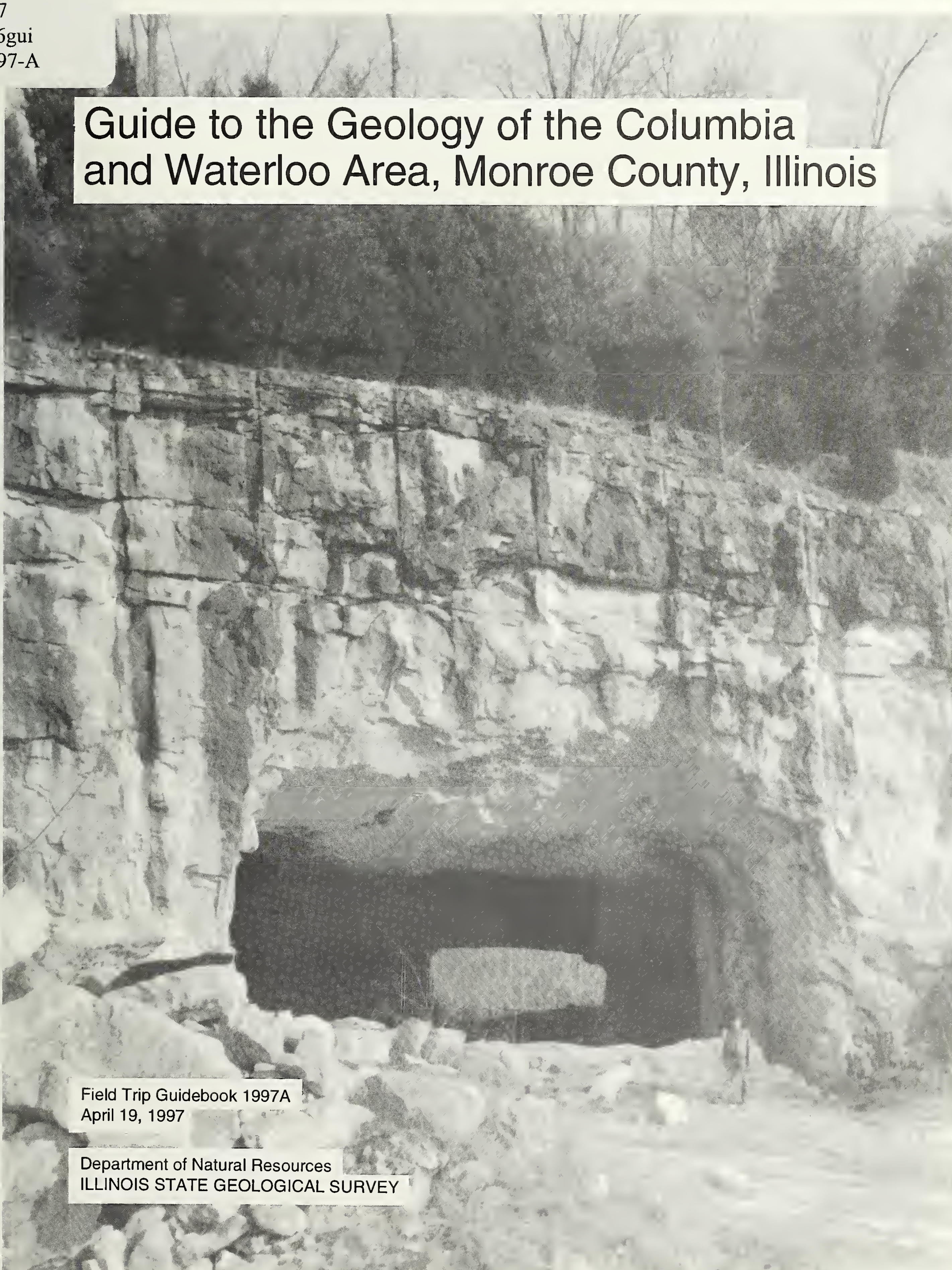

Guide to the Geology of the Columbia and Waterloo Area, Monroe County, Illinois

Field Trip Guidebook 1997A
April 19, 1997

Department of Natural Resources
ILLINOIS STATE GEOLOGICAL SURVEY

Guide to the Geology of the Columbia and Waterloo Area, Monroe County, Illinois

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Cover photo Exposure of Ordovician strata in the bluff face at the Valmeyer quarry at stop 4 (photo by Wayne T. Frankie).

Six USGS 7.5-Minute Quadrangle Maps (Columbia, Oakville, Paderborn, Renault, Valmeyer, and Waterloo) provide coverage for this field trip area.

Geological Science Field Trips The Educational Extension 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 led to their origin. 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 who prepare 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 for planning class tours and private outings may be obtained by contacting the Educational Extension Unit, Illinois State Geological Survey, Natural Resources Building, 615 East Peabody Drive, Champaign, IL 61820. Telephone: (217) 244-2427 or 333-4747.

ILLINOIS DEPARTMENT OF NATURAL RESOURCES

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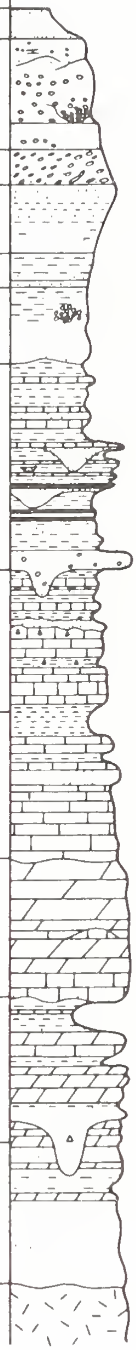
CONTENTS

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.

COLUMBIA AND WATERLOO AREA

The Columbia and Waterloo area geologic science field trip will acquaint you with the *geology**, landscape, and mineral resources for part of Monroe County, Illinois. Columbia is located in southwestern Illinois on top of the eastern bluffs of the Mississippi River Valley. It is approximately 310 miles southwest of Chicago, 110 miles southwest of Springfield, 15 miles south of East St. Louis, and 140 miles northwest of Cairo.

This upland region adjacent to the Mississippi River basin is often called the "sinkhole plain" because of its great number of sinkholes. This sinkhole plain includes, from north to south, southern St. Clair, most of Monroe, and northern Randolph Counties.

GEOLOGIC FRAMEWORK

Precambrian Era Through several billion years of geologic time, Monroe County and surrounding areas have 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 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 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 movement 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 broad hilly Precambrian region began to sink slowly, allowing the invasion of a shallow sea from the south and southwest. During the several hundred 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 times during this era, the seas withdrew and 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 from more than 520 million years (the Cambrian *Period*) to less than 290 million years old (the Pennsylvanian Period). Figure 2 shows the succession of 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.

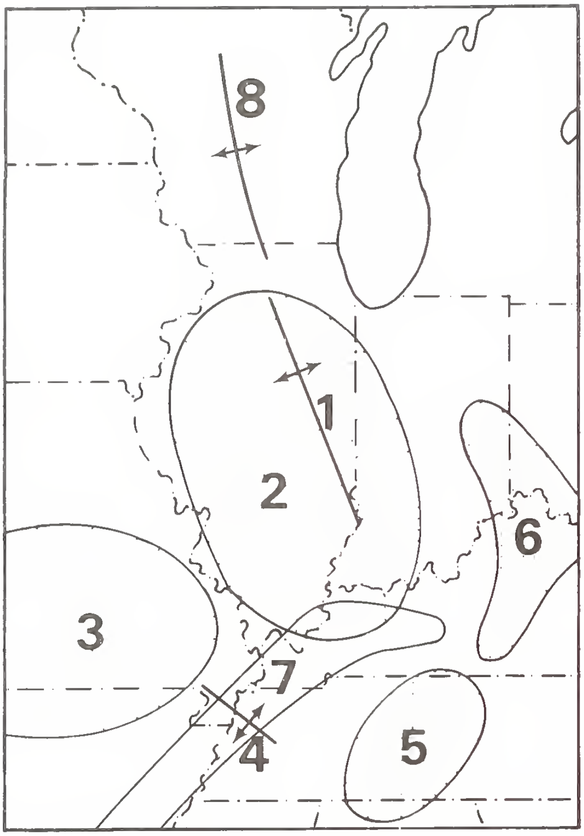


Figure 1 Location of some of the major structures in the Illinois region. (1) La Salle Anticlinorium, (2) Illinois Basin, (3) Ozark Dome, (4) Pascola Arch, (5) Nashville Dome, (6) Cincinnati Arch, (7) Rough Creek Graben-Reelfoot Rift, and (8) Wisconsin Arch.

The elevation of the top of the Precambrian basement rocks within the field trip area ranges from 3,000 feet below sea level in central Monroe County to 4,500 feet below sea level in eastern Monroe County. The thickness of the Paleozoic sedimentary strata ranges from about 2,800 feet in western Monroe County to about 4,850 feet in eastern Monroe County.

Pennsylvanian-age bedrock strata consisting of shale, siltstone, sandstone, limestone, coal, and underclay were deposited as sediments in shallow seas and swamps between about 320 and 286 million years ago. The Pennsylvanian rocks are limited to an area of about 1.5 square miles in parts of sections 33 and 34 in Township 1 South, Range 10 West, and sections 3 and 4 in Township 2 South, Range 10 West, approximately 3 miles south of Columbia, and along the eastern part of Monroe County, where the maximum thickness is less than 200 feet.

Most bedrock exposed in Monroe County belongs to the Mississippian Valmeyeran series (see fig. 2). These rocks are the limestones, shales, and thin sandstones that were deposited as sediments in shallow seas between 360 and 320 million years ago. (See *Mississippian Rocks in Illinois* in the supplemental reading at the back of this guidebook for a more complete description of these rocks.)

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 and Mesozoic Eras 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

SYSTEM	SERIES	GROUP, STAGE	FORMATION, MEMBER	ROCK TYPE	THICKNESS	DESCRIPTION
QUATERNARY		Holocene				Sand, silt, clay
QUATERNARY	Pleistocene	Wisconsinan	Peoria			Loess
QUATERNARY	Pleistocene	Wisconsinan	Roxana			Loess
QUATERNARY	Pleistocene	Illinoian				Till, some outwash
PENNSYLVANIAN		Kewanee	Carbondale: Hanover Ls, Houchin Creek Coal, Colchester Coal		40	Sandstone; siltstone; shale; limestone; coal; underclay
PENNSYLVANIAN		Raccoon Creek			25	Sandstone; siltstone; shale; thin coal
MISSISSIPPIAN	Valmeyeran		Ste. Genevieve		70	Limestone, oolitic, some chert
MISSISSIPPIAN	Valmeyeran		St. Louis		245	Limestone, some dolomite, some chert
MISSISSIPPIAN	Valmeyeran		Salem		80	Limestone, some oolites, some chert
MISSISSIPPIAN	Valmeyeran		Ullin		65	Limestone, some chert
MISSISSIPPIAN			Warsaw		25	Shale
MISSISSIPPIAN			Keokuk		60	Limestone, very cherty
MISSISSIPPIAN			Burlington		100	Limestone very cherty
MISSISSIPPIAN			Fern Glen		60	Limestone, some chert; shale
MISSISSIPPIAN	Kinderhookian		Chouteau		30	Limestone and shale
DEVONIAN		New Albany			15	Shale
SILURIAN					75	Dolomite, cherty
ORDOVICIAN	Cincinnatian	Maquoketa	Scales Shale		150	Siltstone; shale; some limestone
ORDOVICIAN	Cham.	Kimmswick	Wise Lake Dunleith		100	Limestone
OLDER ORDOVICIAN AND CAMBRIAN STRATA					2450	Limestone; dolomite; sandstone; shale
PRECAMBRIAN						Granite; other igneous and metamorphic rocks

Figure 2 Generalized geologic column of strata in the Columbia-Waterloo area (modified from Reinertsen 1981).

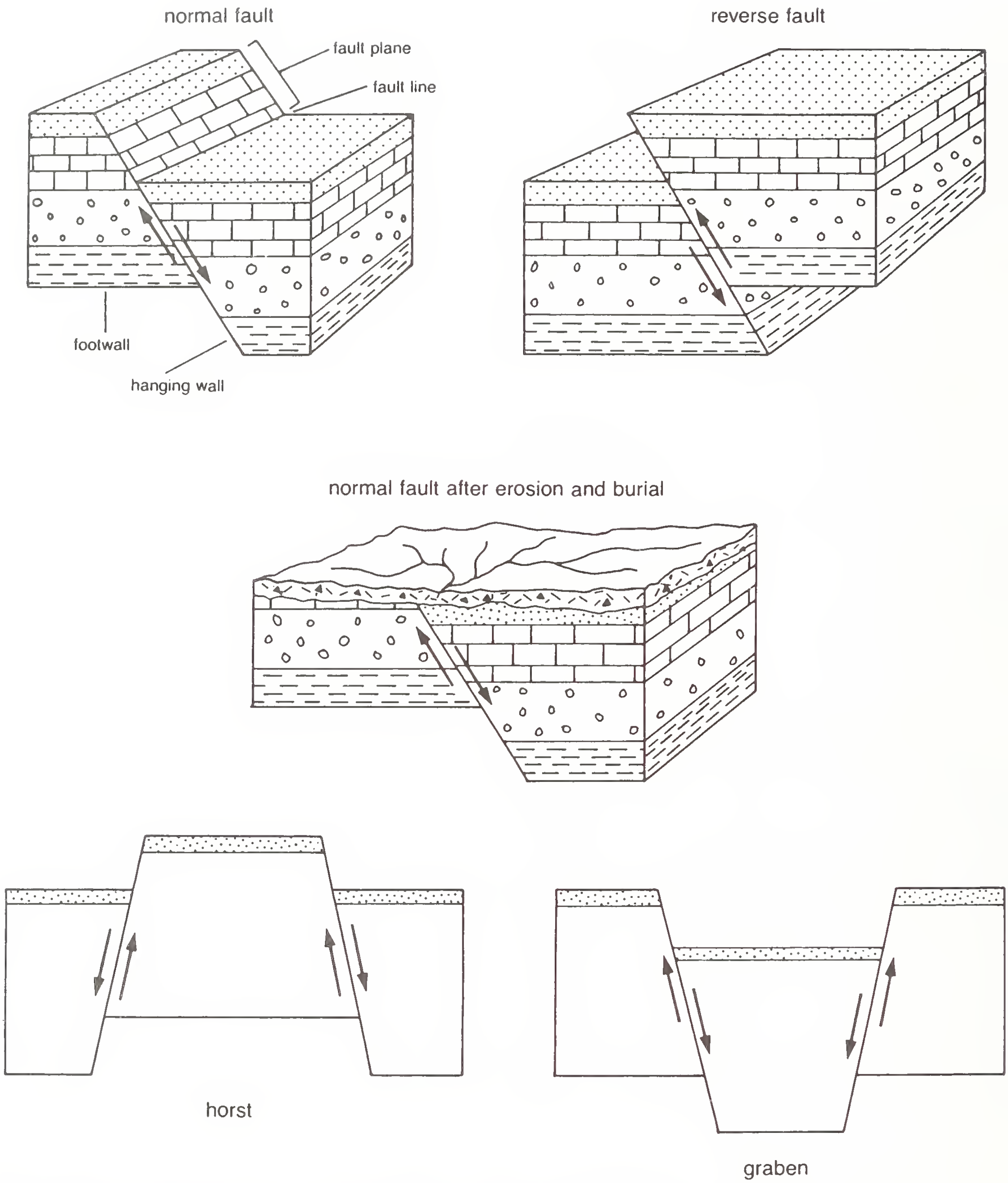


Figure 3 Diagrammatic illustrations of fault types that may be present in the field trip area (arrows indicate relative directions of movement on each side of the fault).

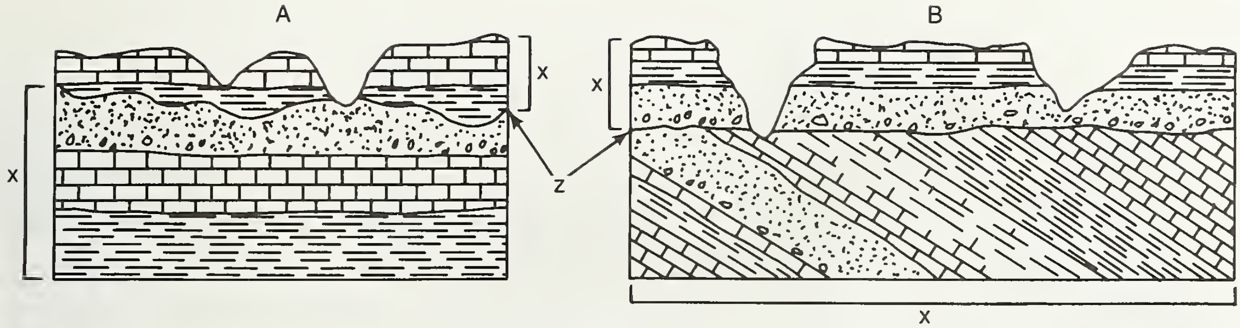


Figure 4 Schematic drawings of (A) a disconformity and (B) an angular unconformity (x represents the conformable rock sequence and z is the plane of unconformity).

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. Earth's thin crust was periodically flexed and warped as stresses built up in places. 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.

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 (fig. 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 some places, however, the top of the lower formation was at least partially eroded before deposition of the next formation began. 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*; if the lower beds have been tilted and eroded before the overlying beds were deposited, the contact is called an angular unconformity.

Unconformities are shown in the generalized stratigraphic column in figure 2 as wavy lines. Each unconformity represents an extended interval of time for which there is no rock record.

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 anti-clinorium. 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 eroded), 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.

During the Mesozoic Era, which followed the Paleozoic Era, the rise of the Pascola Arch (figs. 1 and 5) in southeastern Missouri and western Tennessee formed 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 deeper parts of the area to the north, gave the basin its present asymmetrical, spoon-shaped configuration (fig. 6). The geologic map (fig. 7) shows the distribution of the rock *systems* of the various geologic time periods as they would appear if all the glacial, wind-blown, and surface materials were removed.

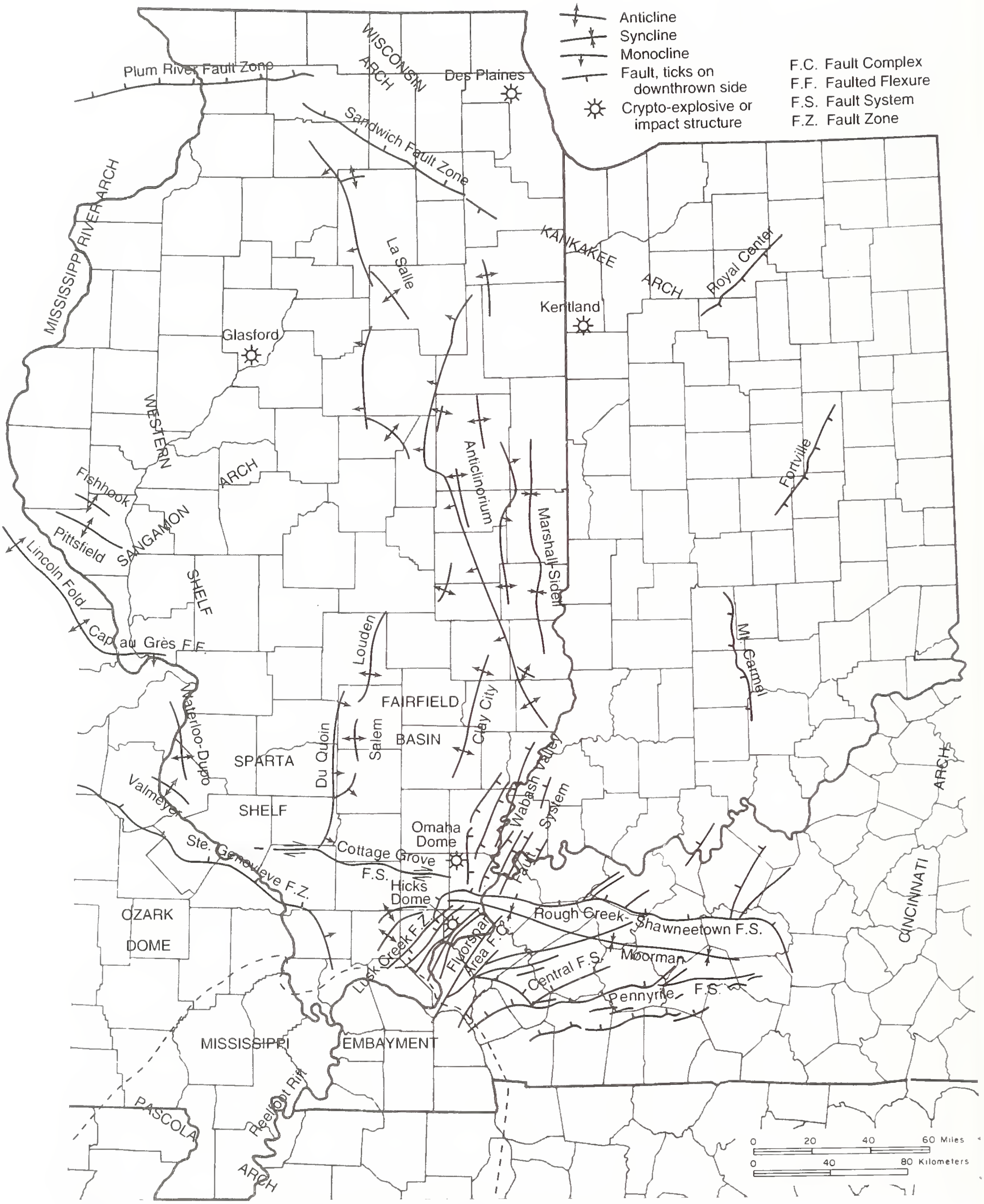


Figure 5 Structural features of Illinois (modified from Buschbach and Kolata 1991).

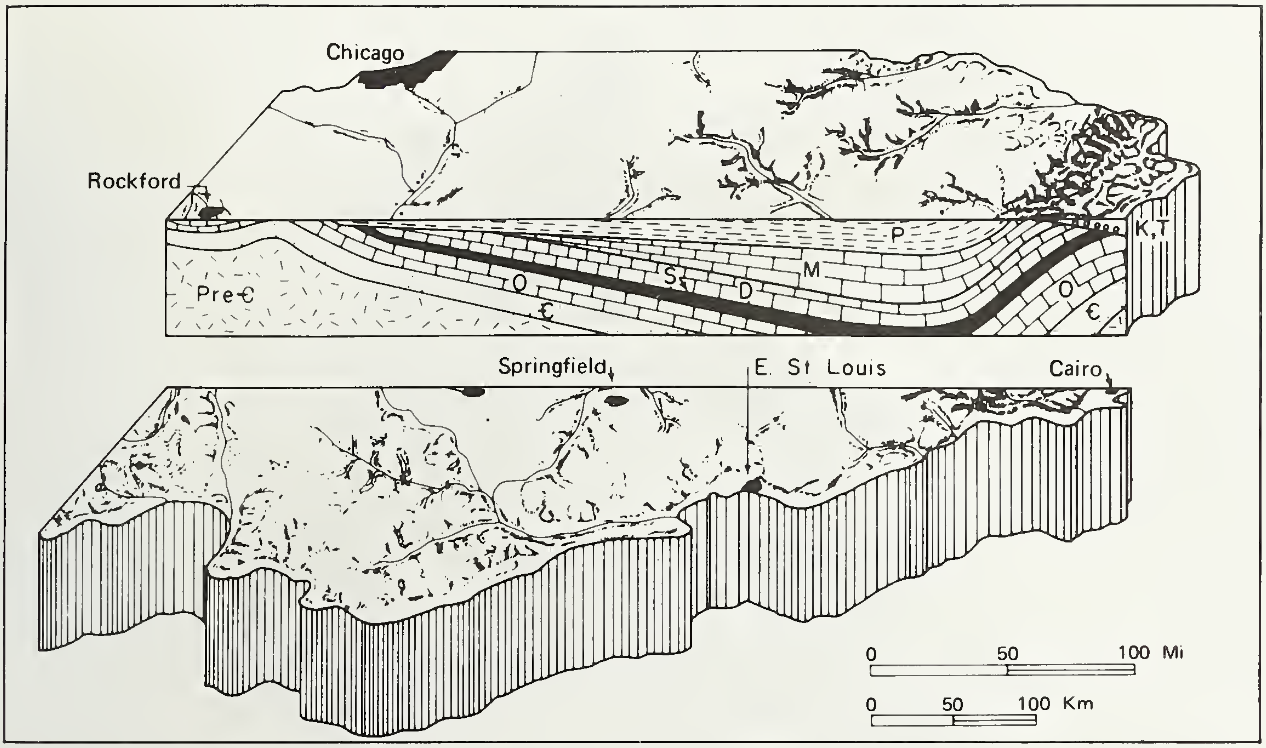


Figure 6 Stylized north–south cross section shows the structure of the Illinois Basin. To show detail, the thickness of the sedimentary rocks has been greatly exaggerated and younger, unconsolidated surface deposits have been eliminated. The oldest rocks are Precambrian (Pre-Є) granites. They form a 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.

Structural features The Columbia and Waterloo field trip area is located along the southwestern edge of the Illinois Basin. Three major structural features are located within the field trip area: the Waterloo-Dupo Anticline, the Valmeyer Anticline, and the Columbia Syncline (fig. 8). The following descriptions of these structures are taken from *Structural Features in Illinois* by W.J. Nelson (ISGS Bulletin 100, 1995). The Waterloo-Dupo Anticline is a sharply asymmetrical structure, the axis of which strikes slightly west of north. The name Waterloo-Dupo was derived from two oil fields that were developed at different times and in separate areas of closure (an area of equal elevation surrounding a high or low) on the Waterloo-Dupo Anticline. The east limb of the anticline dips 2° to 4°, whereas the west limb dips steeper than 45° in places. More than 300 feet of closure has been mapped on the top of the Middle Ordovician Kimmswick Limestone of the Galena (Trenton) Group in the Waterloo Oil Field near the south end of the anticline. The Waterloo-Dupo Anticline apparently underwent at least two separate periods of movement. Late Devonian uplift is indicated by subsurface thinning of Silurian and Devonian strata across the crest of the fold. The main episode of folding took place near the end of the Mississippian or early in the Pennsylvanian Period. Nearly horizontal strata of the Carbondale Formation (middle Pennsylvanian) overlie Chesterian formations (upper Mississippian) dipping 40° to 50° on the west limb of the fold. Slight post-Pennsylvanian folding may have taken place, but is difficult to demonstrate because Pennsylvanian rocks are absent along the anticlinal crest.

