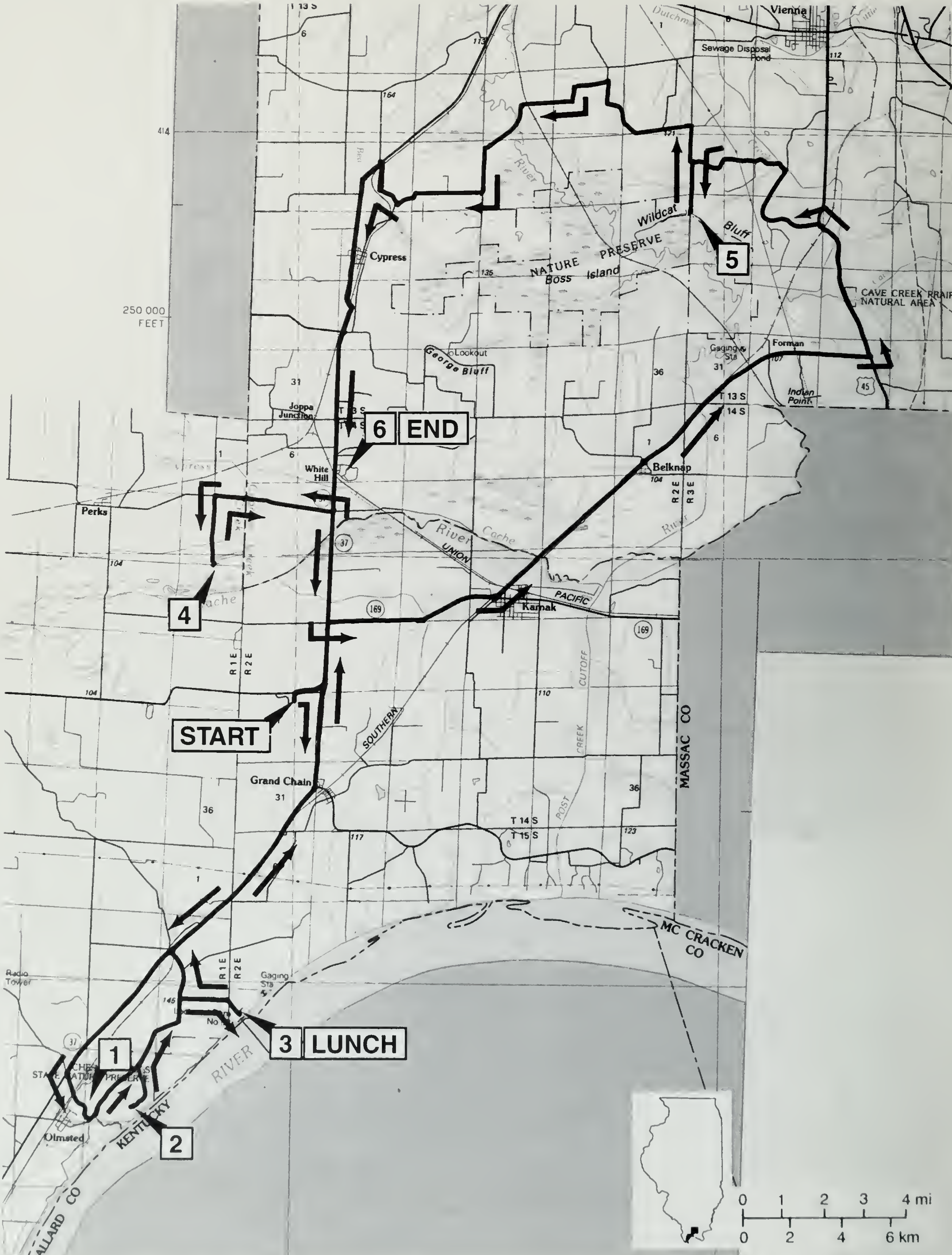
Instruments to measure magnitude had not yet been invented at the time of the New Madrid, Missouri sequence of earthquakes in 1811-1812, but from historical reports available on the effects and damage of that tremendous shaking, the total energy released in the New Madrid sequence is thought to be equivalent to at least magnitude 7.5 on the Richter scale. The first of the quakes, which took place on December 16, 1811, was estimated to have a maximum intensity of XI.

The so-called "New Madrid seismic region," which includes portions of extreme southern Illinois, southeast Missouri, western Tennessee and Kentucky, and northeastern Arkansas, has historically been an area of frequent earthquakes. In the southern Illinois area, the release of energy has occurred generally as numerous small shocks, most so small that they have caused little or no damage to man-made structures.

MODIFIED MERCALLI SCALE OF EARTHQUAKE INTENSITIES
WITH APPROXIMATELY CORRESPONDING MAGNITUDES*

Intensity		Description of characteristic effects	Richter scale magnitude approximately corresponding to highest intensity reached
I	Instrumental:	detected only by seismography	
II	Feeble:	noticed only by sensitive people	3.5 to 4.2
III	Slight:	like the vibrations due to a passing heavy truck; felt by people at rest, especially on upper floors	
IV	Moderate:	felt by people while walking; rocking of loose objects, including standing vehicles	4.3 to 4.8
V	Rather strong:	felt generally; most sleepers are wakened and bells ring	
VI	Strong:	trees sway and all suspended objects swing; damage by overturning and falling of loose objects	4.9 to 5.4
VII	Very strong:	general alarm; walls crack; plaster falls	5.5 to 6.1
VIII	Destructive:	car drivers seriously disturbed; masonry fissured; chimneys fall; poorly constructed buildings damaged	6.2 to 6.9
IX	Ruinous:	some houses collapse where ground begins to crack, and pipes break open	
X	Disastrous:	ground cracks badly; many buildings destroyed and railway lines bent; landslides on steep slopes	7.0 to 7.3
XI	Very disastrous:	few buildings remain standing; bridges destroyed; all services (railway, pipes and cables) out of action; great landslides and floods	7.4 to 8.1
XII	Catastrophic:	total destruction; objects thrown into air; ground rises and falls in waves	8.1+

* From Holmes, Arthur, 1965, Principles of Physical Geology: Ronald Press, N.Y., p. 901.



START
1
2
3 LUNCH
4
5
6 END
Vienna
Cypress
Joppa Junction
White Hill
Perks
Karnak
Belknap
Forman
Grand Chain
Olmsted
NATURE PRESERVE
Boss Island
Wildcat Bluff
George Bluff
Lookout
CAVE CREEK PRAIRIE NATURAL AREA
Indian Point
Sewage Disposal Pond
Cache River
UNION PACIFIC
SOUTHERN
POST CREEK CUTOFF
MASSAC CO
MC CRACKEN CO
BALLARD CO
KENTUCKY RIVER
Radio Tower
Gaging Sta
250 000 FEET
R1E R2E R3E
T 13 S
T 14 S
T 15 S
0 1 2 3 4 mi
0 2 4 6 km