The Valmeyer Anticline lies southwest of the Waterloo-Dupo Anticline, strikes northwest, and is strongly asymmetrical. The Kimmswick Limestone (Middle Ordovician) comes to the surface at the crest of the anticline, and Mississippian rocks crop out on both flanks. The southwest limb dips 15° to 25°, and the northeast flank dips gently. No oil has been produced from the Kimmswick, which is

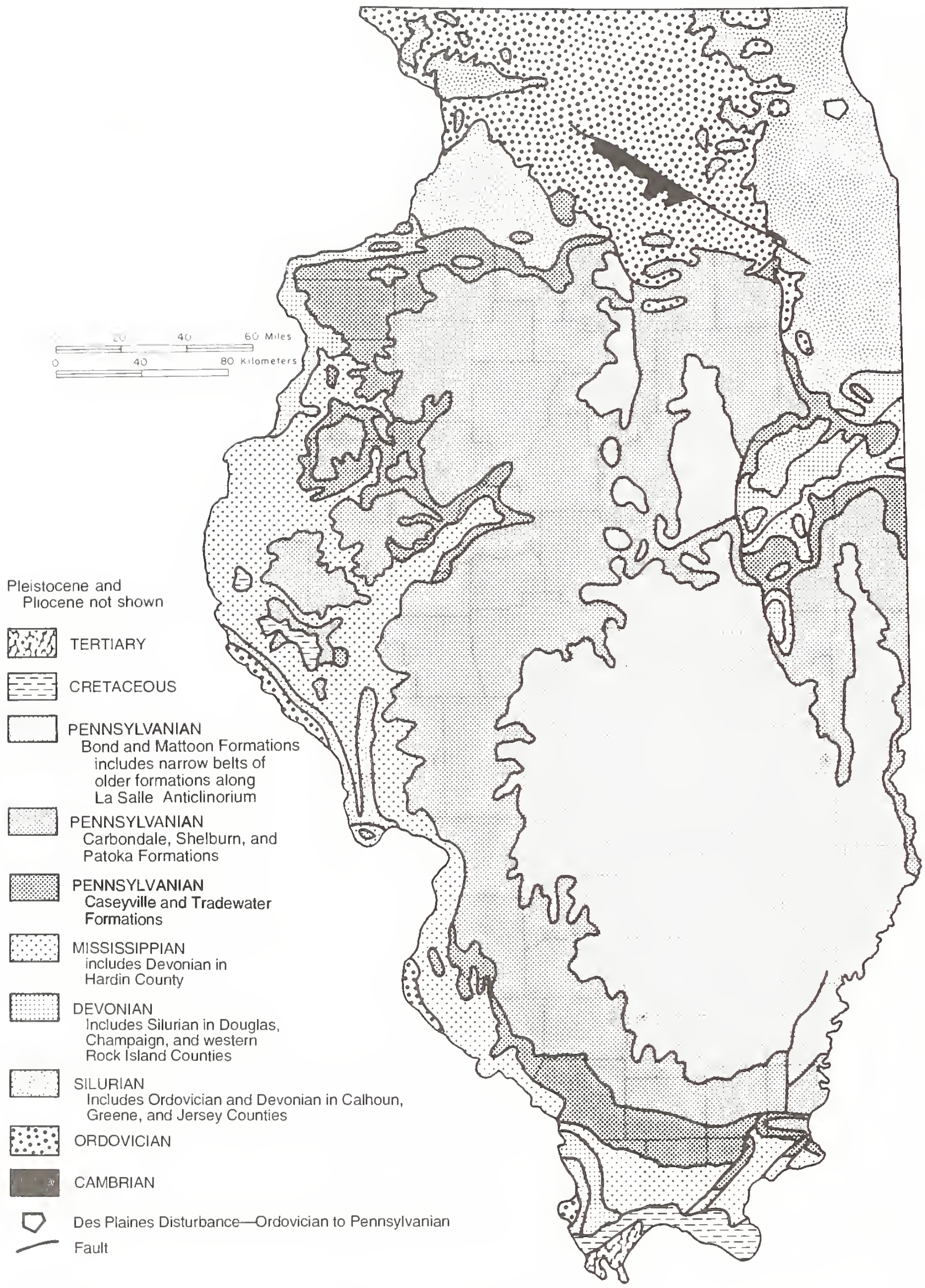


Figure 7 Bedrock geology beneath surficial deposits in Illinois.

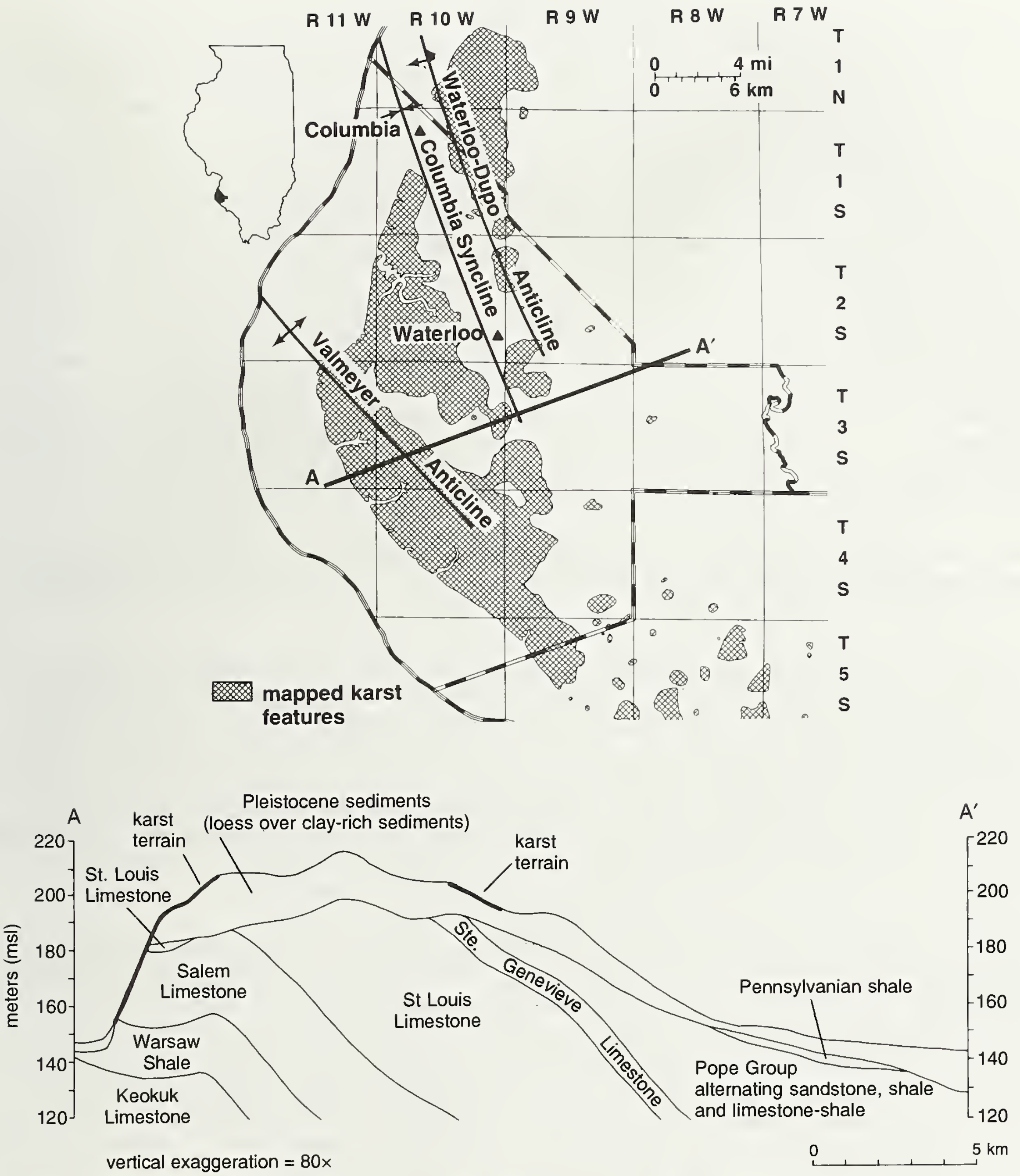


Figure 8 Karst terrain and associated structural features in the sinkhole plain as shown in (a) map view, which shows the distribution of karst features and major structural features, and (b) cross section (A–A′), which shows the stratigraphy and major rock units (from Panno et al. 1996).

the principal producing horizon in the Waterloo and Dupo oil fields, because the Kimmswick is breached by erosion on the Valmeyer Anticline.

The Columbia Syncline separates the Waterloo-Dupo Anticline and the Valmeyer Anticline. The synclinal axis runs north to northwest, parallel with the Waterloo-Dupo Anticline. Structural relief on the top of the Ordovician Kimmswick Limestone is more than 450 feet. The east limb dips steeper than 45° in places; the west limb is considerably broader and gentler.

Pennsylvanian-age bedrock occurs on the east flank of the Waterloo-Dupo Anticline, and in a small 1.5-square-mile area along the axis of the Columbia Syncline approximately 3 miles south of Columbia. The Pennsylvanian rocks are exposed along the Kaskaskia River and many of its smaller tributaries in eastern Monroe County. Younger rocks of the latest Pennsylvanian and perhaps the Permian (the youngest rock systems of the Paleozoic) may have at one time covered the area of Monroe County. Mesozoic and Cenozoic rocks (see the generalized geologic column) could also possibly have been present 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 8,000 feet of latest Pennsylvanian and younger rocks once covered southern Illinois. However, during the more than 240 million years since the end of the Paleozoic Era (and before the onset of *glaciation* 1 to 2 million years ago), 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 were removed. During this extended period of erosion, deep valleys were carved into the gently tilted bedrock formations (fig. 9). Later, the topographic *relief* produced by the preglacial erosion 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 last glaciers about 13,500 years ago left behind the non-lithified deposits in which our Modern Soil has developed.

Cenozoic Era: Glacial history A brief general history of glaciation in North America and a description of the deposits commonly left by glaciers may be found in *Pleistocene Glaciations in Illinois* at the back of this guidebook.

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 (fig. 9). Prior to glaciation, a large part of eastern Monroe County was drained by an ancient northeast–southwest bedrock valley called the Kaskaskia Bedrock Valley. The Kaskaskia Bedrock Valley begins in northeastern Shelby County and extends southwestward to its junction with the Mississippi River near Fort Kaskaskia in Randolph County. The Illinoian glacial drift in the Kaskaskia Bedrock Valley is about 100 feet thick from the mouth of the valley to the east boundary of Monroe County. The modern Kaskaskia River follows the same course as the ancient Kaskaskia Bedrock Valley. Because of the irregular bedrock surface and erosion, glacial *drift* is unevenly distributed across Monroe County.

During the Pleistocene *Epoch*, beginning about 1.6 million years ago, massive sheets of ice (called continental glaciers), thousands of feet thick, accumulated and flowed slowly southward from Canada. The last of these glaciers melted from northeastern Illinois about 13,500 years before the present (B.P.). During the Illinoian glacial episode, which began around 300,000 years B.P., North American continental glaciers reached their southernmost position, approximately 95 miles southeast of here, in the northern part of Johnson County (fig. 10). The maximum thickness of the later Wisconsin Episode glacier was about 2,000 feet in the Lake Michigan Basin, but only about 700 feet over most of Illinois (Clark et al. 1988). Monroe County is too far south to have been covered by the Wisconsin Episode glaciation.

The *topography* of the bedrock surface throughout much of Illinois is largely hidden from view by thick glacial deposits, except along the major streams. In Monroe County, however, the buried bedrock surface elevation is highly variable because of structural warping of the crust, and was only slightly modified and covered by a relatively thin layer of drift deposited during and after the Illinois glacial episode.

Although Illinoian glaciers probably built moraine ridges similar to those left by the later Wisconsinan glaciers, Illinoian glacial features generally are not as conspicuous as the younger Wisconsinan features because Illinoian moraines have been exposed to weathering and erosion for hundreds of thousands of years longer than their younger Wisconsinan counterparts.

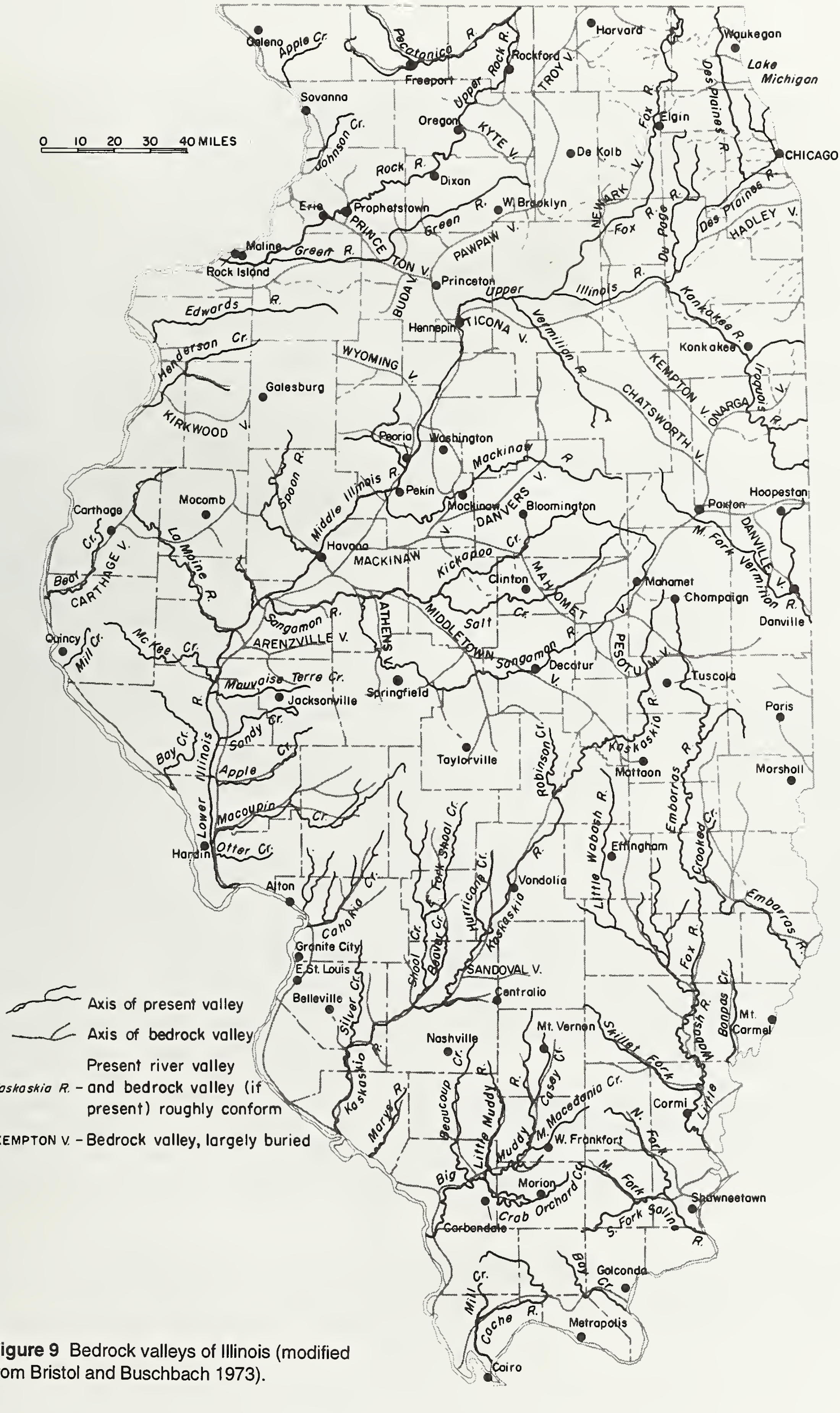


Figure 9 Bedrock valleys of Illinois (modified from Bristol and Buschbach 1973).

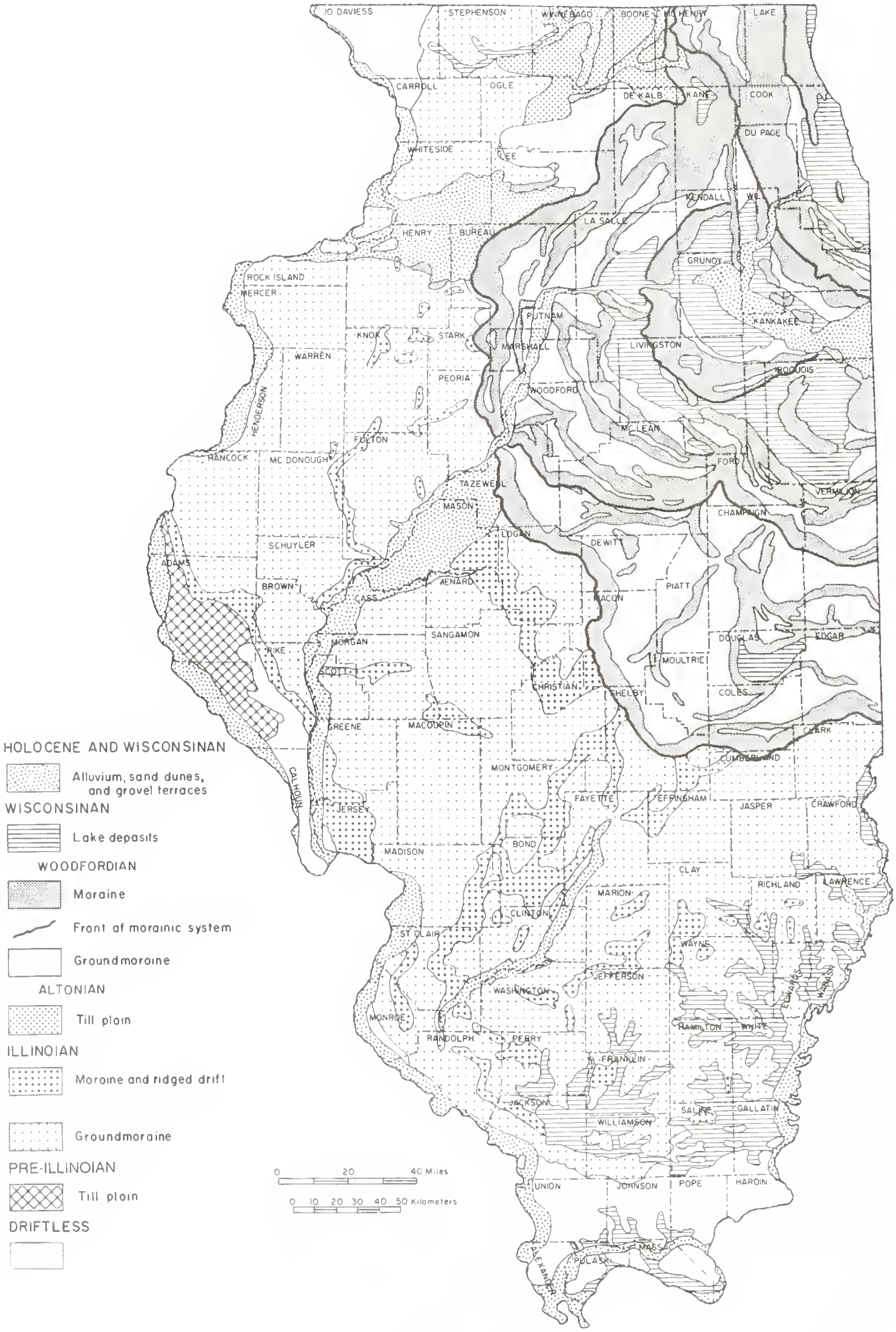


Figure 10 Generalized map of glacial deposits in Illinois (modified from Willman and Frye 1970).

Overlying the Illinoian Episode deposits in Monroe County is a thin cover of sediments called the Peoria *Loess* (pronounced "luss"). These sediments, deposited as wind-blown silts during the Woodfordian Subage, which began about 22,000 years B.P., cover the glacial drift throughout the field trip area (see *Ancient Dust Storms in Illinois, Geogram 5,* at the back of this guidebook.) In Monroe County, the loess deposits are thickest near the Mississippi River Valley, where they are thicker than 25 feet, but they thin to generally less than 6 feet in eastern Monroe County. This fine grained dust, which covers most of Illinois outside the area of Wisconsinan glaciation, commonly reaches thicknesses exceeding 25 feet along the east edges of both the Mississippi and Illinois River Valleys. Soils in this area have developed in the loess, in the underlying weathered silty, clayey Illinoian *till*, and in the alluvium that fills the valleys. Some thin soils have developed in exposed bedrock.

In the field trip area, glacial drift ranges in thickness from less than 25 feet, in the central part of the county, to slightly more than 100 feet, in the eastern and northwestern parts of the county along the Kaskaskia Bedrock Valley and the Mississippi River Valley.

The highest land surface on the field trip route is along IL Route 156 at the intersection with the road to the new Village of Valmeyer, where the surface elevation is 733 feet above mean sea level (msl). The lowest elevation is about 400 feet above msl at stop 2, below the levee at the surface of the flood plain. The total relief of the field trip route, calculated as the difference between the highest and lowest elevations, is 333 feet. The *local relief* in the field trip area is most pronounced near the bluffs of the Mississippi River, where local relief ranges from 100 feet at stop 1, near Columbia, to 430 feet just north of stop 4, near Valmeyer.

GEOMORPHOLOGY

The Columbia-Waterloo area is in the Salem Plateau physiographic division, and is often called the "sinkhole plain" (figs. 11, and 12). The area received this name because it contains approximately 10,000 sinkholes, three-quarters of which are in Monroe County (Panno 1996). These sinkholes are, as they say, only the tip of the iceberg. Below the surface are many hundreds of miles of underground drainageways and caves. In Illinois Caverns alone, approximately 6 miles of underground passages have been mapped.

Bedrock in the sinkhole plain is mostly Mississippian-age limestone (see description of the Paleozoic Era above). These rocks were originally deposited as layers of calcareous mud and fossils in a marine environment between about 360 and 320 million years ago. The environment of deposition was probably similar to the shallow-water environment that surrounds the modern Bahama Islands. After these layers of mud and fossils were buried and solidified into rock, tectonic stresses folded the bedrock and formed anticlines and synclines (fig. 8). Folding resulted in the fracturing (jointing) of these rocks. The fractures are important in the karstification process because they allow surface and groundwater to move vertically into the bedrock through the fractures and then into the more permeable horizontal bedding planes within the layers of rock.

The western margin of the sinkhole plain offers scenic limestone bluffs that tower 300 feet or more above the floodplain of the Mississippi River. The valley is the site of the catastrophic Great Flood of 1993 that caused widespread damage and property loss and forced the relocation of the town of Valmeyer. The town now occupies a site in the karstified upland area overlooking the abandoned site on the floodplain below.

KARST LANDSCAPE

Karst topography is characterized by sinkholes, rolling surfaces, caves, underground drainage systems, and springs. Most karst landscapes occur over limestone or dolomite bedrock. An area containing numerous karst features is called a karst plain.

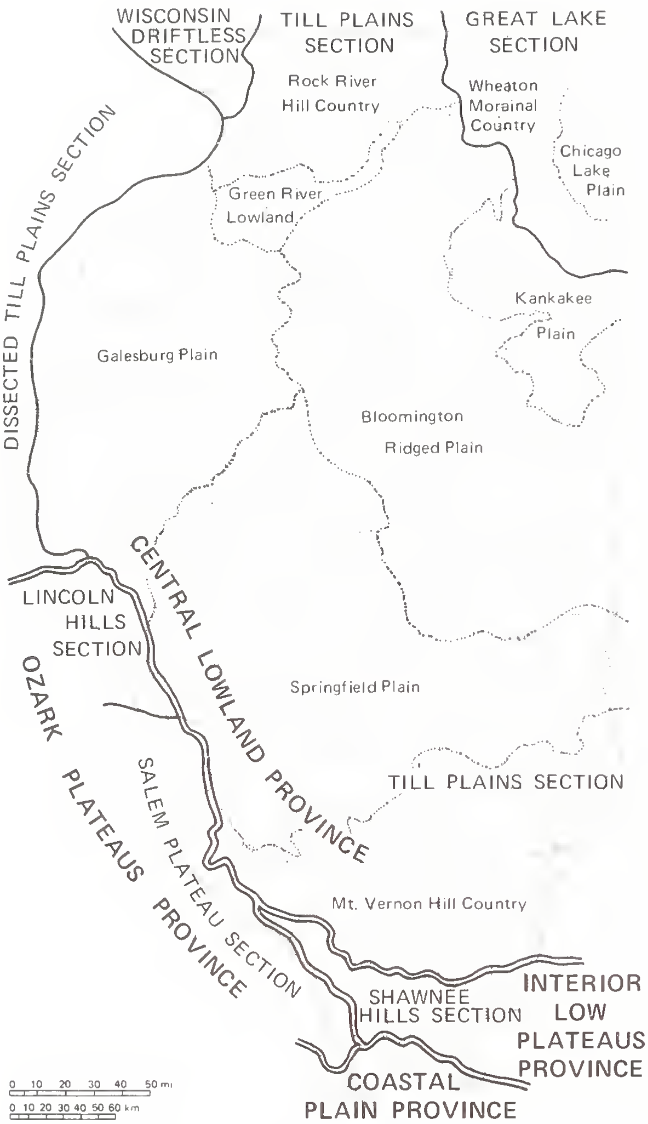


Figure 11 Physiographic divisions of Illinois.

Karstification Karstification is the process by which karst features (such as sinkholes and caves) are created by the combined processes of the dissolving action of naturally acidic water and the mechanical action of water flowing through limestone, dolomite, or gypsum bedrock.

Water and carbon dioxide are the two main components necessary for dissolving limestone. Carbon dioxide gas, both atmospheric and that generated by bacterial activities in the soil, dissolves in rainwater or snow melt seeping through the soil to form relatively small amounts of carbonic acid. This weak acid mixes with water and migrates through fractures and along bedding planes and, over thousands of years, dissolves significant amounts of limestone and dolomite. As the fractures in the surface of the bedrock enlarge, they allow water and soil to seep deeper into bedrock. Conduits formed along bedding planes provide lateral routes for discharge of the infiltrating water at springs. In southern Illinois, sinkholes act as natural drains that funnel rainfall and snow melt into the subterranean streams and conduits beneath the karst landscape.

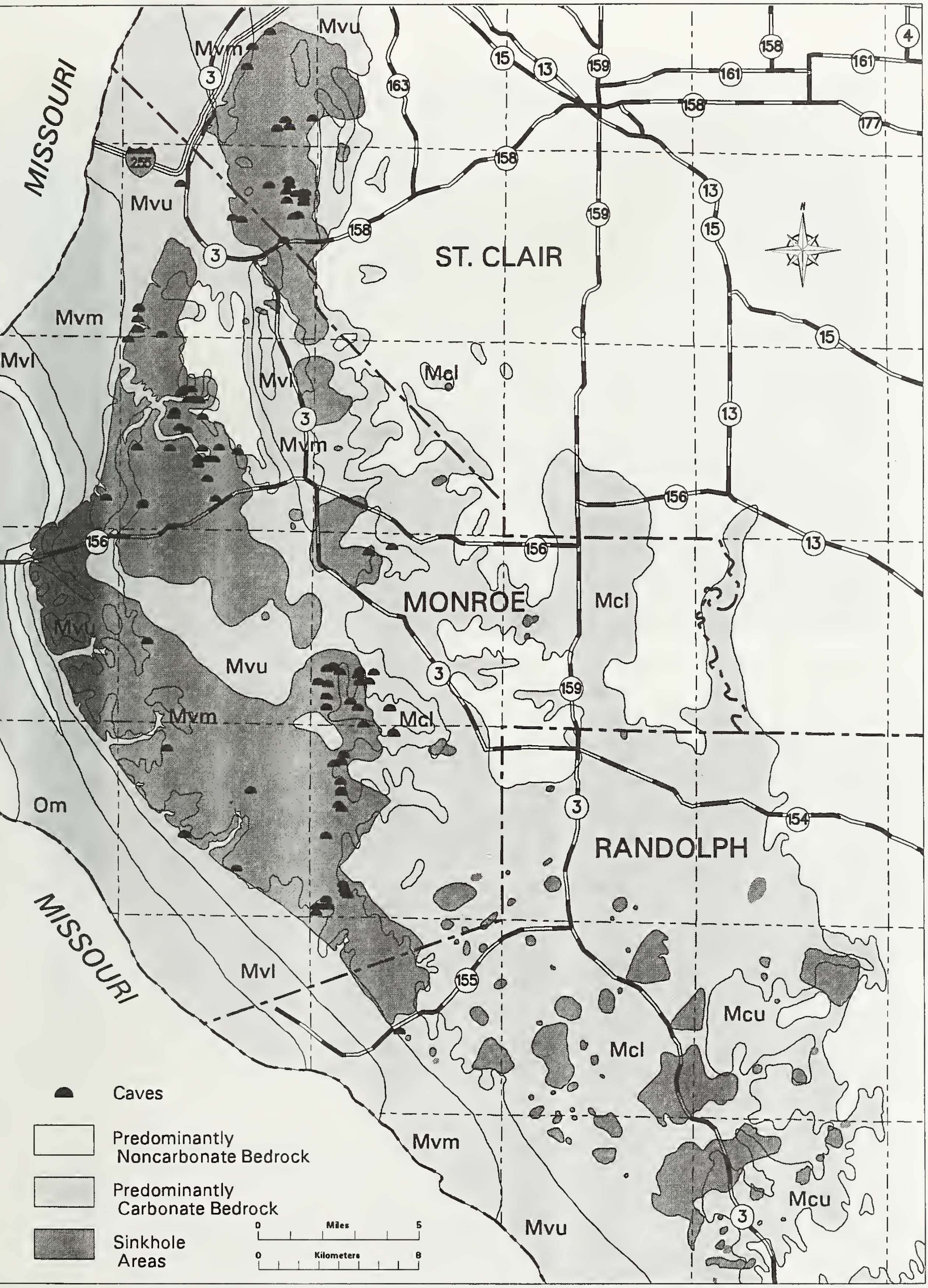


Figure 12 Map of the karst regions of the sinkhole plain of southwestern Illinois shows areas containing abundant sinkholes and caves (modified from Weibel and Panno 1997).

SINKHOLES

Sinkholes are naturally occurring cone- or bowl-shaped depressions in the landscape that have internal drainage; that is, drainage flows underground within the bedrock instead of on the surface in streams (fig. 13). Sinkholes typically are circular in plan view and range from less than 3 feet across with a single drain to the bedrock below, to more than ½ mile across with multiple drains or openings to the bedrock.

Sinkholes are often occupied by a concentration of trees and low ground cover (fig. 14). Farmers either avoid these areas when plowing or remove the vegetation prior to plowing. In many sinkholes, bedrock and the open conduits are visible at the center.

Sinkhole formation Sinkholes are the result of the collapse of near-surface materials (soil or bedrock) into cavities that have formed in the underlying, soluble limestone bedrock. Sinkholes commonly form where limestone bedrock is near the surface and is slowly being dissolved by infiltrating surface water. Some sinkholes are ponded, others are dry, and some may flood only during periods of high rainfall. Compound sinkholes can form when adjacent cone-shaped sinkholes merge as a result of continued collapse. Sinkholes drain surface water into underground conduits and indicate karst terrain.

Sinkhole formation can begin by soil piping (movement and entrainment of soil along an initially small pathway in soil) or collapse of soil into underground cavities. If groundwater moving through underground cavities carries the soil away, additional collapse is possible. The result is the formation of an ever enlarging sinkhole. Plugging the underlying conduit with sediment can stop the growth of a sinkhole.

The pattern of sinkholes at the surface may reflect the processes occurring beneath. For example, the solubility potential of the rock tends to be greatest at places where vertical joints in the rock intersect, relative to the solubility along a single joint. Thus, if two fractures are nearly perpendicular (as they commonly are in limestone) and soil conditions are conducive to acid formation, then sinkholes will tend to form at fracture intersections.

Acceleration of erosion is also a significant problem in karst terrain. Disruption of the natural vegetation and construction in karst terrain can accelerate erosion and increase the potential for additional sinkhole formation. Unlike erosion in other landscapes, soils overlying shallow, swiss cheese-like bedrock can be eroded from above and below. Soil piping can remove large volumes of soil from below the surface. Eventually, the overlying soil collapses and a sinkhole may form. When this occurs in soils underlying structures, damage to the foundation and the building may result.

Shallow water wells drilled into karstified bedrock that is overlain by unconsolidated sediments thinner than 65–100 feet can take water out of the overlying sediments, which can cause subsidence of the soil into cavities. Pressure exerted by the water in the soil helps to hold the soil in place. If enough water is pumped out so that the water table drops below the top of bedrock surface, the soil can collapse into cavities and be eroded from below by flowing water. If the soil collapse reaches the surface, a sinkhole will form.

Ponded sinkholes As surface water drains into a sinkhole, the soil it carries with it may be deposited in the bottom of the sinkhole. If the drain (outlet) at the bottom is small or becomes so clogged with wood debris, leaves, and sediment that the outflow is slowed to trickle, the outlet may become plugged and a ponded sinkhole (fig. 15) is formed. Ponded sinkholes are common in southwestern Illinois, and those with long-standing water can become a habitat for wetland vegetation, reptiles, amphibians, water fowl, and other native animals.

Figure 13 Aerial photograph of the sinkhole plain in Monroe County shows sinkholes, ponded sinkholes, and sinking streams (photo by Joel Dexter).

Figure 14 A typical sinkhole in Monroe County with trees occupying its center collapse zone (photo by Sam V. Panno).

Figure 15 A ponded sinkhole in Monroe County shows the characteristic circular shape of sinkholes (photo by Sam V. Panno).

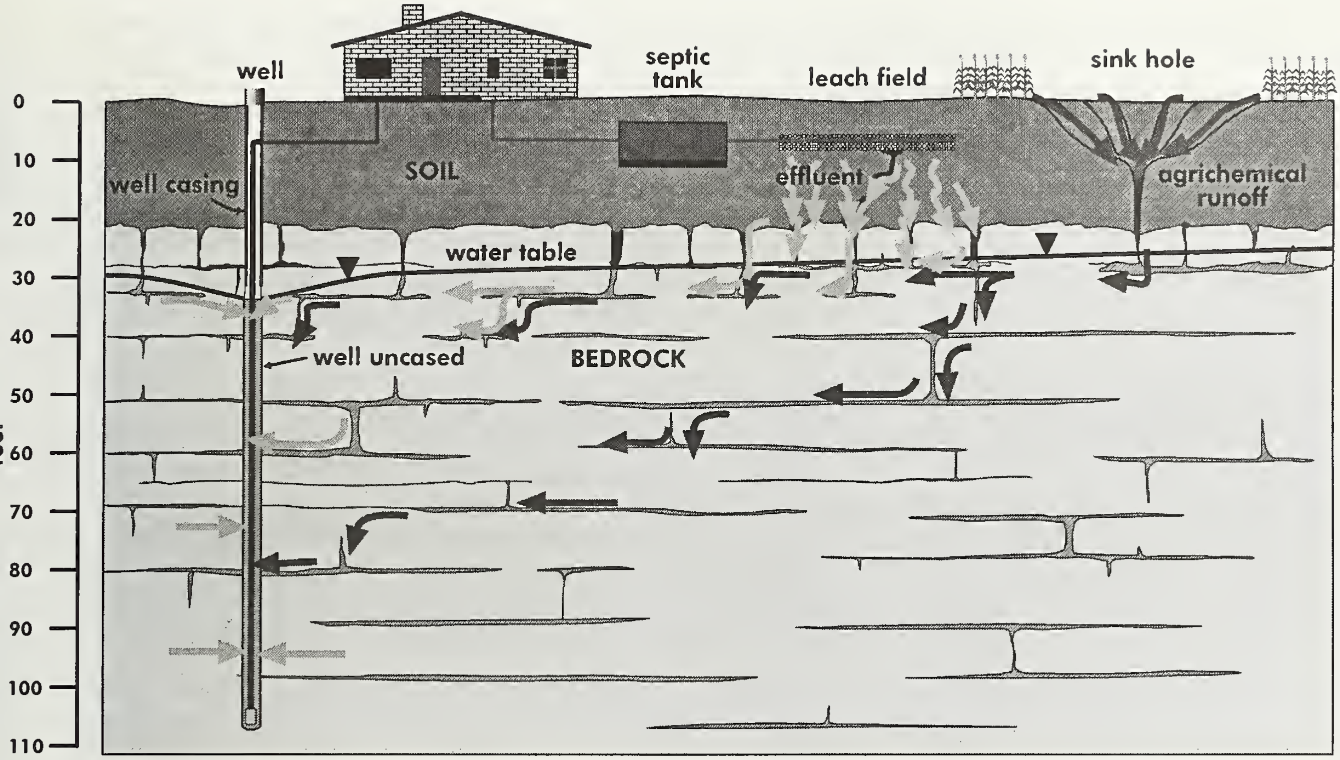
Sinking streams Long stream valleys are common only in areas where sinkholes are rare or absent. If a surface stream flows into a karst landscape, the stream generally will flow into a sinkhole (known as a swallow hole) and enter the underground conduit system of the shallow karst aquifer. The stream will then flow underground to a point of discharge such as a cave spring. Only in karst landscapes are there true underground "rivers."

Springs Natural springs and cave springs are common in karst landscapes. The springs are the discharge points for rainwater, snow melt, and groundwater that have entered and flowed through the bedrock. Water emerging at springs in such areas may have been at the surface only a few hours before it exits at the spring. The potential for contamination of spring water is extremely high, and its use for drinking without treatment is strongly discouraged.

GROUNDWATER CONTAMINATION IN KARST LANDSCAPES

Groundwater in karst landscapes is particularly susceptible to contamination (fig. 16). Because of the extensive system of conduits in the limestone bedrock, shallow groundwater in karst landscapes does not have the benefit of the slow filtering that occurs when water seeps through thick sequences of clay-rich glacial till or low-permeability bedrock in other landscapes. Recharge and movement of water within karst aquifers is very rapid (in seconds to minutes), often comparable to the flow rates of surface streams. Suspended sediment particles, dissolved contaminants, and bacteria are readily carried into shallow karst aquifers. Groundwater in karst areas may have relatively high concentrations of nitrate, bacteria, inorganic ions, and organic chemicals, such as pesticides.

Sinkholes have always been tempting places to dispose of trash. However, household garbage, old appliances, dead animals, and old cars and trucks generally contain contaminants such as oil, gasoline, bacteria, toxic chemicals from home cleaners, and pesticides that can pollute the groundwater. Septic systems that drain directly into sinkholes often introduce sewage (human effluent) into the groundwater. In addition, large objects thrown into sinkholes can plug the sinkhole and alter the established drainage pattern, causing localized flooding and accelerated erosion.



igure 16 Conceptual representation of potential sources of groundwater contaminants and their flow paths from the surface to well (modified from Panno et al. 1996).

Water in ponded sinkholes often seeps through the bottom of these ponds and enters groundwater. In this situation, however, the water has slowly filtered through the soil at the sinkhole bottom; because of this filtering, the water is likely to contain fewer contaminants when entering the groundwater.

Karst regions do not always have many sinkholes. The soil cover may be riddled with animal burrows and root tracks that rapidly funnel surface water to solution-enlarged fissures in the underlying limestone bedrock. Thus, karst areas that contain few obvious sinkholes and have relatively thick sequences of unconsolidated material overlying fractured limestone may also be susceptible to groundwater contamination.

Most contaminants do not enter karst aquifers at a continuous rate; contaminant concentrations often range from very low to very high throughout a year. Concentrations of contaminants depend on the combination of (1) the rate, amount, and timing of rainfall and snow melt, (2) the rate, amount, and timing of the introduction of contaminants to the land surface, and (3) the geology of the area. Agricultural activities (for example, pesticide and animal waste run-off) and failed septic systems are examples of potentially significant sources of contaminants in a karstic region. Residents using springs and shallow karst aquifers as sources of household water in this region are at risk and should have their water tested for contaminants at least once a year.

NATURAL RESOURCES

Mineral production Of the 102 counties in Illinois, 98 reported *mineral* production during 1992, the last year for which complete records are available. The total value of all minerals extracted, processed, and manufactured in Illinois during 1992 was $2,894,300,000, 0.5% lower than the 1991 total. Minerals extracted accounted for 90% of this total. Coal continued to be the leading commodity, accounting for 64% of the total, followed by industrial and construction materials at 21.4%, and oil at 14.2%. The remaining 0.4% included metals, peat, and gemstones. Illinois ranked 13th among the 31 oil-producing states in 1992 and 16th among the 50 states in total production of nonfuel minerals, but continues to lead all other states in production of fluorspar, industrial sand, and tripoli. However, the last operating fluorspar mine closed in December 1995.

Monroe County ranked 81st among all Illinois counties in 1992 on the basis of the value of all minerals extracted, processed, and manufactured. Economic minerals currently mined in Monroe County include stone and oil.

Of the 39 counties reporting oil production in 1992, Monroe county ranked 34th with 23,000 barrels of oil, which equals 0.1% of the state's total production. More than 405,000 barrels of oil have been produced from the Kimmswick Limestone (Ordovician) in the Waterloo Oil Field, which was discovered in 1920. A portion of the oil field was converted to a gas storage field in 1951 by the Mississippi River Transmission Corporation, but the storage field was abandoned in 1973.

Groundwater Groundwater is a mineral resource frequently overlooked in assessments of an area's natural resource potential. Groundwater availability 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.

GUIDE TO THE ROUTE

Assemble at the parking lot on the west side of Turner Hall, 211 East Cherry Street, Columbia (NE SW SW, Sec. 15, T1S, R10W, 3rd P.M., Monroe County, Columbia 7.5-Minute Quadrangle).

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.

Six USGS 7.5-Minute Quadrangle Maps (Columbia, Oakville, Paderborn, Renault, Valmeyer, and Waterloo) provide coverage for this field trip area.

Miles to next point	Miles from start	
0.0	0.0	Assemble at the parking lot on the west side of Turner Hall. Exit the parking lot and turn right onto East Cherry Street.
0.5	0.5	STOP (4-way). Intersection of 200 East Cherry and 200 South Metter. CONTINUE AHEAD.
0.5	0.1	STOP (2-way). Intersection of 100 East Cherry and 200 South Main. TURN RIGHT onto Main Street. NOTE: Follow Main Street to the intersection with IL Route 3. As you drive along main street, notice that several homes and buildings are made from the native limestone, which is light tan in color.
1.55	1.65	Stoplight. Intersection of North Main Street and IL Route 3. CONTINUE AHEAD. NOTE: As you cross Route 3, the road is now called Sand Bank Road.
0.3	1.95	Stop 1. Entrance to Luhr Brothers Construction Company, on left side of road. On the day of the field trip, we will be using the large parking lot in front of the main building. Assemble near the small Caterpillar tractor display on the west side of the property.

STOP 1 Peoria Loess and Overview of the Mississippi River Valley We will discuss and view the Mississippi River valley "American Bottoms" and loess exposure along Sand Bank Road.

0.0	1.95	Leave Stop 1. From the parking lot, TURN LEFT onto Sand Bank Road. As you leave stop 1, you will descend the bluffs and enter onto the flood plain of the Mississippi River.
0.05	2.0	STOP (T-intersection, DD Road/2620N and Bluff Road). TURN RIGHT onto Bluff Road. Note: Sand Bank Road is marked as DD Road at the base of the bluff.
0.1	2.1	CAUTION: Road makes a 90° turn to the left. Note: The road is now called DD road.
0.2	2.3	T-intersection (Palmer Road) from the right. CONTINUE AHEAD. To the right is Palmer Creek; on each side of the creek is a small set of levees.
0.45	2.75	CAUTION: Road makes a 90° turn to the left, then a 90° turn back to the right.
0.1	2.85	CAUTION: Cross double set of railroad tracks (Union Pacific Railroad). Guarded crossing with lights and guard gates.
0.1	2.95	T-intersection (Ramsey Road) from the right. CONTINUE AHEAD.
1.05	4.0	Road curves 45° to the left. To the right is the main levee along the Mississippi River.
0.5	4.5	To the left and straight ahead is a view of the levees along Carr Creek. The levees along Carr Creek are higher than the levees along Palmer Creek. The levees along Palmer Creeek are lower because the drainage from Palmer Creek is pumped over the main levee along the Mississippi River, whereas the drainage from Carr Creek empties directly into the Mississippi River. Therefore, the elevation of the levees along Carr Creek must equal the elevation of the levees along the Mississippi River.
0.4	4.9	T-intersection (at the top of the levee on the north side of Carr Creek). TURN RIGHT.
0.2	5.1	On the left side of the levee is a flood control gate with a date of 1958 on the top. To your right in the bottom lands, next to the base of the levee, are several round corrugated sheet metal structures approximately 4' high. These structures are drainpipe inlets; they drain the low area on the right into a pipe that flows toward the flood control gate on the left. When the water level is low in Carr Creek and high in the field to your right, the flood control gate is opened and water drains from the lowlands to your right into Carr Creek on your left.
0.2	5.3	T-intersection. Main levee road curves to the right. TURN LEFT onto road descending the levee. After making the turn, to the right are the river loading docks of Luhr Brothers Construction Company. Notice the bluffs to the right on the Missouri side of the Mississippi River.

0.4	5.7	T-intersection from the right (entrance to Luhr Brothers Construction Company dock). CONTINUE AHEAD and cross bridge over Carr Creek.
0.1	5.8	STOP (1-way). Intersection of Bottom Road/2000 and Levee Road/10400. CONTINUE AHEAD. From the top of Levee Road, to your far right, you can see the Mississippi River. Notice the smaller levee between the main levee and the Mississippi River. This smaller secondary levee partially protects the farmland between the Mississippi River and the main levee. Also notice the large number of dead trees along the west side of the levee. These trees were killed by the Great Flood of 1993 when they were under water for an extended period of time; the trees were, in effect, drowned.
0.7	6.5	Road passes under high-power transmission lines. To your left is a good view of the bluffs on the Illinois side of the river.
0.3	6.8	T-intersection to farm buildings from the right. During the Great Flood of 1993, the main break in the levee system along this portion of the Mississippi river occurred just south of these buildings and extended to a point just north of the curve in the road that is visible to the south along the base of the levee. The low area to your immediate right is where a large scour hole was formed by the water rushing through the broken levee.
0.15	6.95	T-intersection (Taake Road/2380N) from the right. TURN RIGHT. After making the turn, notice that the road ahead of you dips. This dip marks the location of a former large scour hole (see route map for location of the scour hole). To the left in the field is a large ridge of sand which was scraped from the field and piled up.
0.25	7.2	Another large pile of sand to the right of the road.
0.1	7.3	Stop 2. Road curves 90° to the left.

STOP 2 Levee along the Mississippi River We will discuss the failure of the levee during the Great Flood of 1993, and what decision was made to protect Prairie du Rocher from the same fate that struck the village of Valmeyer.

This stop gives you a good view of the bluffs on the Illinois and Missouri sides of the Mississippi River valley. Looking west from the top of the levee you see the Mississippi River. Notice the small private levee that was built to protect the farmland located between the main levee and the Mississippi River. Note again the large number of dead trees. Many of these trees snapped off where they rotted just below the water line of the Great Flood of 1993.

0.0	7.3	Leave Stop 2. CONTINUE AHEAD on the road at the base of the levee.
0.7	8.0	Levee entrance road on the right side of the road. CONTINUE AHEAD.
0.2	8.2	Road ascends to the top of the levee. Drive onto the top of the levee.
0.8	9.0	T-intersection from the left (exit road from the levee). TURN LEFT, then LEFT onto the road at the base of the levee.

0.6	9.6	T-intersection (Levee Road/9300 and B Road/9200). TURN LEFT onto Levee Road/9300.
0.9	10.5	Y-intersection (Levee Road/9600 and Steppig Road/2000). BEAR RIGHT and continue on Steppig Road. Note: View of eroded valley to the right in the bluffs on the Illinois side. This valley is Long Slash Hollow, which was carved by Long Slash Creek. In the early spring and possibly late fall when leaves are off the trees, you can trace a single distinctive limestone bed in the bluffs. Following this single bed from north to south, you can detect a slight rise in the strata to the south. This structural rise of the strata highlights the low-angle dip of the Mississippian St.Louis Limestone beds on the northeast flank of the Valmeyer Anticline.
0.3	10.8	Cross Little Carr Creek.
0.1	10.9	Road curves 90° to the left.
0.3	11.2	Road curves 90° to the right.
0.6	11.8	CAUTION: Cross dual set of railroad tracks. Guarded crossing with signal lights and guard gates. This is the Union Pacific Railroad. To the right is Long Slash Hollow.
0.2	12.0	Good view of the bluffs; note the houses dotted along the top of the bluffs.
0.2	12.2	Road curves 90° to the left.
0.1	12.3	Road curves 90° to the right.
0.35	12.65	STOP (1-way). T-intersection (Steppig Road/2700 and Bluff Road/5900). TURN RIGHT onto Bluff Road. To the left is the valley cut by Little Carr Creek.
0.2	12.85	T-intersection from the left. CONTINUE AHEAD.
0.55	13.4	Stop 3. Terry Spring. Pull over to the right side of the road and stop.

STOP 3 Terry Spring We will discuss the development of Terry Spring, located on the left side of the road.

Above Terry Spring at the top of the bluff are several sinkholes (shown on the route map). Several of these large sinkholes are generally filled with water.

The opening to Terry Spring is about 80" wide and 40" tall. This opening goes back into the bluff at least several tens of feet (actual distance was not confirmed). Also near the base of the spring is a shale layer within the limestone beds; the shale layer is probably the flow path that started Terry Spring.

Several additional signs of springs occur in the talus slope along the base of the bluff. A V-shaped erosional cut into the talus slope indicates that water has been flowing from the bluffs and eroding and carrying away some of the sediments. A large opening in the bluffs is located just south of Terry Spring.

0.0	13.4	Leave Stop 3. CONTINUE AHEAD.
0.4	13.8	Cross Long Slash Creek; note the valley to the left.
0.3	14.1	Large overhang in the bluffs on your left. This may have been the site of an old spring. Several springs and small caves are located along this stretch of the bluff.
0.9	15.0	Crossroad Intersection. (Hanover Road and Bluff Road). CONTINUE AHEAD on Bluff Road. This intersection is known as Fountain Gap. Cross Fountain Creek just past intersection. CAUTION: This road is heavily used by bicyclists.
1.5	16.5	Y-intersection. BEAR RIGHT. CAUTION: Approaching second Y-intersection at the top of the levee.
0.10	16.6	Y-intersection on top of the levee (Bluff Road and HH Road).. TURN RIGHT onto Bluff Road.
1.0	17.6	T-intersection (Fountain Road/1900 and Bluff Road/9200). TURN LEFT onto Bluff Road. The community of Fountain lies directly west of this intersection.
0.4	18.0	Concrete marker on the right side of road. (Bond, James? No! Bond, Shadrach). The marker reads:

> Shadrach Bond, Sr., a soldier of the Revolutionary War and the Army of George Rogers Clark. Settled about ⅓ mile east of this marker in 1782. His nephew, Shadrach Bond, the first governor of the State of Illinois, 1818–1822, moved here from Maryland in 1794 and lived with him until 1810. He purchased land near Moredock Lake where he lived until 1814. He died in Kaskaskia in 1832. Erected by the Monroe County Historical Society, 1974.

0.15	18.15	Center-pivot irrigation system on the left side of the road.
0.3	18.45	Another center-pivot irrigation system on left side of the road.
0.25	18.7	T-intersection (Herpst Road/1900) from the right. CONTINUE AHEAD on Bluff Road/8800.
0.2	18.9	View of the bluffs directly ahead. The bluff projects westward at this point. This westward projection of the bluffs outlines an ancient course of the Mississippi River, which was diverted westward at this point because of the Valmeyer Anticline (see route map).
0.5	19.4	T-intersection (Ziebold Road/1950) from the right. CONTINUE AHEAD on Bluff Road.
0.3	19.7	T-intersection (Trout Road/2000) from the left. CONTINUE AHEAD and cross Trout Creek. The valley carved by Trout Creek is called Trout Hollow. The large new slump to the left near the base of the bluff was caused by removal of material at the toe of the talus slope.

0.7	20.4	Moredock Lake to the right. Moredock Lake occupies an old abandoned meander of the Mississippi River (see route map). Note the number of duck blinds out in the lake.
0.3	20.7	Cross small creek. The unique pillar-shaped limestone formation in the bluff to the left is an example of karstic erosion, which is a common feature in this area.
0.9	21.6	CAUTION: Cross dual set of Union Pacific Railroad tracks. Guarded crossing with signal lights and guard gates.
0.1	21.7	Road curves 90° to the left.
0.1	21.8	To the left in the bluffs, you can see the openings of the old underground room-and-pillar Valmeyer Quarry.
1.1	22.9	Road curves to the left. In the bluff to the left, you can see the openings in the abandoned Valmeyer Quarry extending for over a mile along the limestone bluff. The mining operation was following a particular bed in the Ordovician limestone. By visually following the openings, you will notice the dip to the south. The Bluffs at Valmeyer consist of two distinct vertical limestone bluff faces; there is a talus slope at the base of the lower face and a second talus slope between the lower and upper bluff faces. The upper talus slope marks the position of a less resistant bed of shale.
0.2	23.1	Cross small creek and prepare to TURN LEFT.
0.05	23.15	T-intersection from the left. TURN LEFT toward the abandoned quarry.
0.05	23.2	CAUTION: Cross dual set of Union Pacific Railroad tracks. Guarded crossing with signal lights and guard gates.
0.1	23.3	Pass between two old quarry buildings.
0.1	23.4	Stop 4. Abandoned Valmeyer limestone quarry. Pull over to the right side of the road and stop. Do not block the T-intersection from the right or the barricade directly ahead blocking the entrance to old quarry road. Note the old native limestone building to your left.

STOP 4 Valmeyer Quarry We will discuss the history of the mining and other operations of the abandoned Valmeyer limestone quarry.

0.0	23.4	Leave stop 4. Retrace route back towards the railroad tracks. Heading west.
0.2	23.6	CAUTION: Recross railroad tracks.
0.05	23.65	T-intersection. TURN LEFT.
0.05	23.7	Cross small creek flowing into Moredock Lake.
0.3	24.0	Cross small creek. Entering the old Village of Valmeyer.

0.3	24.3	STOP (1-way). Crossroad intersection. TURN LEFT onto IL Route 156.
0.1	24.4	CAUTION: Cross dual set of railroad tracks. Guarded crossing with signal lights and guard gates.
0.15	24.55	T-intersection from the right. CONTINUE AHEAD on IL Route 156. The road to the right is Bluff Road; it leads to the community of Fults.
0.25	24.8	Cross creek just prior to St. Johns Cemetery on the left side of road. Road starts to ascend to the top of the bluffs. You are entering Dennis Hollow. Note the dipping beds on the right side of the road.
1.8	26.6	Crossroad intersection (C Road). CONTINUE AHEAD. The new Village of Valmeyer is to the left.
0.4	27.0	The farm house on the right side of the road is built from native limestone.
0.4	27.4	Road descends into the valley eroded by Bond Creek. Prepare to turn left.
0.2	27.6	T-intersection (D Road/6300 and IL Route 156/2400) to the left. TURN LEFT onto D Road. Cross Bond Creek just before the T-intersection.
0.1	27.7	Road follows the valley eroded by Bond Creek.
0.2	27.9	Cross Bond Creek.
0.05	27.95	Road curves 90° to the left and then back 90° to the right as it ascends out of the valley cut by Bond Creek.
0.75	28.7	Y-intersection (Trout Road/2300 and D Road/6750). TURN RIGHT onto Trout Road. Note the large sink hole to the left after making the turn.
0.3	29.0	Sinkholes on either side of the road commonly are filled with water just after a rain. The water is reddish brown, the same color as the loess.
0.4	29.4	Descend the valley cut by Bond Creek. CAUTION: One lane bridge ahead.
0.2	29.6	Cross Bond Creek. To the left before you cross the bridge is an exposure of loess.
0.35	29.95	T-intersection (Deer Hill Road/6800 and Trout Camp Road/2700). TURN LEFT onto Deer Hill Road. Note: Deer Hill Road and Trout Camp Road follow the same course for the next 0.65 miles.
0.65	30.6	Y-intersection (Deer Hill Road/7000) from the left. CONTINUE AHEAD on Trout Camp Road. Road starts to curve to the right.
0.05	30.65	Pass Deer Hill Cemetery on the left.
0.35	31.0	View of the village of Waterloo directly ahead. You can see the water tower in the distance.

1.2	32.2	T-intersection (Camp Vandeventer Road from the left). TURN LEFT. CAUTION: the narrow road leading to the Boy Scout camp winds back and forth across the countryside between numerous sinkholes.
0.8	33.0	Apache campsite and picnic area with fitness area to the left. To the right is a karst window.
0.1	33.1	Entrance to the Boy Scout camp. Drive through the Paul Hodson Gateway. Road to the left leads to the ranger's house. Road straight ahead is the entrance to the parking lot. Note: Just before the gate, a large sinkhole has developed along the right side of road.
0.05	33.15	Stop 5. Camp Vandeventer Boy Scout Camp

STOP 5 Camp Vandeventer Boy Scout Camp: LUNCH We will view and discuss some of the unique geological features located within the scout camp. When leaving stop 5, retrace route to the T-intersection of Camp Vandeventer Road and Trout Camp Road. Reset odometer to 0.0.

Miles to next point	Miles from start	
0.0	0.0	STOP (1-way). Intersection of Camp Vandeventer Road and Trout Camp Road. TURN LEFT onto Trout Camp Road.
0.1	0.1	Kinzinger Landscaping Material company on the left.
0.2	0.3	T-intersection (Fountain Oaks Lane from the left). CONTINUE AHEAD.
0.15	0.45	Prepare to stop.
0.1	0.55	STOP (1-way). Intersection (Trout Camp Road and IL Route 156/3700). TURN RIGHT onto Route 156.
0.45	1.0	T-intersections (Lee Drive) and (Old Orchard Lane) on the left. CONTINUE AHEAD. Note the sinkholes on the right and left sides of the road at the curve.
0.2	1.2	T-intersection (David Scott Drive) on the right. CONTINUE AHEAD.
0.5	1.7	Road makes a sharp turn to the right.
0.10	1.8	T-intersection (Old Baum Church Road/6500 and Route 156/1620N) from the left. TURN LEFT onto Old Baum Church Road.
0.95	2.75	T-intersection from the left. CONTINUE AHEAD. Along this stretch of the route are heavily wooded lots of oaks; many of the sinkholes have trees growing in them.
0.75	3.5	Ostrich farm on the right.

0.2	3.7	Abandoned Salem Baum Evangelical Church on the right, and cemetery on the left. This church was built in 1883, using native limestone from the area. The only thing that remains of this beautiful church today is the masonry itself. Plaque on the door reads: On May 11, 1845, a German-speaking Protestant congregation was organized at the Phillip Baum residence near here. That same year a log church was erected and a cemetery was opened on six acres immediately north of the spot which was donated by Henrick Mueller and Phillip Hochman. In 1883 a stone church with steepled bell and rooster was built on this ¾ acre plot which was donated by Anton Sparwasser. The stone masons were Ilchner and Neumann. The congregation belonged to the German Evangelical Synod of North America which later became the United Church of Christ. In 1938 the congregation disbanded. The church was closed and the bell was placed in the Trinity United Church of Christ in Belleville. This plaque was placed by the Salem Baum Cemetery Association in 1979.
0.3	4.0	CAUTION: STOP (1-Way, sign missing). T-intersection (Ahne Road/3500 and Old Baum Church Road/5700). TURN LEFT onto Ahne Road.
0.4	4.4	View of the water tower at Waterloo to the far northeast, and the Holy Cross Church steeple at Wartburg to the right.
0.8	5.2	Entering the community of Wartburg.
0.25	5.45	STOP (1-way). T-intersection (Ahne Road/4060 and Maeystown Road/5800). TURN LEFT onto Maeystown Road.
0.45	5.9	T-intersection (JJ Road/3800) from the right. TURN RIGHT onto JJ Road.
0.75	6.65	Cross buried pipeline under the road.
0.15	6.8	Cross Fountain Creek. The creek flows to the left. This is a good fossil collecting spot; several types of limestone layers outcrop along the creek, including a cherty zone that contains well-preserved fossils. Many karst solution features occur on some of the bedding plains and are exposed both at creek-level and just above the creek. These features indicate there were old flow pathways of underground streams before the present stream incised this particular outcrop. The exposure of limestone continues upstream in a small cut sto the south and west of the creek. Fossils include large horn corals, bryozoans, and brachiopods. After crossing the bridge, the road takes a sharp 90° turn to the right and follows upstream along Fountain Creek. The small valley we are in was carved out by Fountain Creek.
0.3	7.1	The road ascends out of Fountain Creek valley.
0.2	7.3	Road makes another sharp 90° curve to the right.
0.05	7.35	Another 90° curve back to the left.

0.15	7.5	The road flattens out, and we are back on top of the bluffs.
0.25	7.75	Loess is exposed on both sides of the road.
0.15	7.9	T-intersection (Lemen Road/6000) from the right. CONTINUE AHEAD.
0.1	8.0	Road makes a sharp 90° turn to the left and a second sharp 90° turn to the right. The section of road between Fountain Creek and Route 3 generally lacks sinkholes. The landscape is still rolling topography, but the sinkholes are not as prevalent in this portion of the field trip.
0.75	8.75	STOP (1-way). T-intersection (JJ Road/4800 and Old Route 3/6500). TURN RIGHT onto Old Route 3.
0.25	9.0	STOP (1-way). T-intersection (Old Route 3 and new Route 3). TURN RIGHT onto new Route 3. CAUTION: Fast moving traffic from the left.
0.4	9.4	T-intersection (Kaskaskia Road) from the left. CONTINUE AHEAD, and PREPARE TO TURN LEFT at quarry entrance road.
0.1	9.5	T-intersection (Old Redbud Road/5100) from the left. TURN LEFT onto Old Redbud Road. Note: The Ranch House Eatery and Spirits is on the southeast side of the intersection.
0.4	9.9	T-intersection from the left. CONTINUE AHEAD.
0.2	10.1	T-intersection from the left. CONTINUE AHEAD.
0.2	10.3	Road makes a 90° turn to the left and enters the quarry.
0.1	10.4	Stop 6 Waterloo Quarry. Enter the quarry and follow the main road back to the pit.

STOP 6 Waterloo Quarry We will discuss the limestone deposits and quarrying operations at the Waterloo Quarry. This is a fossil collecting stop. Retrace route back to the quarry entrance. Reset your odometer to 0.0 at the main gate as you exit.

Miles to next point	Miles from start	
0.0	0.0	Leave stop 6.
0.2	0.2	T-intersection from the right. CONTINUE AHEAD.
0.2	0.4	T-intersection from the right. CONTINUE AHEAD.
0.35	0.75	T-intersection (Old Redbud Road/5100 and Route 3/6150). TURN LEFT onto Route 3. CAUTION: Fast moving traffic from both directions.
0.15	0.9	Large red transmitting tower to the southwest.

0.5	1.4	Cross Rockhouse Creek.
0.35	1.75	T-intersection (Sportsman Road/5400) from the right. TURN RIGHT onto Sportsman Road. Note: Sign indicates St. Patrick's Church, Tipton.
0.45	2.2	T-intersection (entrance to Grand Terrace housing development) on the right. CONTINUE AHEAD.
0.35	2.55	T-intersection (KK Road and Sportsman Road/6625) from the left. CONTINUE AHEAD.
0.15	2.7	This is the community of Burksville.
0.05	2.75	T-intersection (KK Road/5400) to the right. TURN RIGHT onto KK Road.
0.6	3.35	Monument made from Mississippian limestone on the right. The plaque reads:

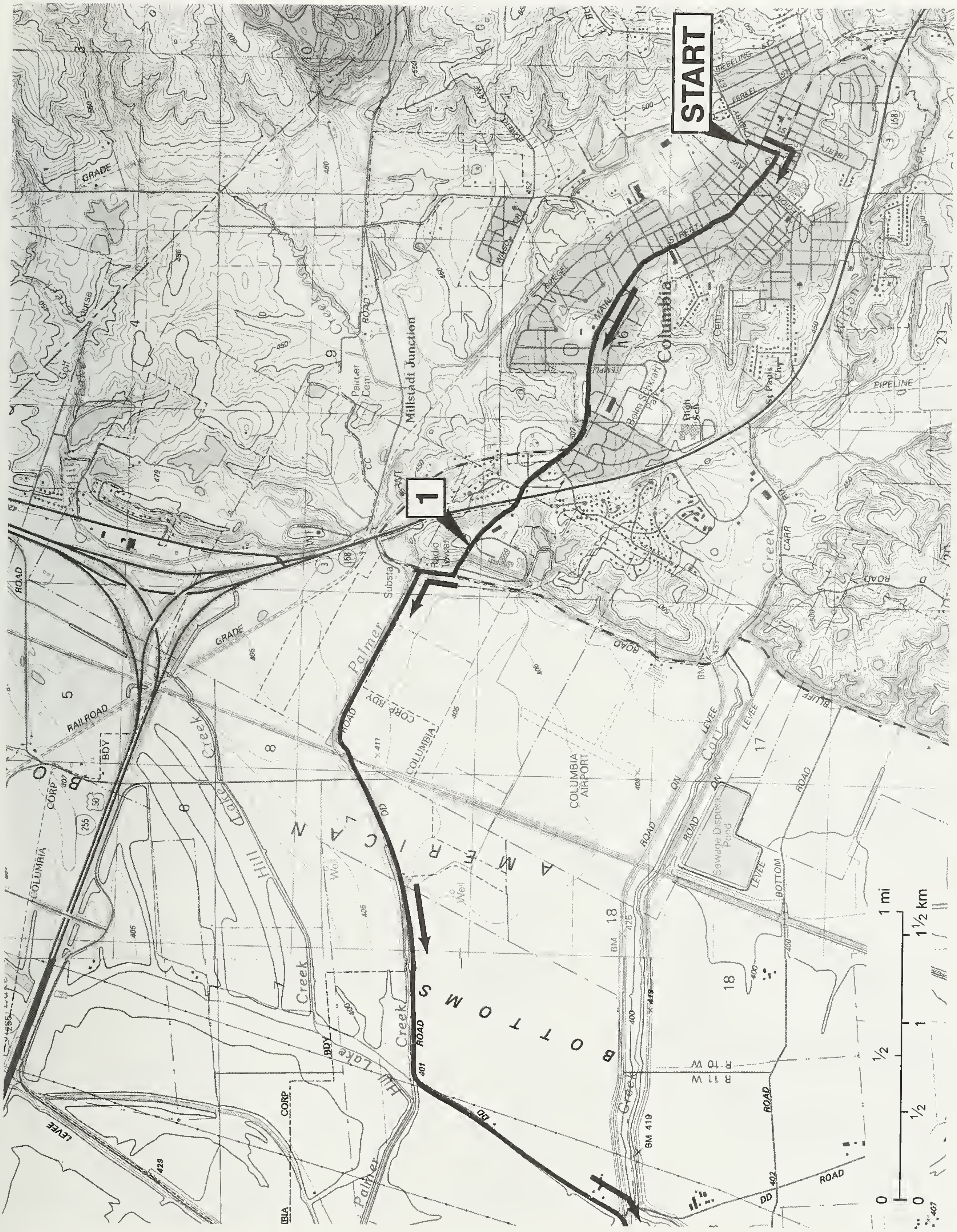
> On this site in the year 1783 stood the first English-speaking public school in the State of Illinois. It was taught by Samuel J. Seely. The school was an abandoned squatters cabin located on a tract of land known as the James Lemon Grant, later the Varnham Homestead. Plaque donated by the 233rd Woodmen of the World, Waterloo, Illinois.

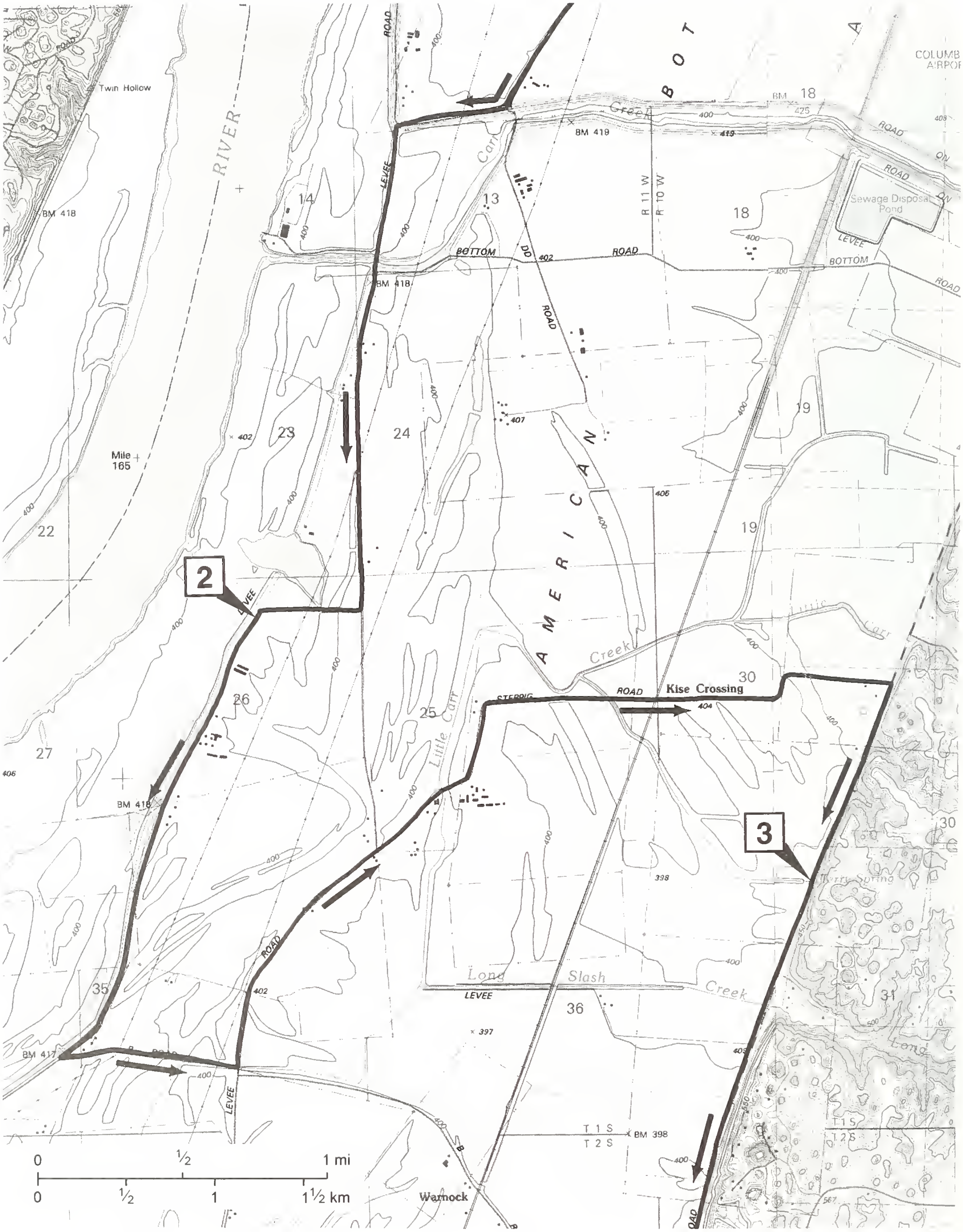
0.15	3.5	T-intersection (G Road/5200 and KK Road/5400) from the left. TURN LEFT onto G Road. Heading South. Note: Sign points to Illinois Caverns State Natural Area.
0.6	4.1	Road starts to descend into a low area.
0.15	4.25	Ostrich farm to the right.
0.25	4.5	Road makes another sharp descent into a small karsted valley. Sinkhole on the left.
0.7	5.2	Road ascends out of the small shallow valley to the top of the bluff.
0.3	5.5	T-Intersection (entrance to Illinois Caverns from the right). TURN RIGHT. Hours of Illinois Caverns: Summer—8:30 am to 7:30 pm; winter—8:30 am to 3:30 pm.
0.15	5.65	Two sinkholes on the left side of the road. The first one is filled with water.
0.05	5.7	Stop 7. Entrance to parking lot of Illinois Caverns. The office is on the right side of the road opposite the gate to the parking lot.

STOP 7 Illinois Caverns We will discuss the development of Illinois Caverns and the biologic diversity of the cave, and venture down into the darkness.

End of Field Trip. The total mileage of the field trip is 49.25 miles. Use the following road log to guide you back to IL Route 3. Reset odometer to 0.0

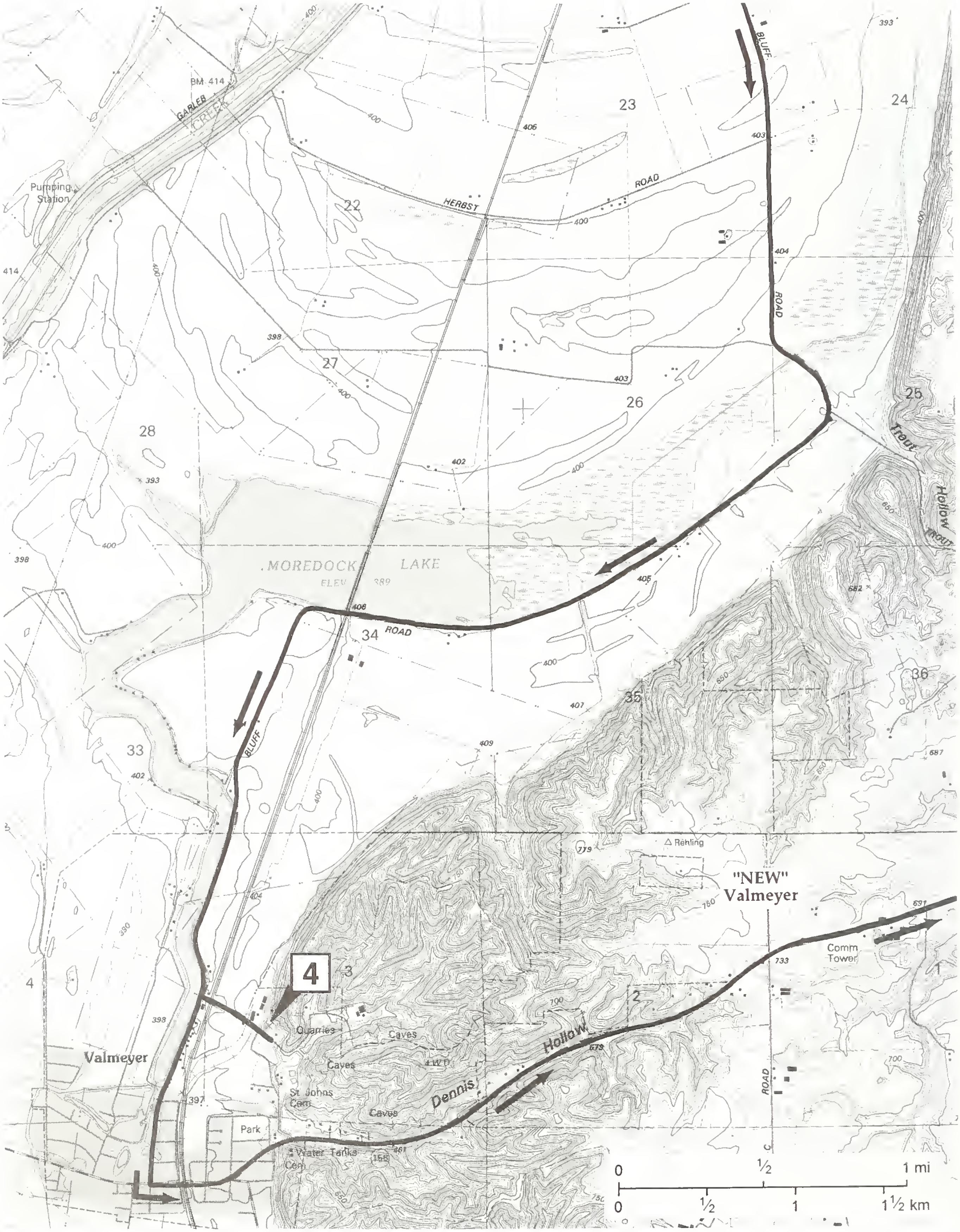
0.0	0.0	Exit Illinois Caverns. TURN LEFT onto G Road.
2.05	2.05	T-intersection (G Road and KK Road). TURN RIGHT.
0.80	2.85	STOP (1-way). T-intersection with Sportsman Road. TURN LEFT.
0.10	2.95	T-intersection (KK Road/4500) from the right. CONTINUE AHEAD.
0.80	3.75	Stop (1-way). T-intersection (Sportsman Road/5400 and Route 3/5560). TURN LEFT. This road will take you back to the city of Waterloo, population 5,100. Note: This portion of Route 3 is part of the Great River Road system.


START
1
Columbia
Millstadt Junction
Palmer Cem
Radio Tower
AMERICAN BOTTOMS
COLUMBIA AIRPORT
Palmer Creek
Hill Lake Creek
Golf Course
High Sch
MAIN
RAILROAD GRADE
LEVEE
BLUFF ROAD
DD ROAD
R 10 W
R 11 W
PIPELINE
0 ½ 1 mi
0 ½ 1 1½ km

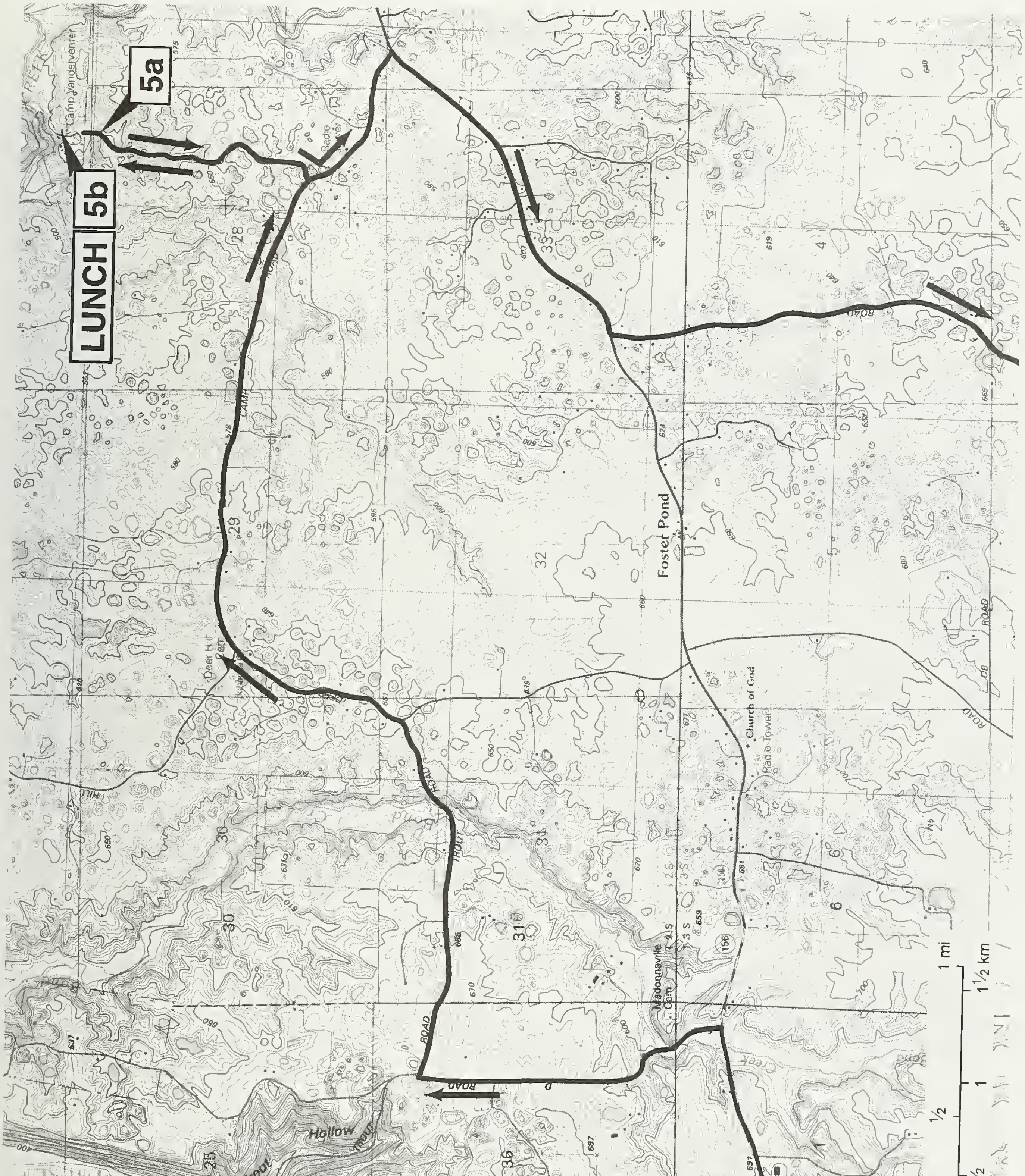


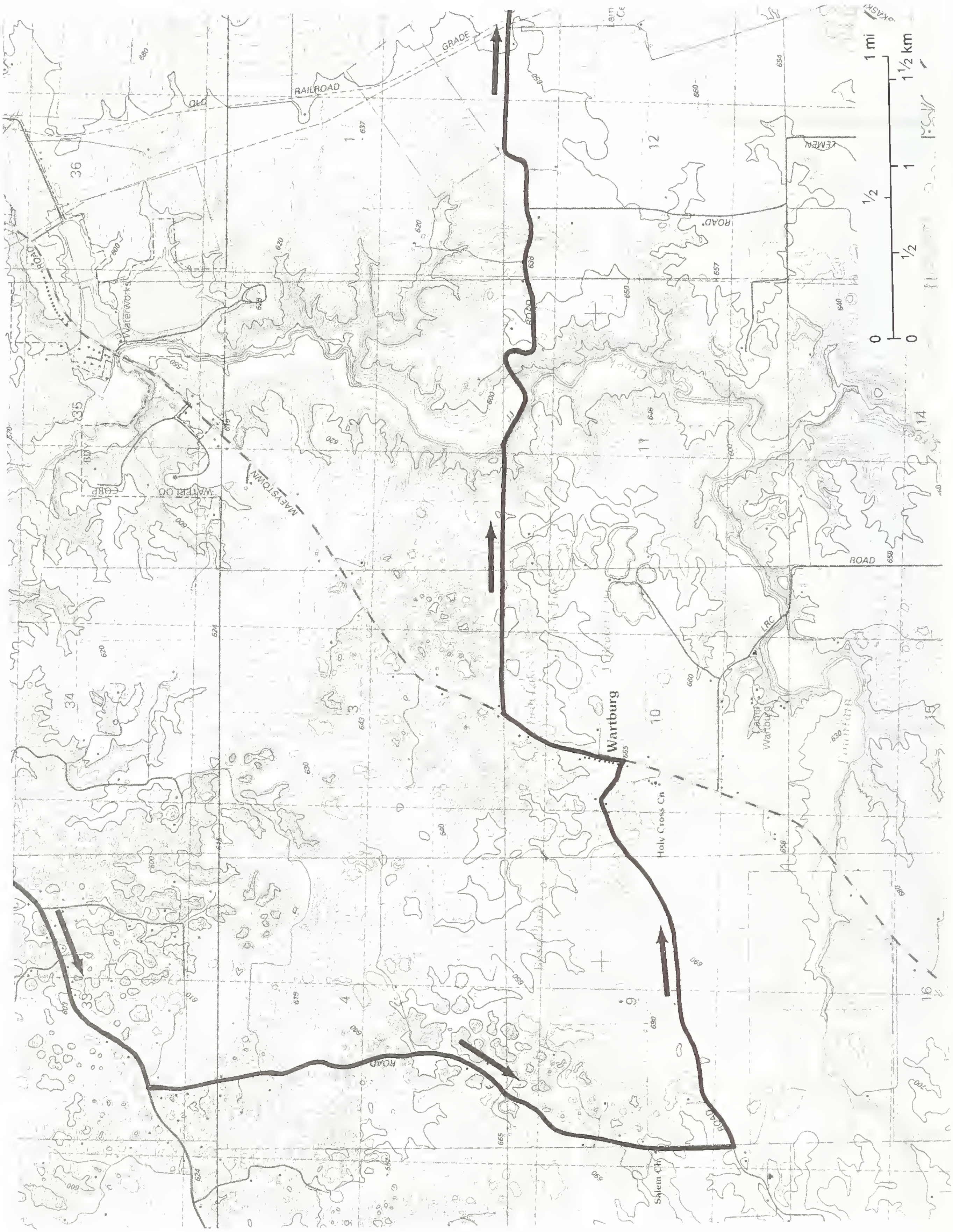
Twin Hollow
RIVER
BM 418
Mile 165
22
23
24
14
13
18
19
27
26
25
35
36
30
31
2
3
LEVEE
ROAD
BOTTOM
DD
402
BM 419
BM 417
BM 398
Creek
Carr
Little Carr
AMERICAN BOT
R 11 W
R 10 W
Sewage Disposal Pond
COLUMB AIRPOR
STERRIG
Kise Crossing
Long Slash Creek
T 1 S
T 2 S
Warnock
0
½
1 mi
0
½
1
1½ km


Fountain Gap
BM 417
Fountain Creek
Fountain
BLUFF
LEVEE
ROAD
HANOVER
Eagle Cliff Cem
Deer Hill Ch
Long Slash Creek
BM 406
BM 416
BM 398
T 1 S
T 2 S
R 11 W
R 10 W
0 1/2 1 mi
0 1/2 1 1/2 km

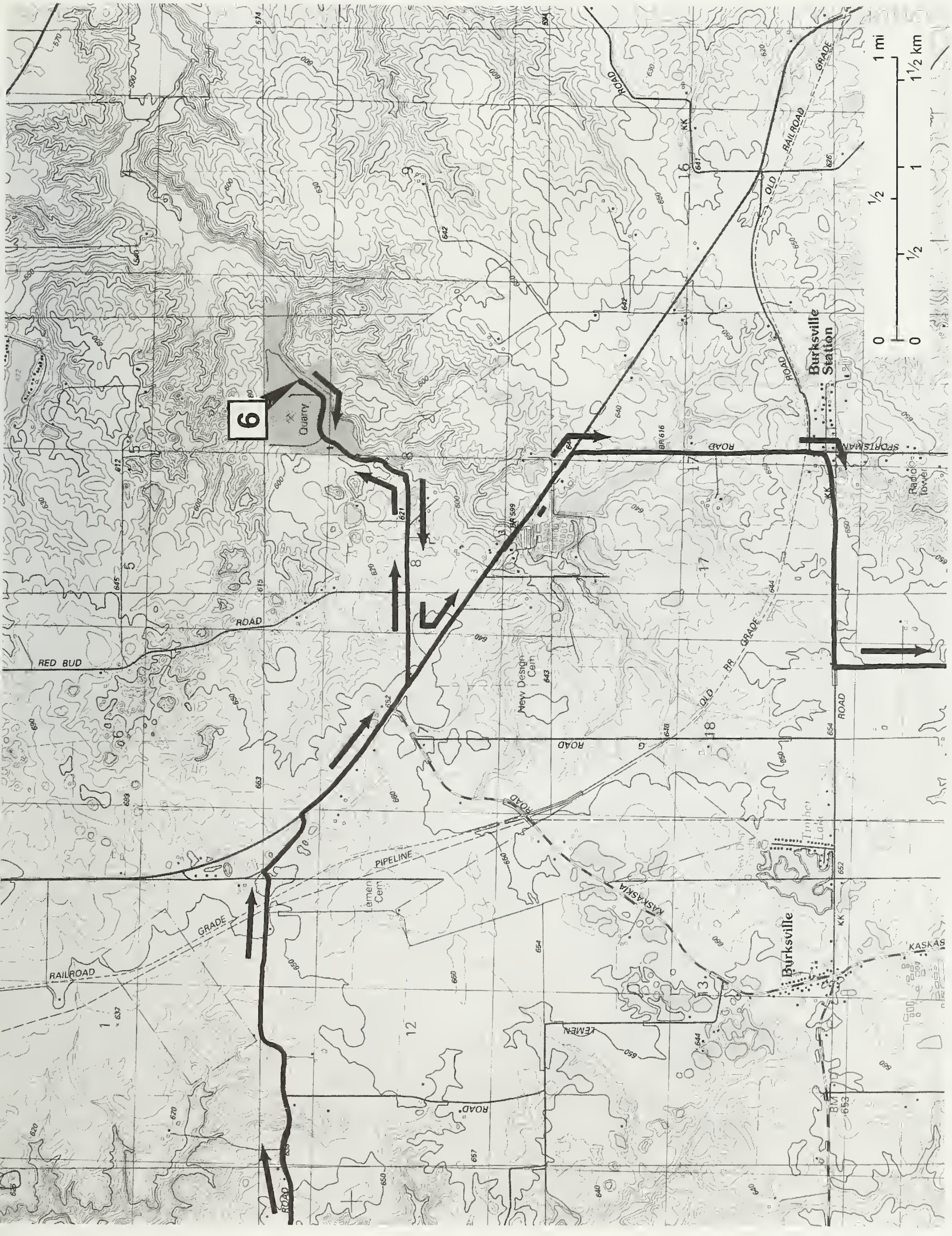


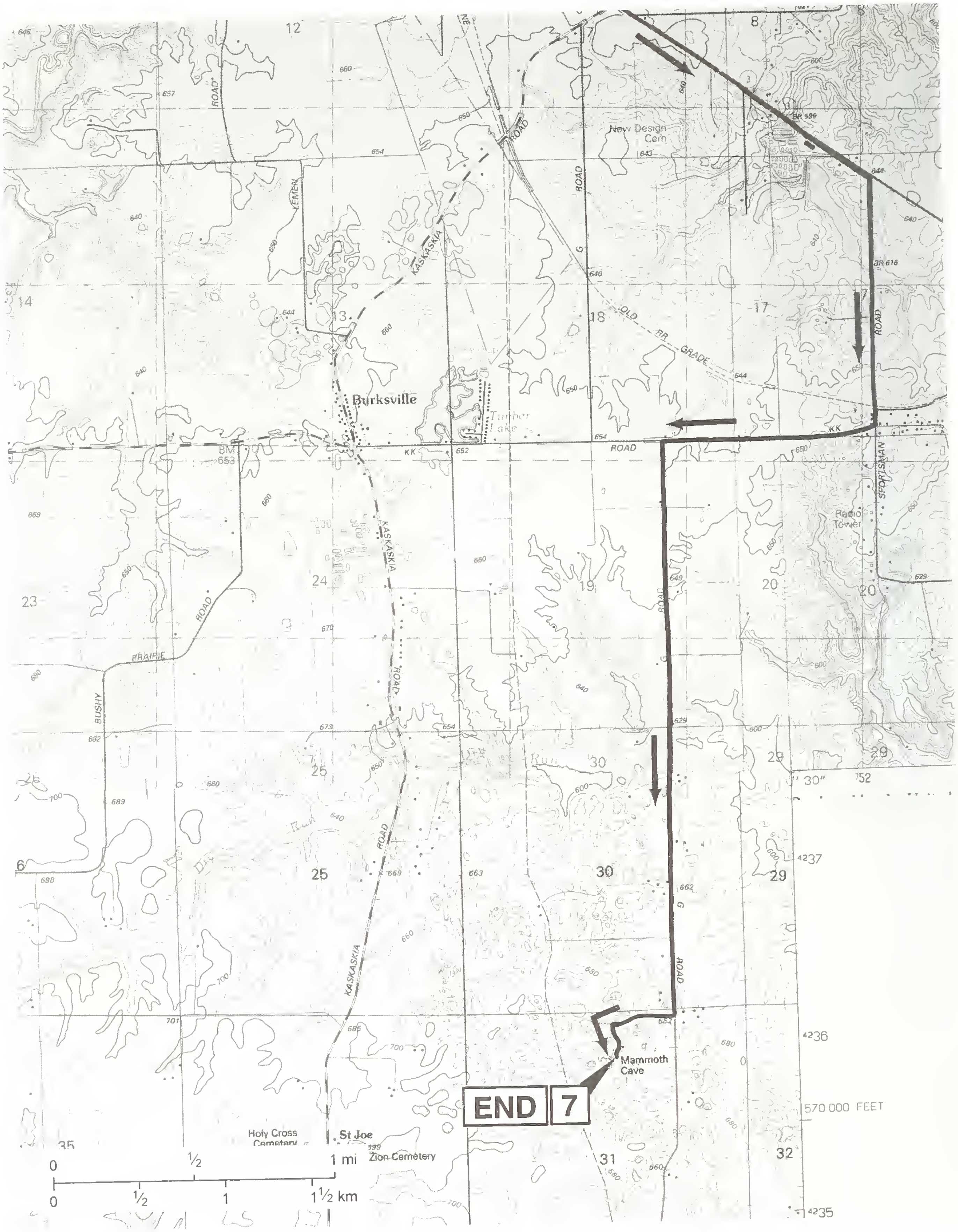
BM 414
GARLEB CREEK
Pumping Station
414
22
23
24
HERBST ROAD
BLUFF
ROAD
27
26
25
28
Trout Hollow
MOREDOCK LAKE
ELEV 389
ROAD
34
35
36
33
BLUFF
Rehling
"NEW" Valmeyer
4
3
2
1
Comm Tower
Quarries
Caves
Valmeyer
St Johns Cem
Dennis Hollow
Park
Water Tanks
Cem
0
½
1 mi
0
½
1
1½ km


LUNCH
5b
5a
Camp Vandeventer
Foster Pond
Church of God
Radio Tower
Madonnaville Cem
Comm Tower
Trout
Hollow
0
½
1
1 mi
1½ km



Wartburg
Holy Cross Ch
Salem Ch
Waterworks
MAEYSTOWN
OLD RAILROAD GRADE
ROAD
JJ
0 1/2 1 mi
0 1/2 1 1 1/2 km


6
Quarry
RED BUD
ROAD
PIPELINE
RAILROAD
GRADE
New Design Cem
Lemen Cem
KASKASKIA
OLD RR GRADE
OLD RAILROAD GRADE
SPORTSMAN ROAD
LEMEN
Burksville
Burksville Station
Timber Lake
Radio tower
KK
BM 653
0 1/2 1 mi
0 1/2 1 1 1/2 km



Burksville
New Design Cem
Timber Lake
Radio Tower
Mammoth Cave
END 7
KASKASKIA ROAD
OLD RR GRADE
KK ROAD
G ROAD
SPORTSMAN ROAD
PRAIRIE ROAD
BUSHY
LEMEN
Holy Cross Cemetery
St Joe
Zion Cemetery
570 000 FEET
0 ½ 1 mi
0 ½ 1 1½ km

STOP DESCRIPTIONS

STOP 1 Peoria Loess and Overview of the Mississippi River Valley (NW SE SE, Sec. 8, T1S, R10W, 3rd P.M., Monroe County, Columbia 7.5-Minute Quadrangle)

Peoria Loess and Roxana Silt

The geologic materials in the road cut along Sand Bank Road consist of more than 25 feet of wind-blown silt (loess) that overlies the Mississippian St. Louis Limestone. The limestone is not visible at this stop but outcrops a short distance to the south along the road at the base of the bluff. The loess consists of two units: the sandier, reddish brown Roxana Silt below and the siltier, light brown Peoria Loess above (fig. 17). The Roxana is covered by talus from the overlying Peoria Loess. These deposits of loess originated from the Mississippi River floodplain during the time when meltwaters of the Wisconsin Glacial Episode flowed down the valley.

Tremendous quantities of silt, sand, and gravel (outwash) were discharged by glacial meltwaters along major river valleys (Mississippi, Illinois, Missouri, Wabash, and Ohio River Valleys) in the Midwest during glaciations. These sorted sediments were deposited in the broad braided-type stream valleys that flowed in the large river valleys. During the winter months when the glaciers refroze, the deposits left by the summer's floods would dry out. Strong prevailing westerly winds picked up the fine ground up silt and clay (rock flour) and in immense dust storms deposited them as loess on the adjacent uplands.

One of the most common questions related to loess deposits is, "How can the loess maintain such vertical faces?" The answer is that loess can stand in massive, vertical banks because the very angular, tightly packed particles cling together: interlocked almost like pieces of a jigsaw puzzle.

A section of loess called the Columbia Section (about 200 yards northeast of the road cut) exposed about 21 feet of the yellowish brown Peoria Silt, which overlay 6 feet of a pinkish colored loess, known as Roxana Silt. The base of Roxana Silt was not exposed. The site no longer exists because the outcrop was part of construction work along a new stretch of Illinois Route 3. However, you might find Roxana Silt in the lower portion of the exposure along Sand Bank Road.

The pinkish color of the Roxana Silt is generally thought to be due to the influence of glaciers that overrode reddish and pinkish rocks and sediments, underlying and near Lake Superior. An interesting feature at the Columbia Section was the presence of a flood clay bed within the middle Peoria Silt at an elevation of 485 feet (about 50' above the level of the Great Flood of 1993). This bed was deposited during an aggradational flood in the Mississippi Valley during peak glaciation. These flood beds occur as sequences of one to three beds in several bluffside exposures of loess in the St. Louis area. On the basis of radiocarbon dating of wood found within the clay beds, this flood is estimated to have occurred about 23,000 years ago. Perhaps you can find the clay bed within the Peoria Silt in this outcrop if you look carefully.

Some loess deposits contain nodules call loess "kindchen," or children of the loess. These ashy colored, irregular, rounded concretions are the result of calcium carbonate's being leached from the upper portion of the loess by rainwater and being re-deposited in the lower part of the loess (Raasch 1950). The re-deposition of the calcium carbonate is generally controlled by the presence of an impervious layer within the loess that prevents further downward movement of the calcium-rich water. Kindchen are sometimes hollow and are then called "rattle stones" (Wilson 1956). Although no loess kindchen were found at this exposure during the initial field work for this tour, they were found within the lower part of the loess deposits at stop 4, along with some rattle stones.

Figure 17 A vertical bank and slumping of Peoria Loess in the south-facing road cut at stop 1 (photo by Wayne T. Frankie).

Mississippi River Valley

This stop affords an excellent view of the Mississippi River Valley. The deposits within the valley near Columbia consist of up to 100 feet of mixed, poorly sorted sand, silt, clay, and abundant lenses of sandy gravel. These river deposits have been mapped by geologists and are called the Cahokia Alluvium and the Henry Formation. The Cahokia Alluvium is younger and overlies the Henry Formation.

The Mississippi River Valley is 3.3 miles wide at this point near Columbia, and gradually widens southward to 5.5 miles, just north of Valmeyer where the Valmeyer Anticline juts out into the valley. South of the influence of the Valmeyer Anticline, the Mississippi River Valley narrows to about 3.8 miles. The widest portion of the valley is located to the north, between Alton and Dupo, where it is approximately 11 miles wide.

This broad floodplain, which is almost entirely located on the Illinois side of the Mississippi River Valley, extends from Alton, Illinois (to the north), to just south of the mouth of the Kaskaskia River near Chester (to the south), a distance of approximately 95 miles. This extensive floodplain with its many lakes and wetlands is known as the American Bottoms, a name derived from the early American settlers.

Locally, parts of the Mississippi River Valley are quite old and probably formed during the Mesozoic Era or, at the very latest, during the Tertiary Period of the Cenozoic Era. While the river has maintained its course along the eastern edge of the Ozark uplift, it has eroded a broad valley in the bedrock up to 300 or more feet below the surrounding uplands. The bluffs along the Mississippi River consist of Ordovician, Mississippian, and Pennsylvanian rocks. Along the bluffs, hard Mississippian limestones outcrop north of Alton and south of Dupo. Between them are the bluffs formed of the softer Pennsylvanian shales, sandstones, and coals. In this area, therefore, the Mississippi River was able to cut a wider floodplain than it could both upstream and downstream against the harder limestones .

The widening and deepening of the American Bottoms portion of the Mississippi River Valley, especially in the northern part, is primarily the result of the scouring action of postglacial flood meltwaters that merged together at the confluence of the Mississippi and Missouri Rivers, just south of Alton. Later, as the amount of melt water from the receding glaciers diminished and the river valley filled with deposits of silt, sand and clay, the river took a meandering course, changing its route many times, swinging from east to west across the valley.

Ronald E. Yarbrough, of Illinois Natural Heritage, has described the history of glacial deposition in the American Bottoms:

> The Wisconsinan glaciers approached the field trip area from the northwest, but stopped some 95 miles to the north. However, these ice sheets had a major impact on the American Bottoms because the Mississippi, as well as the Missouri and the Illinois Rivers, were major drainage ways for the heavily-laden melt waters. The river began to aggrade to a level of at least 445 feet in elevation, which is 47 feet higher than the present river level. Today, the valley fill averages 120 feet in thickness and in places as much 160 feet of alluvial material lies in the old bedrock valley of the Mississippi. Heavy deflation took place during the Wisconsinan winters when westerly winds blew across the exposed rock flour outwash. The lighter particles were deposited on the upland as loess, attaining a thickness of 50 feet in places adjacent to the floodplain but with a progressive decline in thickness going eastward. As the Wisconsinan glaciers retreated from Illinois, the river again began to degrade and remove the valley fill of Pleistocene times.
>
> Today, the floodplain is filled with alluvial materials that vary in thickness from a few feet to over 150 feet. The alluvium may be divided into two formations; the Henry of Wisconsinan age and the Cahokia Alluvium of Wisconsinan and Holocene (Recent) ages. The Henry formation overlies bedrock throughout most of the Bottoms and appears on the surface only in the northern portion as distinct terraces. The material consists dominantly of sand and gravel from glacial outwash. The formation, because of its coarseness, is the primary source of groundwater in the floodplain. Overlying the Henry formation is the Cahokia Alluvium, consisting of silts, clays, and reworked Henry sands. The silts and clays are derived from outwash, loess and till upstream. The formation consists largely of silt-sized particles; where sand lenses do occur, they contain large amounts of soil.
>
> The Cahokia Alluvium on the American Bottoms varies in thickness from 0 to over 50 feet. The variability in thickness is due to recent cut-and-fill processes on the Henry sands and gravels. It is known that the Mississippi has scoured its bed over 50 feet during periods of high water or when ice packs in winter cause the river to deepen its channel to flow under the ice. Thus, the many migrations of the channel across the floodplain has created valleys in the underlying sands and gravels and has replaced the valley train with thick deposits of Holocene materials. (Adapted from Yarbrough 1974)

William R. Iseminger, of the Illinois State Museum, has described the formation and natural features of the American Bottoms:

> As former meanders were cut off from the main channel they became lakes, sloughs and marshes; streams draining the uplands captured other old meanders (see route maps). These various fluvial features formed an interconnected "inland waterway" beyond the eastern banks of the Mississippi. They also provided a superb resource base of fish, waterfowl and aquatic plants. Periodic flooding of the region also deposited fertile soils across the ridge and swale terrain of the American Bottoms.
>
> There were scattered woodlands concentrated around these aquatic sources consisting primarily of cottonwood, willow, sycamore, maple and hackberry, surrounded by large areas of prairie. Bluff crests often were topped with hillside prairies and cedar; denser hardwood forests, primarily oaks and hickories, were concentrated along the bluff slopes and adjacent dissected uplands, and tallgrass prairies dominated the interior uplands.
>
> These various environmental zones would have provided a stable set of floral and faunal resources within less than a day's walk from any settlement in the American Bottom, and ethnobotanical evidence from archaeological sites show that all zones were being exploited, although in varying degrees in different time periods. However, the stability of these resources would be impacted by increased and even over-exploitation, especially as population densities and distributions increased through time.
>
> Archaeologists recognize several prehistoric cultural traditions in this region. In turn, most of these traditions are seen to have had several sub-phases of cultural development and change. Paleo Indian is generally believed to have ranged from 9500 to 8000 B.C.; Archaic from 8000 to 600 B.C.; Woodland from 600 B.C. to A.D. 800; Emergent Mississippian from A.D. 800 to 1000; Mississippian from A.D. 1000 to 1450; and Oneota from A.D. 1450 to 1550. Actually, the beginning and ending "dates" for these traditions are imprecise and would vary from region to region, but they represent the generally accepted time frames recognized in the American Bottom area. The sub-phases and their durations are constantly undergoing revision and refinement as new data accumulates from ongoing research. (Adapted from Iseminger 1996)

Discontinuities and Interruptions in the Land Grid System in Illinois
Notice on the 7.5-minute quadrangle map (see route map) that the land grid system in this area is divided into an irregular rectangular grid system that trends NE–SW. This land grid is part of the original French Land Grants. These land grants date from the early French colonization and from old Indian treaty boundaries that were honored when the grid system was established. The old land grants are found mainly along the Wabash and Mississippi Rivers in southern Illinois because these rivers were the main travel and trade routes along which settlement first occurred.

STOP 2 Levee along the Mississippi River (NE NW NE, Sec. 26, T1S, R11W, 3rd P.M., Monroe County, Oakville 7.5-Minute Quadrangle)

From the top of the levee, there is a good view of the Mississippi River and the Mississippian limestone bluffs on both sides of the river. Notice the smaller levee between the main levee and the Mississippi River. This secondary levee partially protects the farmland between the Mississippi River and the main levee. Along the west side of the levee are a large number of dead trees. These trees were killed by the Great Flood of 1993 when they were under water for an extended period of time; the trees essentially drowned.

During the Great Flood of 1993, a large break in the levee system along this portion of the Mississippi River occurred. It began at a point just north of the bend in the road at the base of the levee, and extended northward to a point just south of the farm buildings located to the north. The low area immediately east of the levee shows where a large scour hole formed when the levee was breached (see route map and fig. 18). In the field to the southeast is a large ridge of sand that was scraped from the field by bulldozers. Up to 8 feet of sand were deposited over the fields by the Mississippi River when it breached the levee (fig. 18). Much of this sand probably came from the floodplain deposits that were eroded out of the scour hole by the flood waters passing through the break in the levee.

Flooding

Some rainfall that reaches the ground soaks into the ground (infiltration), and some may flow across the ground surface and into streams (runoff). Runoff occurs when the rate of rainfall exceeds the rate at which water can infiltrate the soil. The amount of runoff is affected by many features of the drainage basin, including the permeability of the soil, the vegetation, density of streams in the basin, and the saturation of the soil in the basin by earlier rainfall. Runoff in stream channels is measured in two ways: by the stage height (depth of the water) or by the rate of discharge (the volume of water per unit of time). The discharge rate is more commonly used by geologists and can be determined from the stage height at a gauging station. During a flood, the flood crest is the stage height that occurs during the peak discharge. The peak discharge may last for several hours or days.

A flood occurs when the capacity of the stream channel is exceeded by the volume of runoff, and the water flows out of the channel and onto adjacent land (or the floodplain). Rivers carry sediment in suspension, and during a flood when the water leaves the channel and spreads out, the river quickly loses energy and first drops coarse grained sediments (sand and gravel). These materials create a natural levee at the top of the bank along the normal channel. Farther out on the floodplain, the water moves very slowly, and the fine grained sediments (silt and clay) are deposited over large areas and build up the floodplain's level. The floodplain also serves as a storage area for flood water, which is not released until the flood recedes.

Small streams have flash floods that occur shortly after heavy rainfalls and may only last for several hours. Flash flooding is hard to predict because rainfall can vary widely during a single storm. The National Weather Service, which now uses Doppler radar to estimate the total rainfall in an area, can predict flash flooding up to several hours before it occurs. Floods along large rivers, like the Mississippi and Ohio, are caused by large amounts of rain falling over several days or even weeks. Because it can take days or weeks for the water to move downstream, the National Weather Service, the U.S. Army Corps of Engineers, and the U.S. Geological Survey can forecast with fairly high accuracy the crests of these large floods several days before they occur. These forecasts allow residents time to prepare.

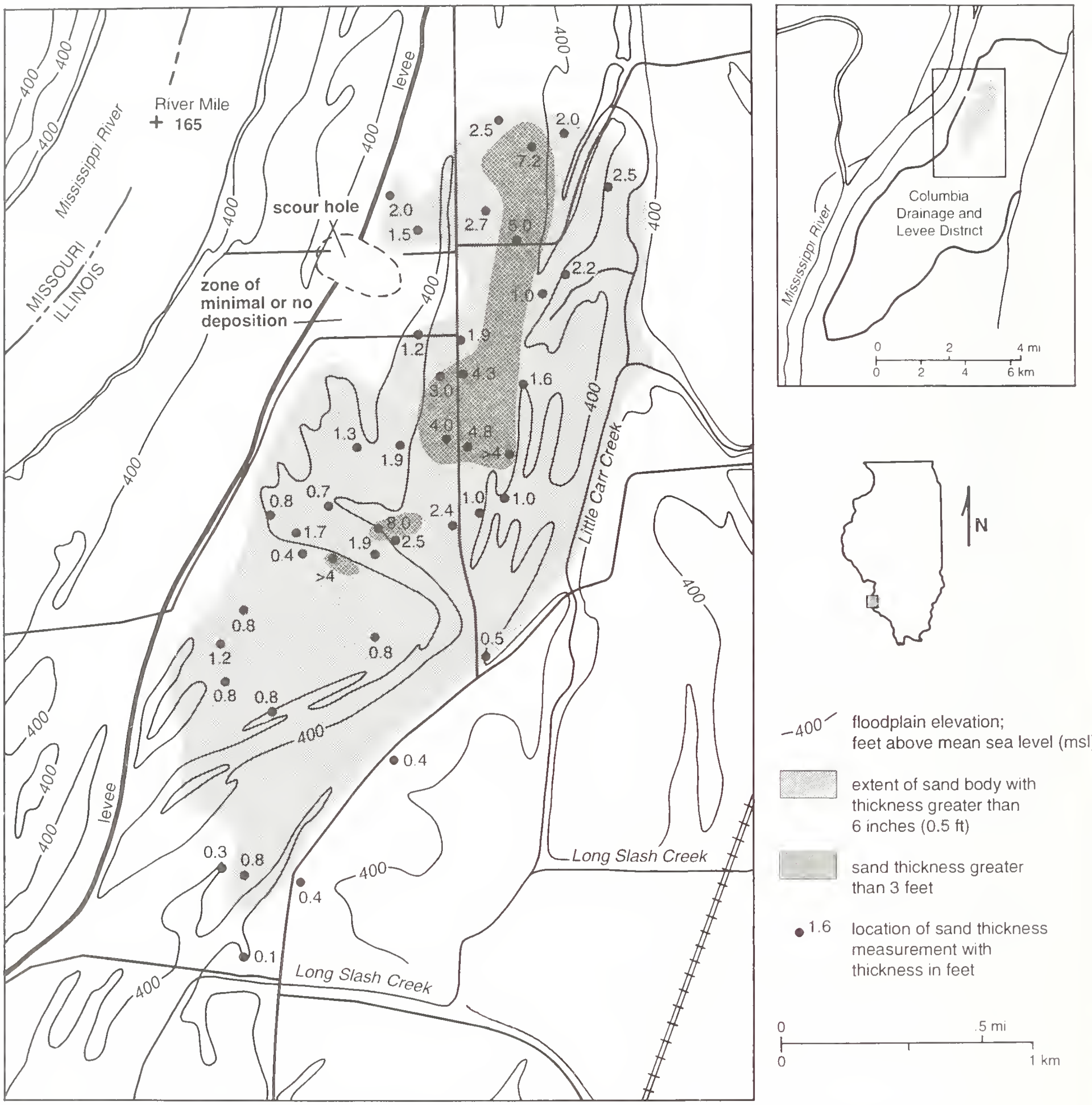


Figure 18 Generalized map of the extent and thickness of the sand ridge deposited on top of the floodplain near the breach of the Columbia levee (from Chrzastowski et al. 1994).

Flood Recurrence

The flood recurrence interval is a numerical representation of the likelihood of flooding. The historical record is analyzed statistically, and a probabilty of occurrence (for example, one chance in fifty) is assigned to each of the discharges in the historical series. The recurrence interval expresses the annual likelihood for the occurrence of a flood at a particular discharge or stage height; it does not mean that a certain size flood will occur once every so many years.

The recurrence intervals are only as reliable as the data used to calculate them. Most streams in Illinois have been monitored for fewer than 100 years, so the recurrence intervals for large floods are not well supported by the data available. The effect of this data gap can be minimized by examining floodplain deposits and by estimating possible rainfalls and associated runoff. A larger problem with the data may be that the geological environment that produces the floods has been drastically altered by humans over the past 200 years. Alterations to drainage basins and river channels allow runoff to enter the rivers and flow downstream more quickly. The effects of these changes on flood recurrence are difficult to determine because man is constantly altering drainage basins by, for example, building new levees, adding drainage tiles, and digging new channels.

Responses to Flood Hazards

The flood crest stages associated with the 100-year and 500-year recurrence intervals are commonly used when planning land use on the flood plane. Zoning laws can be used to restrict development in flood-prone areas: for example, homes may have to be built on stilts or on hills that are above the 100-year flood stage. Levees may be built to withstand small or large floods depending on the land use to be protected. Construction and maintenance of the levees are paid for by those protected. Flood insurance can be purchased through the federal government to provide relief after a flood. Insurance rates are based on the flood hazard, and flood insurance rate maps are distributed to libraries and local government agencies.

During a flood, the predicted crest and the condition of the levees are constantly monitored. Unprotected areas are evacuated, as are areas threatened by levee failure. The Coast Guard, the Corps of Engineers, and the National Guard assist local governments in evacuation and rescue efforts. Boat traffic is restricted due to the effects of wakes on levees and other structures.

After a flood, residents, business owners, and local governments are responsible for clean up. If the state and federal governments declare a disaster area, monetary assistance is provided; otherwise, money for recovery may be very limited. Insured homes whose damage is greater than half of their value must be rebuilt away from the flood zone. Homes repaired using federal disaster assistance must be insured against floods to receive future disaster assistance.

Levees

Levees are an important part of the flood protection system along the Mississippi River. Two types of levees are present in this area. (1) Most levees along the floodplains in Illinois are agricultural levees. Built by farmers to protect farm land outside of the federally built levees that protect towns, these levees usually hold back 1- to 10-year floods. (2) Urban levees are higher and broader structures that protect cities. Built by the U.S. Army Corps of Engineers to withstand the 100- or 500-year floods, urban levees are paid for and maintained by a local levee district that collects property taxes on protected land and buildings. The levees are inspected regularly by the Corps of Engineers.

In order to be effective, the levee must surround the protected area or connect to points of high elevation such as bluffs. Rainfall within the protected area must be pumped out or held until the river level falls and drains may be opened. Major tributaries to the Mississippi must be allowed to flow past the leveed area, or the area would quickly fill with water. The levees must extend along the tributaries to prevent backwater flooding.

Flood Control

There are two basic approaches to flood control. One is to minimize the extent of flooding by building dams, reservoirs, levees, and other manmade structures. The other is to minimize floods by conservation practices designed to hold the water where it falls in the drainage basin, or watershed.

During periods of high flow, a levee confines the water within a narrow band; this confinement raises the peak stage height of flood waters upstream and downstream. Once construction of levees begins, they usually have to be built at all the low points along a river system. Furthermore, a system of levees is only as strong as its weakest spot; thus, uniform height and strength are required.

Overview of Levee Construction and Failure

Levees are linear, earthen mounds that are typically constructed of sediments dredged from the river channels or excavated from the adjacent floodplains. Properly compacted clay is ideal for levee construction because it resists erosion and forms a relatively impermeable barrier to the infiltration of flood water. In contrast, sand allows infiltration, which can weaken the levee and lead to structural failure. Sand is also easily eroded from the levee.

The characteristics of sediments relate to three causes of levee failure (fig. 19):

Surface erosion The surface of the levee is eroded by flood water lapping against it or by precipitation, as during a heavy rainfall, when drops of water pelt the surface and dislodge particles of sediment.

Levee seepage The levee is internally weakened as it is saturated by water seeping through permeable layers within the levee or by piping, the process by which water carries sediment through animal burrows or along the openings made by plant roots, particularly tree roots.

Underseepage The ground under the levee is weakened as water moves through porous sand layers beneath the levee and pipes sediment away. Because of the loss of support, the levee may subside or collapse.

A levee can also be weakened by overtopping, which simply means that water floods over the levee. Overtopping is not a type of levee failure, but a case of flood height exceeding the design height of the levee. Once overtopping begins, the flow of flood water usually breaches the levee.

Figure 19 illustrates how water moves through, under, and over a levee as it holds back flood water. During the Great Flood of 1993, most levees that were breached in Illinois were overtopped rather than weakened by structural failure. In several cases, seepage and underseepage probably contributed to localized weakening and subsidence of levees, which made them more vulnerable to overtopping and breaching.

Flood water applies great pressure against the river side of levees, which are constructed to hold back the flood water for a relatively short time. Because of the unusually long duration of high water in the Great Flood of 1993, most levees became saturated; water also infiltrated permeable layers within and beneath the levees. The result was seeps that piped sand out of the levee on exposed levee slopes. Sand boils were common on the floodplain adjacent to many levees. Sand boils form where lenses of sand under or within a levee provide a pathway for water to pipe sediment. Unless piping (erosion) of sediment under or within the levee is halted, the flowing water quickly weakens the levee structure and causes a catastrophic failure. Sand boils are counteracted by building a dike of sandbags around the boil (see fig. 19) and allowing water to rise within the ring. The rate of flowing water slows within the ring dike, and the sandbags minimize the loss of sediment by trapping it in place and equalizing water pressure. Allowing the water to flow over the sandbag dike prevents water pressure from building up elsewhere in the levee. Sand boils can develop, then cease activity as changes occur in the flow pathways within the levee. Fine grained materials (silt or clay) transported within the levee may block a flow path, shuting off one sand boil while opening a channel for another.

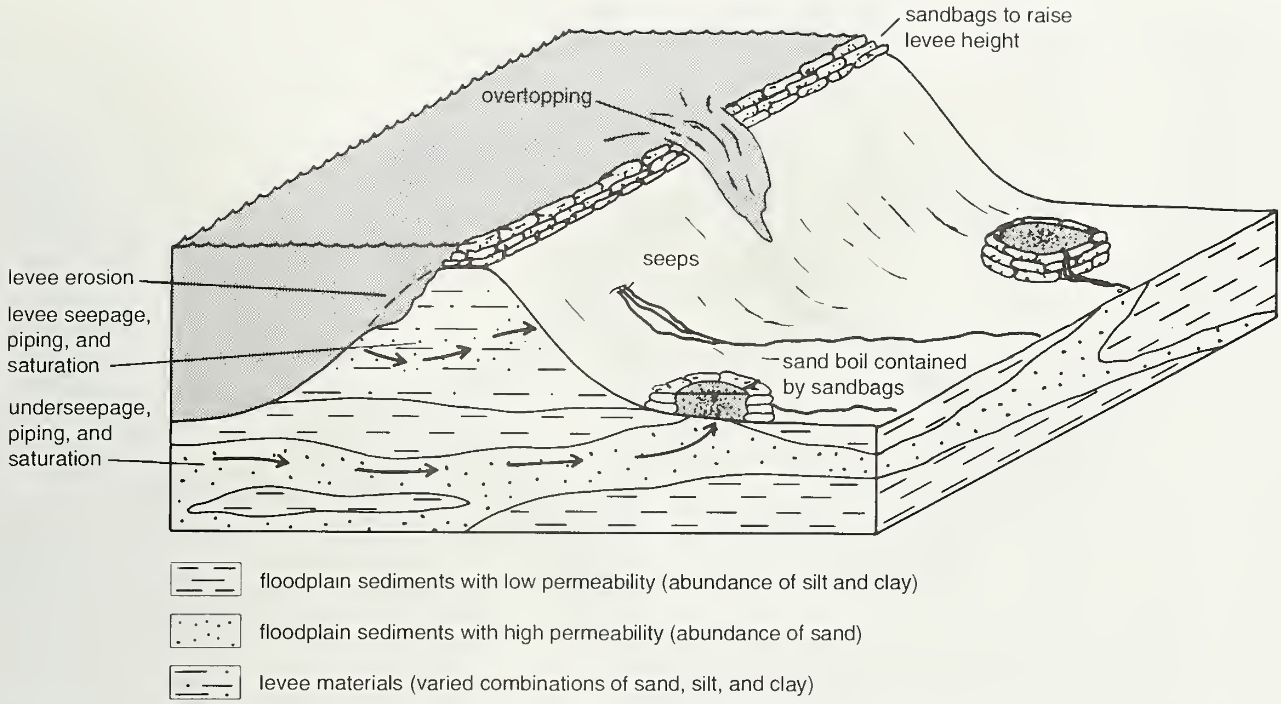


Figure 19 Overtopping, seeps, and piping move water over, through, or under a levee during a flood (from Chrzastowski et al. 1994).

Where a large amount of permeable, uncompacted sediment such as sand underlies a levee, the material may become unstable and mobile as it becomes saturated. If saturation occurs, the levee loses support and may sag, forming a low spot in the levee. If underseepage removes sediment beneath the levee, the undermining may bring about a sudden and catastrophic collapse. In either case, flood water can then pour over the subsided or collapsed segment of the levee and quickly erode a deep and wide breach.

The Great Flood of 1993

The Great Flood of 1993 was caused by extremely heavy rainfall in Illinois, Iowa, Missouri, Minnesota, North Dakota, South Dakota, Nebraska, and Kansas. From January through July, up to 40 inches of rain fell in some areas; this was as much as two times the normal rainfall for some areas. Most of the rain fell in June and July, and this rainfall was up to six times the normal rainfall for that period. The resulting flood was characterized as the 100- to 1,000-year flood for some areas. The duration of the flood caused many problems.

In Monroe and Randolph Counties, the floodplain is protected by three levees. The Columbia District is protected by a levee that extends from Carr Creek south to Fountain Creek; the Harrisonville-Fort Chartes and Ivy Landing-Stringtown District levee extends from Fountain Creek south to Prairie du Rocher Creek; and the Prairie du Rocher levee extends from Prairie du Rocher Creek south to the Kaskaskia River (fig. 20).

On August 1, the Columbia levee failed near the north end (located here at stop 2). The water flowed south, down the valley, toward the levee along Fountain Creek. Because the river and floodplain slope to the south, so does the levee. When a break occurs on the upstream end and the water has no outlet, the area inside the levee fills to the level of the river at the break, which is higher than the river level downstream. This higher water will overtop the levee at the downstream end of the district and cause it to fail, which is what happened just north of Valmeyer along Fountain Creek where the Columbia and Harrisonville levees are parallel (fig. 21). The floodwater began to flow

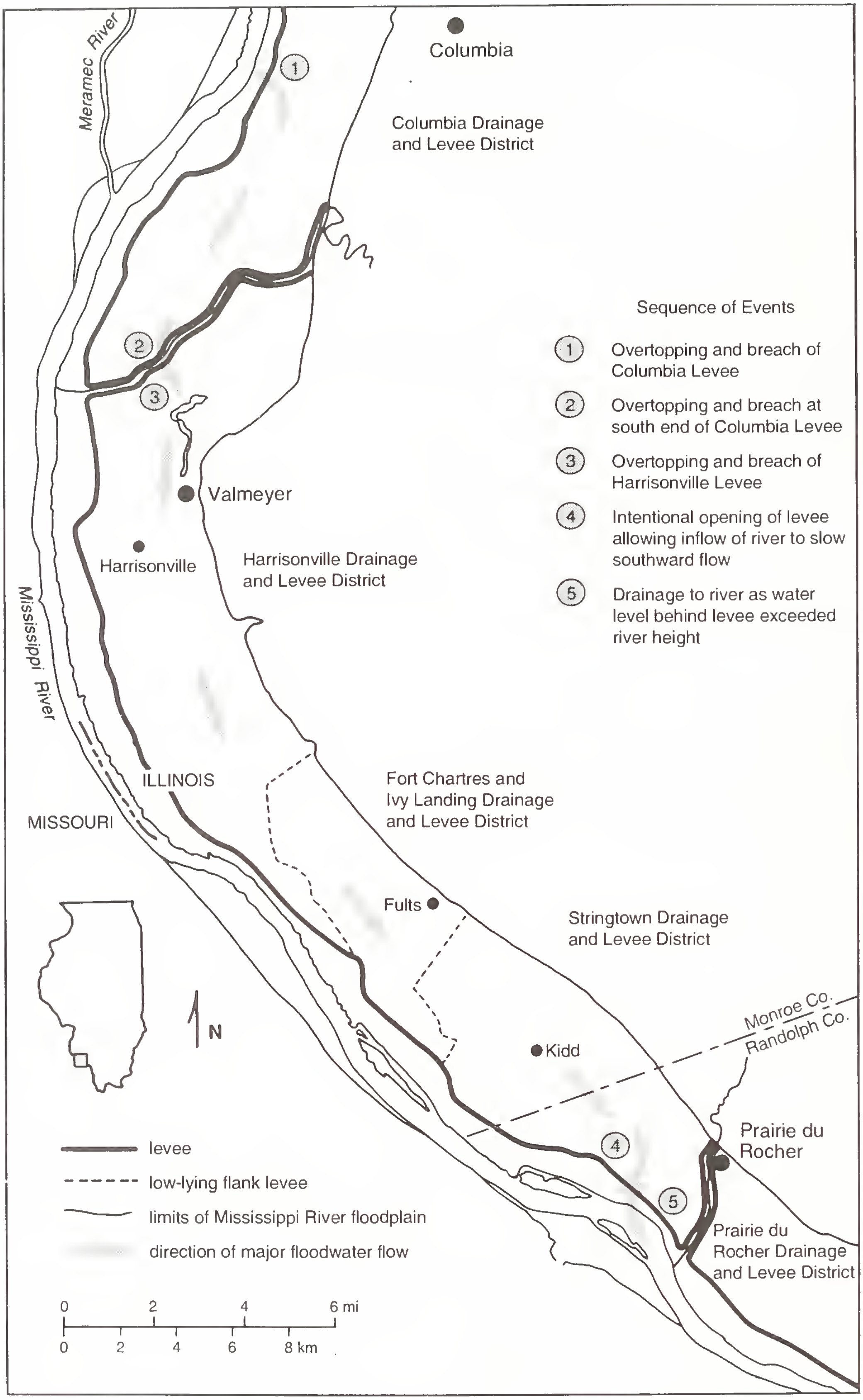
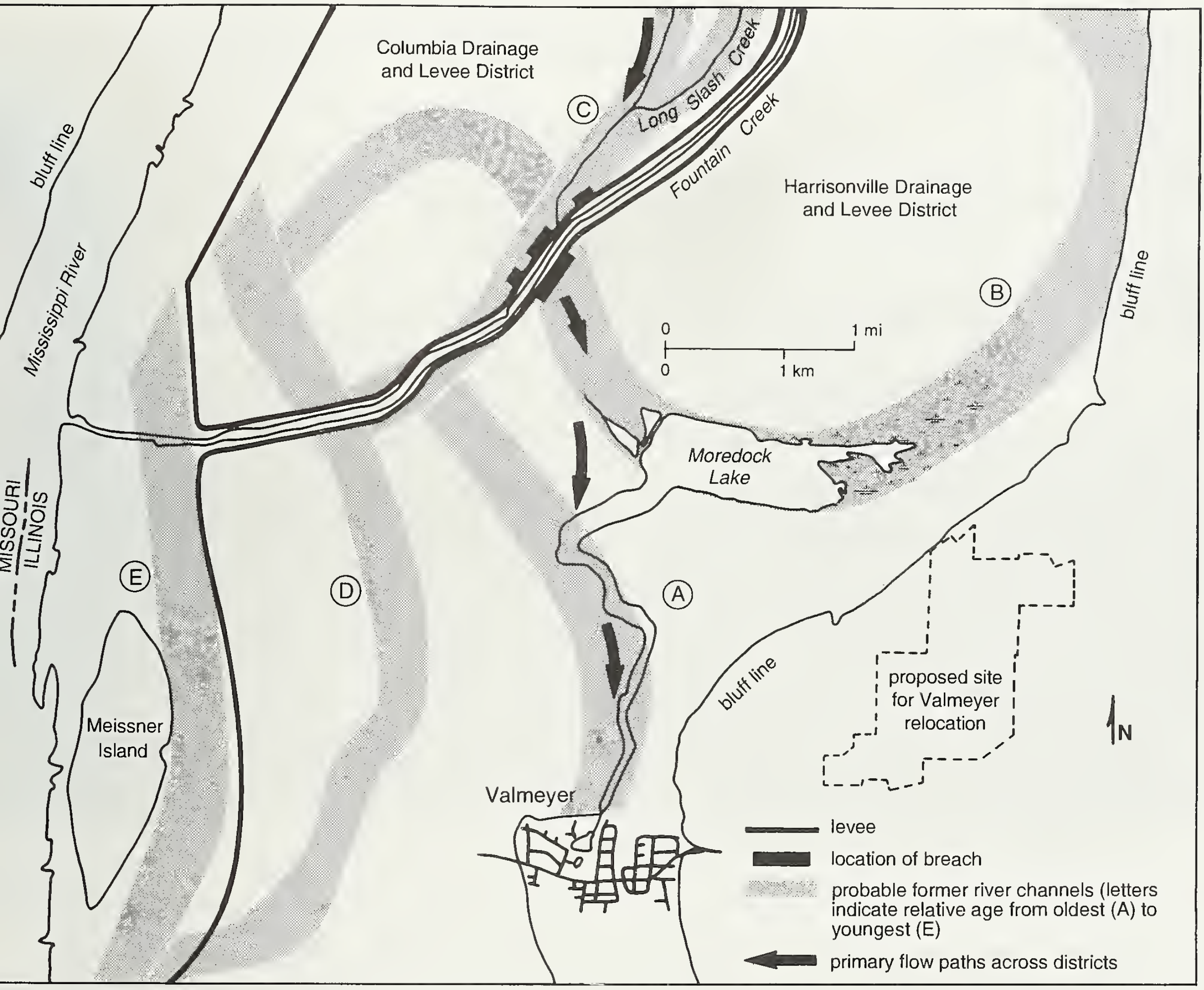


Figure 20 Floodplain and levees in the Valmeyer-Prairie du Rocher area were the setting for the events leading to the flood threat and defense of Prairie du Rocher (from Chrzastowski et al. 1994).



igure 21 Floodplain north of Valmeyer. Four breaches occurred where the levees crossed former river channels. Saturation the sands in these channels may have reduced support for the levee on the north side of Fountain Creek. Once the levee agged, it was quickly overtopped and breached in three locations. Water surging through the two southern breaks overtopped nd breached the levee on the south side of Fountain Creek and flooded the Harrisonville Drainage and Levee District. The ooding damaged Valmeyer so severely that the town relocated to the top of nearby bluffs (from Chrzastowski et al. 1994).

into and fill the Harrisonville-Fort Chartes and Ivy Landing-Stringtown District levee to that higher, upstream level.

On August 2, the U.S. Army Corps of Engineers decided to break the Stringtown levee near Fort Chartres. This may seem like a strange thing to do, but this action probably saved the town of Prairie du Rocher. By breaking the Stringtown levee in several places at the south end, the Corps provided a drain that prevented the water from overtopping the levees paralleling Prairie du Rocher Creek—thus saving the town of Prairie du Rocher.

The flood caused extensive damage, of which only a little evidence remains. The levees have been completely repaired, and the areas that failed must be pointed out by local residents. Large scour holes that formed inside the levee at the break have been filled with the sediment that covered neighboring fields. Damaged homes have been removed or repaired. Wells contaminated by flood water were disinfected with bleach and flushed until the water tested safe. The Village of Valmeyer, largely destroyed by the flood, elected to relocate on top of the bluffs, away from future flood hazards.

STOP 3 Terry Spring (NE SE NE NW, Sec. 31, T1S, R10W, 3rd P.M., Monroe County, Columbia 7.5-Minute Quadrangle)

Site Geology

Terry Spring is a conduit spring like many others in this region. The water flows along a bedding plane and discharges from a cave opening several feet up from the base of a 100 foot bluff of St. Louis Limestone located above the Mississippi River Valley floodplain (fig. 22). The cave formed along a bedding plane within the limestone as a result of rainwater and snowmelt seeping through thin soils and entering and dissolving limestone on the sinkhole-strewn plateau above.

The water exiting Terry Spring has flowed through a karst aquifer that is recharged through sinkholes on the plateau above. Most water in a karst aquifer moves through relatively large fissures and conduits ranging in size from less than ¼ inch wide to more than 16 feet in diameter (Quinlan 1988). The chemical composition of the water flowing from the spring is dominated by the calcium and carbonate ions from the dissolved limestone. Also, because of the activities of people in the recharge area above, the water is typically contaminated with coliform and fecal coliform bacteria derived from private septic systems and, to a lesser extent, from animal wastes (Panno et al. 1996). It is important to realize that this water should not be used for drinking or cooking.

The spring water flowing down the bluff face contains dissolved manganese and iron. When the water is exposed to atmospheric oxygen, oxides of manganese and iron precipitate on the bluff face as ferric hydroxide and manganese oxide. These are the same compounds that stain porcelain fixtures in households and that can clog a well with well "scale."

STOP 4 Valmeyer Quarry (SW NE SW, Sec. 3, T3S, R11W, 3rd P.M., Monroe County, Valmeyer 7.5-Minute Quadrangle)

This quarry, last operated by the Columbia Stone Company, was designated as Columbia Quarry, Plant No. 3. Ordovician rocks are exposed in the bluff face at the quarry (fig. 23).

The stratigraphic section begins at the base of the quarry (see fig. 24) with less than 3 feet of Ordovician Spechts Ferry Formation of the Decorah Subgroup, made up of dark gray coarse grained limestone and green shale. This is overlain by 14 feet of gray, silty, fine grained limestone of the Kings Lake Formation of the Decorah Subgroup. Finally, this formation is overlain by up to 100 feet of a light gray to pinkish gray, coarse grained limestone named the Dunleith Formation of the Kimmswick Subgroup. The quarry operations occurred in the non-cherty upper part, mainly by underground mining. Overlying the Dunleith is the Cape Formation, which consists of 1.5 feet of coarse grained, very fossiliferous limestone. This formation is a good place to collect fossils. This limestone is very light gray to pinkish gray to white, coarsely crystalline, and quite fossiliferous in some zones. The distinctive fossil *Receptaculites oweni*, the "sunflower coral," occurs in the upper part of the limestone.

Above this unit (covered largely by slumped materials and vegetation) is about 12 feet of the greenish gray shale assigned to the Scales Shale Formation of the Maquoketa Group. This formation completes the section of Ordovician rocks exposed in the bluff face at the mine.

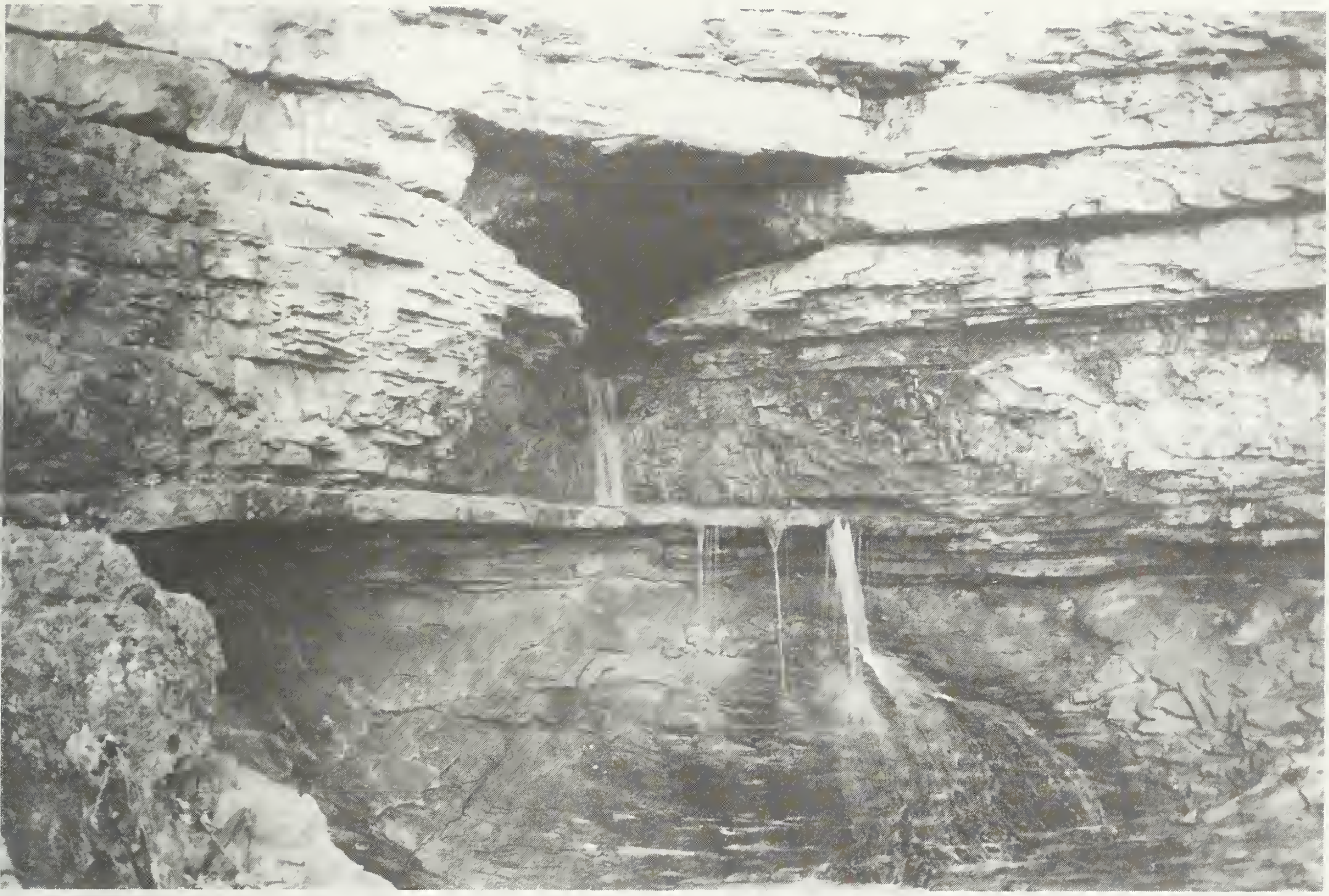


Figure 22 Terry Spring, a small cave spring in St. Louis Limestone at stop 3. This and similar springs drain rainwater and snowmelt from the sinkhole plain similarly to a stream valley. These springs typically form along bedding planes within limestones (photo by Sam V. Panno).

The rocks exposed in the bluff face are not horizontal; at the south end of the quarry, they dip steeply to the south-southwest. The underground quarry is located along the crest of the Valmeyer Anticline, an upfold in the rocks whose crest or axis trends northwest to southeast (figs. 8 and 25). From Valmeyer, the axis of the structure plunges gently southeastward to the vicinity of Mayestown, a distance of about 10 miles, where it flattens out and disappears. This structure has been found in exposures on the Missouri side of the river. The Valmeyer Anticline, like the Waterloo-Dupo Anticline, is asymmetrical; it has a steeper southwest flank, where the strata dip as much as 30°. The northeast flank, on the other hand, has a gentle dip of 1° to 2°. The fold is readily apparent when viewed from Bluff Road near the northwest corner of section 3 (see route map).

Evidence studied by geologists suggests that these rocks were folded in Late Mississippian time with some minor folding occurring later during Pennsylvanian time. Some geologists also have found indications of possible faulting along the steep southwest flank of the anticline (Rodney Norby, ISGS, personal communication).

The Valmeyer Quarry began as an above-ground open-face quarry in the early 1900s, when the Missouri Pacific Railroad used the stone for roadbed ballast, but conventional room-and-pillar underground mining has been carried on for many years in the upper part of the Dunleith Formation. This type of mining produced the many cavernous openings part way up the bluff face.

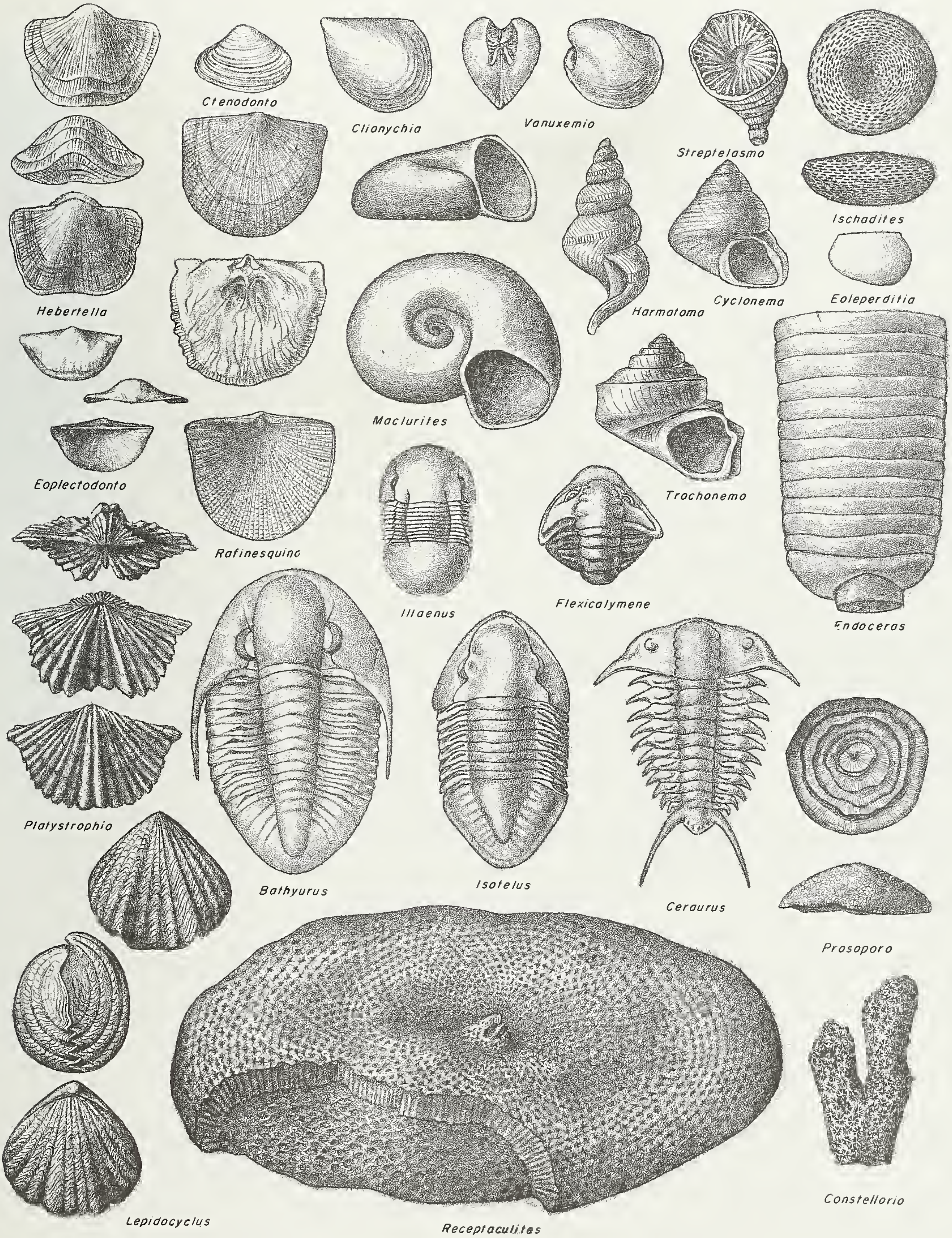
Figure 23 Exposure of Ordovician strata in the bluff face at the Valmeyer quarry at stop 4 (photo by Wayne T. Frankie).

The rooms are 52 feet wide and honeycomb the adjacent hills. Initially, the rooms were mined to a height of 22 feet, leaving about 12 feet of the topmost part of the Dunleith for roof support because the overlying Maquoketa Shale Group is not competent enough for a strong roof. Later mining of the rocks in the floor deepened some of the rooms another 18 feet so that in part of the underground works, the ceiling is 38 to 40 feet high. Chert in the lower part of the Dunleith makes that part of the limestone undesirable and thus limits the depth to which the stone was mined here. Some of the quarried stone was trucked underground for 1 to 1.25 miles from the mine face to the processing plant. The quarry closed in 1992 and since has been purchased by the village of Valmeyer.

The Dunleith Limestone, which is quite pure, was used in the chemical industry, for agricultural feeding material and lime, and for chips in asphalt roofing shingles. The fine dust from the air-cleaning bagging operation was used for top dressing on blacktop aggregates and as a noncombustible rock dust to apply to walls and ceilings in underground coal mines to help prevent coal dust explosions.

In 1948 the Knaust Mushroom Company leased some of the caverns and in 1951 began raising mushrooms here. This firm had a number of mushroom-raising operations and at one time was the largest mushroom grower in the world. Temperature and humidity were relatively easy to maintain in the caverns for optimum growth of the mushrooms, and 110 acres of caverns were used for this purpose. Castle and Cooke, Incorporated, purchased the operation in late 1974 and grew mushrooms here until November 1979. The operation was phased out by September 30, 1981. During one growing period, about 2 million pounds of mushrooms were grown at this plant.

ORDOVICIAN FOSSILS



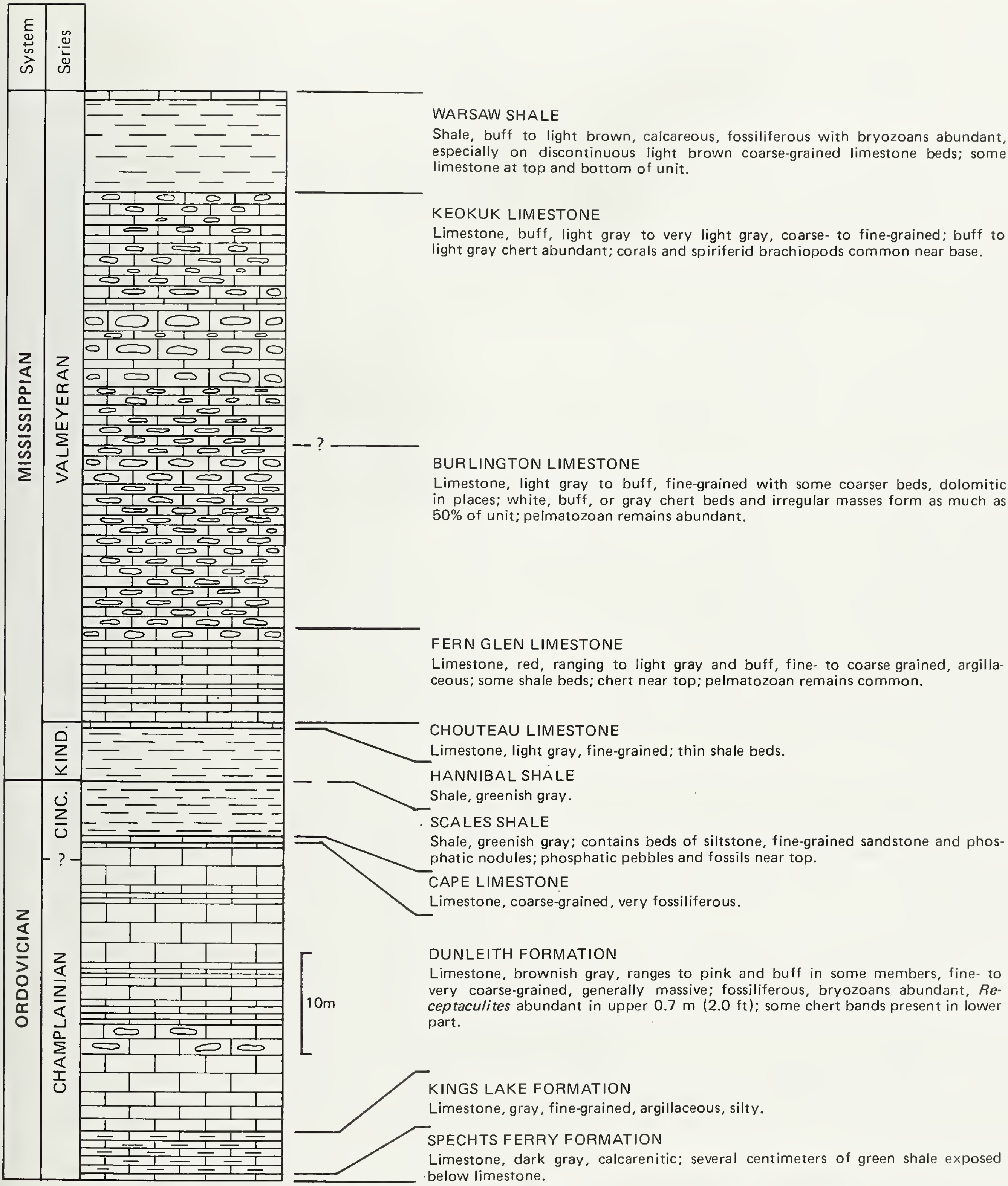


Figure 24 Generalized stratigraphic column of rocks exposed on the Valmeyer Anticline (from Norby 1987).

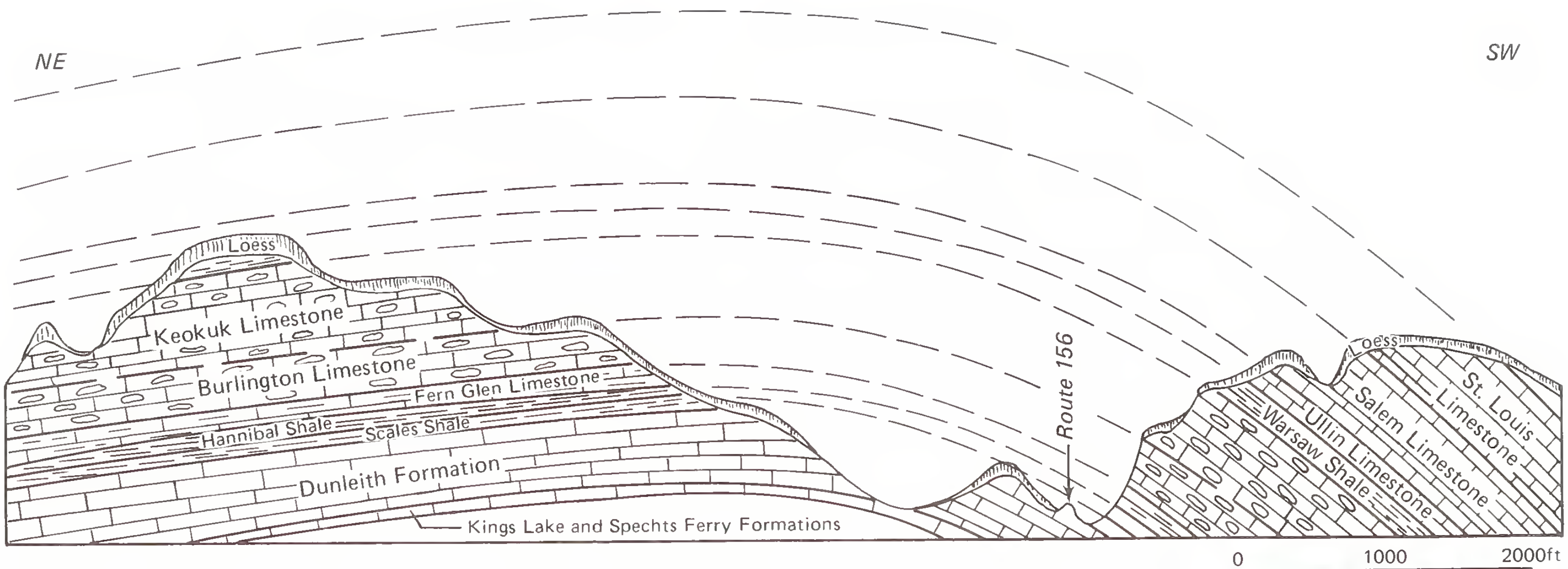


Figure 25 Schematic cross section of Valmeyer Anticline looking southeast from a vantage point approximately 1 mile north of Valmeyer near the northwest corner of section 3. The vertical scale is exaggerated five times; this exaggeration increases the apparent dip angles shown on the diagram. The southwest limb is further distorted because this part of the cross section actually runs more north–south (from Norby 1987).

Other parts of the mined-out areas have at one time been used for warehousing, and the mine was designated the largest Civil Defense Shelter in Illinois. The varied uses of this property are an excellent example of multiple land use. Easy access to the main line of the Union Pacific Railroad in conjunction with the short distance to the St. Louis metropolitan area may encourage renewed interest in this property for storage and manufacturing purposes.

After leaving this stop, our route will follow Illinois Route 156 (which goes up through Dennis Hollow). As you drive up Dennis Hollow, note the rocks exposed along the highway, especially at the base of the bluff, where rocks with some of the steepest dips associated with the Valmeyer Anticline can be seen. These are primarily the Mississippian rocks which unconformably overlie the Ordovician rocks on the anticline (figs. 24 and 25). This exposure near the base of the bluff is considered one of the most completely exposed geologic sections in the state. The following description was provided by ISGS geologist L.E. Workman in 1949:

Mississippian System	
Warsaw Formation	
5. Shale, calcareous, yellowish to grey; limestone lenses; fossiliferous	13 ft
Keokuk Formation	
4. Limestone, shaly, cherty, glauconitic, light greenish gray	16 ft
3. Limestone, cherty, gray, crinoidal	3 ft
2. Shale	2 ft
Burlington Formation	
1. Limestone, cherty, light gray, coarse	3 ft
Total thickness	37 ft

STOP 5 Camp Vandeventer: Lunch (SW SE SE, Sec. 21, T2S, R10W, 3rd P.M., Monroe County, Waterloo 7.5-Minute Quadrangle)

Site Geology

The camp, which lies near the southern end of the Columbia Syncline, contains numerous sinkholes, caves, springs, and steep limestone bluffs formed in the St. Louis Limestone. The camp facilities overlook Fountain Creek, which dissects the plateau. Springs that drain runoff from rainfall and snowmelt on the plateau are numerous along the base of the bluffs that bound Fountain Creek.

Stop 5a: Karst Window (see route map)

The large, steep sided sinkhole across the road from the Apache Camp Site along the entrance road of Camp Vandeventer is a feature called a “karst window” (fig. 26). A karst window is a special type of sinkhole that results from the collapse of the roof of a cave system. The water flowing through the opening in the bottom of this karst window continues as an underground stream that discharges at the base of the bluff just below the Fountain Creek Lodge at Camp Vandeventer. Note the outcrop of bedded limestone within the sinkhole. During periods of high water, following rainfall and snowmelt, the water flowing through the bottom of the sinkhole rises and overflows into a small surface stream that flows under the road and cascades down a ravine toward Fountain Creek.

Stop 5b: Boy Scout Camp Spring (see route map)

The Boy Scout Camp Spring at Camp Vandeventer discharges from a small cave at the base of a 40- to 45-foot-high bluff in the upper St. Louis Limestone (fig. 27). The spring flows directly into Fountain Creek through an entrenched channel. A smaller cave spring is located just to the west of this spring along the same bluff. Discharge from this spring is almost negligible during the drier summer months.

Figure 26 A "karst window" at the base of a sinkhole at Camp Vandeventer at stop 5a. This sinkhole formed when part of an underground cave collapsed, thus exposing the cave stream (photo by Sam V. Panno).

However, during periods of storm runoff, it acts as an overflow for the Boy Scout Camp Spring. Discharge from both springs is a high-energy, turbulent flow following large, springtime rainfalls.

As with most springs in the sinkhole plain, the water that discharges from the Boy Scout Camp Spring is contaminated with fecal coliform bacteria from private septic systems. In fact, this is one of the most severely contaminated springs in Monroe County, and contact with the water should be avoided.

Outcrops of St. Louis Limestone at Camp Vandeventer The exposure of limestone shows karst features. The layered nature of this limestone allows surface-derived water to enter along fissures and flow along bedding planes (fig. 28). Solution of the limestone along one of these layers has slowly enlarged the water's pathways, forming small conduits. With time, the pathways will enlarge downward to form small caves.

Figure 27 Spring at Camp Vandeventer at stop 5b. This typical cave spring is similar to Terry Spring at stop 3 (photo by Sam V. Panno).

Groundwater Protection in the Sinkhole Plain

There are increasing local efforts to protect groundwater in the sinkhole plain. The Mississippi Karst Resource Planning Committee is a group of local citizens, health and government officials, geologists, and soil scientists working together to educate the public about karst-related issues.

Karst regions, such as the sinkhole plain, pose special environmental concerns. Because surface water and groundwater are directly linked in karst regions, groundwater quality is at risk. In the sinkhole plain, anything that is dumped on the ground, such as agricultural chemicals, sewage, trash, or animal waste, can quickly end up in the groundwater.

The Karst Committee has received a grant from the Illinois Environmental Protection Agency through Section 319 of the Clean Water Act. This grant enables the committee to educate the public about karst and related groundwater issues. The grant also funds a research project to test local groundwater

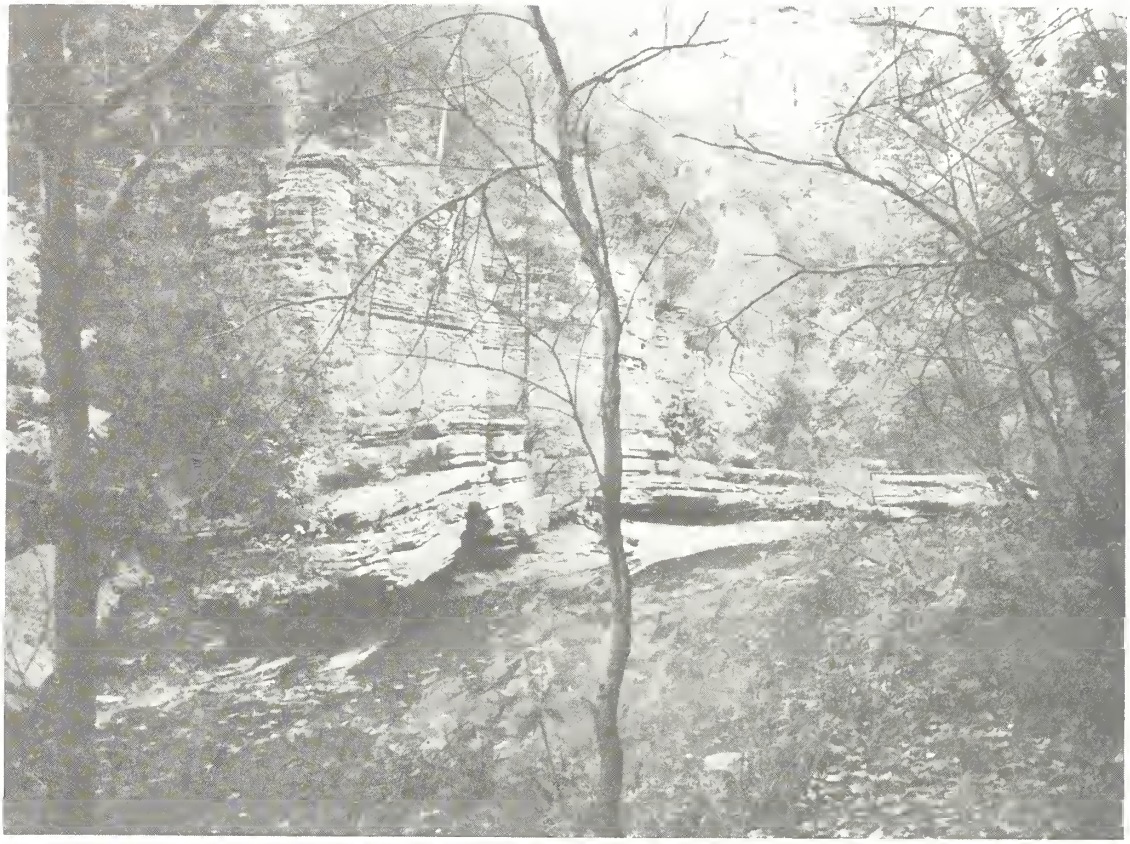


Figure 28 Bedding and solution features in St. Louis Limestone in a bluff along Fountain Creek at Camp Vandeventer at stop 5b (photo by Sam V. Panno).

for several contaminants and to trace the rate and direction of groundwater flow in the karst region with a dye tracing method.

Educational projects of the grant include brochures, a Best Management Practices Manual, a curriculum guide for local schools, newsletters, and a newspaper pull-out describing and explaining groundwater and karst issues. The committee also co-sponsors tours such as today's field trip, informational meetings, and a conference for residents of the karst region and other interested individuals.

More information about the Section 319 Grant and the committee are available from the Karst Educator's office. Kris Ahrens-Voelker, the karst educator, can be reached at (618) 939-3871.

STOP 6 Waterloo Quarry (NW & NE NE, Sec. 8, T3S, R9W, 3rd P.M., Monroe County, Paderborn 7.5-Minute Quadrangle)

Columbia Quarry Company's Waterloo Quarry (Plant No. 7)

The Waterloo Quarry, originally opened in 1971 by the Quality Stone Company, was purchased by Columbia Quarry Company in February 1996. The Quarry is now designated as Columbia Quarry Plant No. 7. The mining operation at this quarry produces approximately ½ million tons of limestone per year; based on the current rate of production and the amount of land currently owned, an estimated 100 to 150 years of resources remain. Total production to date from this quarry is 9 million tons. The stone produced from the Waterloo Quarry is primarily sold as road aggregate and is shipped by truck; however, the company also produces 15 different products ranging from lime dust to 400-pound rip rap.

This quarry exposes a section of middle Mississippian rocks (Valmeyeran Series) that includes more than 40 feet of Salem Limestone and about 150 feet of St. Louis Limestone (fig. 29). The Salem is known to be more than 100 feet thick, so only the upper one-third to one-half of the formation is exposed here. Most of the St. Louis appears to be present, but up to 50 feet of St. Louis may be missing—eroded from the top since the end of the Paleozoic Era.

The Salem, presently exposed in the lowest level of the northwest corner of the quarry, contains two thin sedimentary cycles and the top of a third cycle. Each cycle represents a shoaling environment of deposition within the zone of wave action that became progressively shallower with time. The lower part of the cycle consists of a limestone that is moderately coarse grained (grainstone), closely compacted with well sorted grains (all of about the same size) and very little or no argillaceous sediments ("clean"). Sediments from similar environments are often oolitic, but oolites are uncommon in these particular cycles. As the sea became shallower (regresssed), a lagoonal or tidal flat environment dominated by finer carbonate and argillaceous sediments became prevalent. Laminated beds of fossilized algae, oncolites (spheres of fossilized algae), and fenestrae structures (possibly representing "fossilized" gas bubbles that formed small openings within the tidal flat sediments) are common in the upper part of the cycle. The cycles may be the result of broad, uniform changes in sea level, caused either by glaciation elsewhere in the world that tied up ocean water as ice, or by actual vertical movements of the sea floor and continents, called "eustasy."

The rocks of the St. Louis Limestone were also deposited in very shallow water environments that included some of the same ones as the Salem, although shallow subtidal, lagoonal, tidal flat, and evaporitic conditions seem to have prevailed. These environments are indicated by the very fine grained ("sublithographic") lime mudstones, limestone breccias, dolomites, and cherty limestones characteristic of the St. Louis. Grainstones representing possible shoaling conditions are also present, particularly at this quarry, but their grain size is generally finer than the ones in the Salem. The sedimentary cycles that are a common feature of the Salem are not present in the St. Louis.

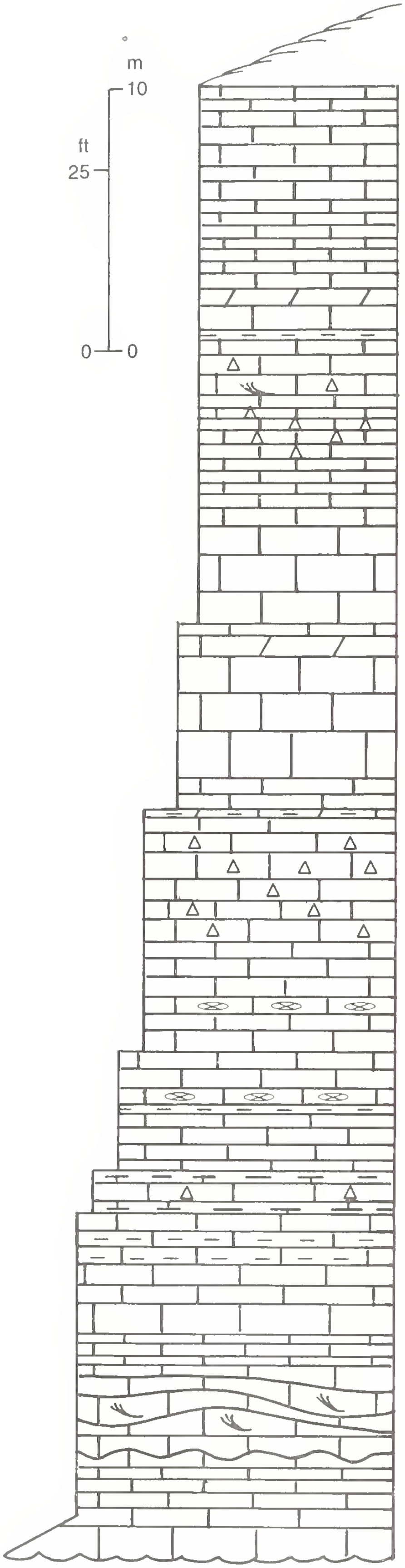
Marine fossils are common throughout the St. Louis and include corals (both colonial and solitary), bryozoans, brachiopods, and echinoderms. The fossils are remarkably abundant in some beds near the top of the St. Louis and are especially well preserved along bedding planes where shale partings interrupt the limestone. The shale, originally deposited as mud, covered and protected a number of delicate fossil forms such as bryozoans and crinoids. These shale zones are excellent places to collect fossils.

The upper portion of the quarry provides an excellent exposure of solution-enlarged cavities within the St. Louis Limestone (fig. 30). Soil and rock debris now partially fill these cavities. These cavities offer a cross section view of the inside of sinkholes like those that dot the upland surface beyond the top of the quarry walls.

STOP 7 Illinois Caverns (SW NW NE, Sec. 31, T3S, R9W, 3rd P.M., Monroe County, Renault 7.5-Minute Quadrangle)

Site History

Three of the largest known caves in Illinois are in Monroe County. Illinois Caverns, the second largest cave in the state and the only cave in Illinois ever to have been commercially developed, lies near the geographic center of the county. The cave was a tour stop of the 1904 St. Louis Exposition and was



ST. LOUIS LIMESTONE

Limestone (mixed grainstone, packstone, and lime mudstone), light brownish gray, with greenish gray color in lower part, very fine grained to coarse grained, bioclastic, thin bedded (10–50 cm); fossils present throughout but more common in upper part including bryozoans, brachiopods, echinoderms (mainly stems), and colonial corals.

Dolomite, finely crystalline, porous, light olive gray, weathers to a distinct medium gray 65 cm thick band. This is underlain by an 80 cm bed of light brownish gray fine grained limestone. These two beds make a distinct dark and light band that is visible around the quarry as marker beds.

Limestone (grainstone to packstone with some wackestone and lime mudstone beds), light brownish gray, very fine to coarse grained, bioclastic, stylolitic, minor amounts of chert in the middle and near top, thin to medium bedded (5–80 cm); faint cross-bedding in upper part; fossils noted include bryozoans, corals and brachiopods. At top of unit is an 5 cm, greenish gray, laminated, siliciclastic mudstone bed with an 18 cm lime mudstone of possible algal origin.

Limestone (grainstone dominates with some packstone and occasional beds of wackestone, lime mudstone and dolomite), light brownish gray to light olive gray, medium grained but ranges from very fine to coarse, dolomitic in part, bioclastic, pelletoidal, oolitic in lower part, glauconitic, pyritic, stylolitic, generally medium to thick bedded, some thinner beds at base (15–200 cm); fossils include brachiopods, bryozoans and calcareous foraminifers.

Limestone (lime mudstone, packstone and grainstone), light to medium brownish gray, generally very fine grained but ranges from medium to sublithographic, bioclastic, pelletoidal, generally thin bedded (10–50 cm); chert abundant in upper part and includes very thin elongate stringers, scattered nodules and mottled white and brown oval-shaped chert; two horizons of geodes in middle part; five greenish gray to dark gray shaley beds (2–15 cm thick) in lower part including one at the base of the St. Louis; algal laminated beds, small algal oncolites, and fenestrae structures (bird's-eye) in lower part.

SALEM LIMESTONE

Limestone (cycles of coarser grained grainstone alternating with finer, more argillaceous lime mudstone), light brownish gray to grayish brown, bioclastic, oolitic?, thin to medium bedded (10–80 cm), irregular chert in lower part, some beds laminated, some cross-bedded; bottom of second cycle lies on undulating surface and includes rip-up clasts from the top of cycle below.

Figure 29 Geologic section of the Salem and St. Louis Limestones (middle Mississippian Valmeyeran Series) at Columbia Stone Company's Waterloo plant.

Figure 30 Exposure of St. Louis Limestone with karst solution-enlarged cavities in the high wall of the Waterloo Quarry at stop 6 (photo by Wayne T. Frankie).

visited by then President Theodore Roosevelt. Attempts in 1901 and 1947 to make the cave a commercial tourist attraction quickly failed. The cave was sold to the state of Illinois in 1985 and is now a State Natural Area, open to self-guided tours. Illinois Caverns was initially mapped by Bretz and Harris (1961). The cave has approximately 6 miles of mapped passages, many of which contain stalactites, stalagmites, and flowstone (Department of Natural Resources 1996).

Site Geology

Illinois Caverns, which is also known as Mammoth Cave of Illinois (fig. 31), was formed in rocks of the same age and type as at Mammoth Cave in Kentucky. The cave may be entered at the bottom of a sinkhole through a relatively large, moss-covered, solutionally enlarged fissure that reveals bedding planes of the St. Louis Limestone (fig. 32). Even though the entrance of the cave is formed along an enlarged fracture, passages within Illinois Caverns do not follow fractures. The cave is a relatively large trunk cave that formed as infiltrating surface and soil water dissolved and enlarged a channel along a bedding plane in the St. Louis Limestone (Panno et al. 1996). A stream flows down the center of the cave, discharges from Dye Spring (P. Wightman, unpublished data, 1996), and drains into Horse Creek to the east (fig. 31). The terrain above Illinois Caverns is dominated by karst features, and the land is used primarily for row crops.

In some parts of the cave, the original conduit (protocave) or channel between bedding planes is preserved in the ceiling (fig. 33). The channel appears to be the upper half of a tubular conduit about 4 to 6 inches in diameter that follows the trend of the cave.

Two main processes are occurring in the cave: precipitation of calcite and dissolution of limestone. Stalactites and stalagmites, two of the most attractive types of features in caves (fig. 34), are common in Illinois Caverns. They are formed when calcite-saturated water passes through soil and enters the cave ceiling; because of a change in pressure, the water dripping from the ceiling loses carbon

Figure 31 Map of Illinois Caverns superimposed on a 7.5-minute USGS quadrangle map (modified from Franz 1983).

Figure 32 The solutionally enlarged fissure at the bottom of a sinkhole leads to the ancient, dark labyrinth of Illinois Caverns. Shown are geologists Wayne Frankie and Russ Jacobson (photo by Sam V. Panno).

dioxide. The loss of this dissolved gas makes the water less acidic and less capable of keeping calcite in solution; as a result, a micro-layer of calcite precipitates and forms the ornate cave formations. Areas where chimneys are forming, that is, those vertical passages that look like elevator shafts going up through the cave roof almost to the surface, are areas of dissolution. Here the acidic soil water does not encounter neutralizing limestone prior to entering the cave ceiling. As a result, it gradually dissolves shafts that may be as high as 70 feet above the cave floor. The stream that flows at the bottom of the cave is the progeny of the initial sinuous conduit in the ceiling. The stream is slowly dissolving the floor of the cave and, in doing so, is lowering the water table in the area.

Living Labyrinths

by Michael R. Jeffords

Illinois has four major cave areas: Shawnee Hills (Hardin, Gallatin, Jackson, Johnson, Pope, Saline, Union, and Williamson counties), the sinkhole plain (St. Clair, Monroe, and Randolf Counties), Lincoln Hills (Adams, Calhoun, Greene, Jersey, and Pike counties), and the Driftless Area of northwestern Illinois (Jo Daviess and Carroll counties).

Geology in action Observing the often spectacular stalactites, stalagmites, flowstone, pillars, draperies, and pearls cave formations (collectively called speleothems) make cave exploration (spelunking) a matchless experience.

Sandstone caves are found on cliff faces where weathering has widened joints and cracks and water and wind have formed long, shallow cavities. Such caves or overhangs do not have true underground tunnels or penetrate very far into the cliff; but many were used for shelter by Native Americans and are prized as archaeological sites. Others, predominantly those found near water, are frequently

Figure 33 Geologist Pius Weibel examining the ancient original channel of Illinois Caverns. This small channel in the ceiling was one of the original conduits that—probably over hundreds of thousands of years—slowly developed into Illinois Caverns by dissolving its way downward (photo by Sam V. Panno).

used by hibernating snakes. Each spring the dry sand floors of the overhangs become a dendritic maze of snake trails.

The cave environment Two features make the cave environment unique: (1) Life-giving sunlight does not reach the cave interior, and (2) The surrounding layers of rock insulate the cave from surface weather and make the cave climate remarkably stable. Caves are cool and usually have high humidity and little evaporation. Caves actually "breathe" as air currents change direction in response

Figure 34 Stalactites and stalagmites are common in Illinois Caverns. These features form when water, enriched with calcium carbonate, seeps into the cave through fractures in the roof. Pressure changes within the cave result in the precipitation of calcite and aragonite over tens to hundreds of thousands of years (photo by Sam V. Panno).

to changes in surface barometic pressure. Within the cave, four zones can be distinguished on the basis of the amount of light and variations in temperature and humidity.

1. The **entrance** is a moist, shaded bluff habitat, where many animals, such as box turtles, snakes, raccoons, owls, and trapdoor spiders, are likely to take refuge.

2. The **twilight zone** extends into the cave as far as unaided human vision is possible and is certainly the most hospitable portion. Temperatures are usually cool and humidity is high, but both fluctuate much as they do just outside the cave. A few ferns or other green plants may live here, and the largest number of animals to be found in any cave lives here, including birds, snakes, frogs, and many kinds of surface invertebrates (animals without backbones). Eastern phoebe nests are frequently found plastered to the walls just inside the entrance.

3. The **middle zone** lies just beyond, and here begins the infamous Stygian blackness. Temperature and humidity are relatively stable,

although they vary somewhat. Inhabitants include bats, cave crickets, millipedes, and several surface-type crustaceans.

4. Deep in the cave is the **dark zone** of a nearly constant temperature of 55°F (in Illinois), total darkness, and nearly 100% humidity. The blind and colorless of the animal world—isopods, amphipods, pseudo-scorpions, and springtails—can usually live here and nowhere else.

Cave fauna Caves are of interest to biologists for many reasons, including the study of the special adaptations of animals to life in the total darkness; but their greatest appeal is perhaps the ease with which the ecological interactions can be deciphered. Unlike an above-ground terrestrial or aquatic ecosystem, where the diagram of the food web may resemble the circuit board of a supercomputer, the food relationships in a cave can usually be described in a relatively simple diagram. This simplicity is caused by the absence of green plants, which are the primary producers of food in an ecosystem. Therefore, all energy in the form of plant or animal material must enter the cave from the outside world: by falling in, being washed in by periodic flooding, or walking and flying in. Energy in caves is at a premium, and most animals that live there are opportunists who cannot afford to be choosy about what they eat.

Three categories of organisms inhabit caves:

1. **Troglobites** are creatures that spend their entire lives within caves and are unable to survive in the surface world; they are often colorless and blind. All Illinois troglobites are invertebrates.

2. **Troglophiles** are organisms that can spend their entire lives within a cave but may live in suitable surface habitats; examples include the spring cavefish, a few species of crayfish, and the cave salamander.

3. **Trogloxenes** are species that spend only part of their lives in caves and must enter the surface world to complete their life cycles; these include the most notable animals associated with caves, bats.

Scientific interest in caves began as early as the 17th century in Europe with studies of cave hydrology. In the United States, general studies and descriptions of cave-inhabiting animals began in the mid- to late 19th century. In Illinois, cave studies span more than a century, from the early writings of Stephen A. Forbes on blind cavefishes in 1881–1882 to a recent technical report by three Natural History Survey scientists. This study, headed by Don Webb of the Center for Biodiversity, looked at cave animals and groundwater quality. Ninety-eight caves, mines, pits, and springs in 13 counties were examined throughout the karst regions of Illinois. This and previous studies on groundwater detected heavy metals and pesticides in cave invertebrates; other pollutants such as nitrates were found in the water.

Over the 2 years of the study, nearly 6,000 cave invertebrates were examined and sorted into 4 phyla, 11 classes, at least 32 orders, and more than 215 species. Compared to the more than 50,000 species of plants and animals of the surface world, Illinois cave animals are certainly sparse, but interesting nonetheless. At least eight species are endemic (occur naturally only in Illinois); only four of these endemic species occur outside of caves in Illinois.

Cave conservation Historically, caves in Illinois have been abused. Many are visited only by the occasional Sunday afternoon caver, usually poorly equipped with a flashlight, a ball of twine, and, unfortunately, often a can of spray paint. More than 60% of the caves that have been inventoried in Illinois show evidence of human disturbance, including vandalism or use as trash dumps. Only a few caves have been protected in Illinois. In response to this neglect, the legislature passed the Cave Protection Act in 1985 to help preserve the natural and cultural resources of Illinois caves.

As a result of efforts by the Illinois Department of Conservation, several caves are included in the Illinois Natural Areas Inventory (a listing of sites in the state that have significant natural features). Others are designated as Illinois Natural Heritage Landmarks. One cave, with at least 12 miles of passageways, was purchased and dedicated as an Illinois Nature Preserve to protect a population of hibernating Indiana bats, a federally endangered species. Illinois Caverns (originally called Mammoth Cave of Illinois and the only cave to be operated commercially in Illinois around the turn of the century and again following World War II) was also purchased and declared an Illinois Natural Area. Currently, approximately 6 miles of passages are open to the public for exploration, but a permit is required to enter (this regulation helps to protect the cave environment). Explorers are required to carry three dependable sources of light and to wear protective clothing. In addition, they are warned to plan on getting their feet wet!

The caves of Illinois have intrinsic, aesthetic, cultural, recreational, and scientific value. Gene Gardner, former Illinois Natural History Survey scientist, writes, "Caves are a viable link in the great environmental chain that binds our planet together. [In addition] caves, like pages in a history book, provide information on past climate, paleontology, and archaeology. Anyone who meets the challenge of exploring dark passageways rarely or never seen will have a memorable and deeply moving experience."

Such habitats speak to the Tom Sawyer in each of us. They are an irreplaceable natural resource that must be protected for future generations.

Bats and Caves

by Joyce E. Hofmann, Mammalogist, Illinois Natural History Survey, Center for Biodiversity

Most of the twelve species of bats that occur in Illinois live in caves or abandoned mines for at least part of the year. During the summer, some Illinois bats use caves or abandoned mines as daytime roosts, but most roost at a variety of other sites, including trees, buildings, bridges, and culverts. Caves play a much more essential role for bats during the winter; nine species have been found hibernating in Illinois caves and mines. During the autumn, the bats accumulate large amounts of body fat that represents their energy reserves for the winter and migrate from their summer ranges to a hibernation site. Thousands or hundreds of thousands of bats may gather in the same cave every winter; such a cave is called a hibernaculum (plural = hibernacula). Caves are good places for hibernation because temperatures underground remain fairly constant and they can provide protection from predators. Not all caves are suitable as hibernation sites. Each species has specific requirements for temperature, humidity, and air flow. For example, the little brown bat (*Myotis lucifugus*) requires stable temperatures above freezing and high humidity, but the big brown bat (*Eptesicus fuscus*) can tolerate temperatures below freezing in sites with low humidity. Microclimates within a cave vary, so different species can hibernate in the same cave. Members of some species hibernate singly or in small groups on cave ceilings or walls, whereas other species form dense clusters that contain up to 300 individuals per square foot. During hibernation, a bat's metabolic rate is drastically lowered and its body temperature drops to near the ambient temperature. Bats hibernate for up to 7 months, although they wake occasionally to drink. Caves in the sinkhole plain of Monroe and St. Clair counties are used as hibernation sites by the little brown bat, big brown bat, eastern pipistrelle (*Pipistrellus subflavus*) (fig. 35), Indiana bat (*M. sodalis*) (fig. 36), and probably by the northern long-eared bat (*M. septentrionalis*).

Because of their habit of congregating in caves, some bats are subject to natural disasters such as ceiling collapse or flooding. More seriously, they are also vulnerable to human actions. Quarrying, sealing entrances, alteration of microclimates, and commercialization can make caves no longer available to or suitable for bats. Large numbers of cave-dwelling bats have been victims of vandalism. Disturbance of bats during hibernation can cause them to arouse and dangerously deplete

Figure 35 Eastern pipistrelle *(Pipistrellus subflavus)* (photo courtesy of the Illinois Natural History Survey).

Figure 36 Federally endangered Indiana bat *(M. sodalis)* (photo courtesy of the Illinois Natural History Survey).

their energy reserves. Disturbance of maternity colonies (females and their offspring) during the summer may result in the death of young pups that fall to the cave floor or cause the colony to abandon the cave. Serious cavers (spelunkers) are careful to avoid disturbing bats, and the National Speleological Society and its local grottoes (caving clubs) have played an important role in bat conservation. Metal gates have been installed in the entrances of many important bat caves, including Fogelpole Cave in Monroe County, to prevent unauthorized access by humans while allowing passage by bats.

Among the Illinois bats that depend on caves are the state's four endangered bat species. The Indiana bat, which is also federally endangered, hibernates in caves and mines. Maternity colonies roost in trees, but some adult males and nonreproductive females occupy caves during the summer as well. A large portion of this species congregates in caves and mines in southern Indiana, Kentucky, and Missouri for hibernation, but there are three important Indiana bat hibernacula in Illinois, including Fogelpole Cave. The federally endangered gray bat (*M. grisescens*) uses caves year-round, but occupies different caves during winter and summer. A maternity colony of gray bats occurs in southern Illinois, although its actual roost site is unknown. Most gray bats that spend the summer in southern Illinois are thought to hibernate in Kentucky. There are also a few records of migrating gray bats occupying caves in counties along the Mississippi River in western Illinois. The state-endangered southeastern bat (*M. austroriparius*) and Rafinesque's big-eared bat (*Plecotus rafinesquii*) occur only in southern Illinois, where they hibernate in caves and abandoned mines. Big-eared bats spend the summer in dilapidated buildings and other manmade structures. In other states maternity colonies of southastern bats occupy caves, but the only maternity roost that has been found in Illinois was a hollow tree.

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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

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.

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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.

PLEISTOCENE GLACIATIONS IN ILLINOIS

Origin of the Glaciers

During the past million years or so, an interval of time called the Pleistocene Epoch, most of the northern hemisphere above the 50th parallel has been repeatedly covered by glacial ice. The cooling of the earth's surface, a prerequisite for glaciation, began at least 2 million years ago. On the basis of evidence found in subpolar oceans of the world (temperature-dependent fossils and oxygen-isotope ratios), a recent proposal has been made to recognize the beginning of the Pleistocene at 1.6 million years ago. Ice sheets formed in sub-arctic regions many times and spread outward until they covered the northern parts of Europe and North America. In North America, early studies of the glacial deposits led to the model that four glaciations could explain the observed distribution of glacial deposits. The deposits of a glaciation were separated from each other by the evidence of intervals of time during which soils formed on the land surface. In order of occurrence from the oldest to the youngest, they were given the names Nebraskan, Kansan, Illinoian, and Wisconsinan Stages of the Pleistocene Epoch. Work in the last 30 years has shown that there were more than four glaciations but the actual number and correlations at this time are not known. Estimates that are gaining credibility suggest that there may have been about 14 glaciations in the last one million years. In Illinois, estimates range from 4 to 8 based on buried soils and glacial deposits. For practical purposes, the previous four glacial stage model is functional, but we now know that the older stages are complex and probably contain more than one glaciation. Until we know more, all of the older glacial deposits, including the Nebraskan and Kansan will be classified as pre-Illinoian. The limits and times of the ice movement in Illinois are illustrated in the following pages by several figures.

The North American ice sheets developed when the mean annual temperature was perhaps 4° to 7°C (7° to 13°F) cooler than it is now and winter snows did not completely melt during the summers. Because the time of cooler conditions lasted tens of thousands of years, thick masses of snow and ice accumulated to form glaciers. As the ice thickened, the great weight of the ice and snow caused them to flow outward at their margins, often for hundreds of miles. As the ice sheets expanded, the areas in which snow accumulated probably also increased in extent.

Tongues of ice, called lobes, flowed southward from the Canadian centers near Hudson Bay and converged in the central lowland between the Appalachian and Rocky Mountains. There the glaciers made their farthest advances to the south. The sketch below shows several centers of flow, the general directions of flow from the centers, and the southern extent of glaciation. Because Illinois lies entirely in the central lowland, it has been invaded by glaciers from every center.

Effects of Glaciation

Pleistocene glaciers and the waters melting from them changed the landscapes they covered. The glaciers scraped and smeared the landforms they overrode, leveling and filling many of the minor valleys and even some of the larger ones. Moving ice carried colossal amounts of rock and earth, for much of what the glaciers wore off the ground was kneaded into the moving ice and carried along, often for hundreds of miles.

The continual floods released by melting ice entrenched new drainageways, deepened old ones, and then partly refilled both with sediments as great quantities of rock and earth were carried beyond the glacier fronts. According to some estimates, the amount of water drawn from the sea and changed into ice during a glaciation was enough to lower the sea level from 300 to 400 feet below present level. Consequently, the melting of a continental ice sheet provided a tremendous volume of water that eroded and transported sediments.

In most of Illinois, then, glacial and meltwater deposits buried the old rock-ribbed, low, hill-and-valley terrain and created the flatter landforms of our prairies. The mantle of soil material and the buried deposits of gravel, sand, and clay left by the glaciers over about 90 percent of the state have been of incalculable value to Illinois residents.

Glacial Deposits

The deposits of earth and rock materials moved by a glacier and deposited in the area once covered by the glacier are collectively called **drift**. Drift that is ice-laid is called **till**. Water-laid drift is called **outwash.**

Till is deposited when a glacier melts and the rock material it carries is dropped. Because this sediment is not moved much by water, a till is unsorted, containing particles of different sizes and compositions. It is also stratified (unlayered). A till may contain materials ranging in size from microscopic clay particles to large boulders. Most tills in Illinois are pebbly clays with only a few boulders. For descriptive purposes, a mixture of clay, silt, sand and boulders is called **diamicton**. This is a term used to describe a deposit that could be interpreted as till or a mass wasting product.

Tills may be deposited as **end moraines**, the arc-shaped ridges that pile up along the glacier edges where the flowing ice is melting as fast as it moves forward. Till also may be deposited as **ground moraines**, or **till plains**, which are gently undulating sheets deposited when the ice front melts back, or retreats. Deposits of till identify areas once covered by glaciers. Northeastern Illinois has many alternating ridges and plains, which are the succession of end moraines and till plains deposited by the Wisconsinan glacier.

Sorted and stratified sediment deposited by water melting from the glacier is called **outwash**. Outwash is bedded, or layered, because the flow of water that deposited it varied in gradient, volume, velocity, and direction. As a meltwater stream washes the rock materials along, it sorts them by size—the fine sands, silts, and clays are carried farther downstream than the coarser gravels and cobbles. Typical Pleistocene outwash in Illinois is in multilayered beds of clays, silts, sands, and gravels that look much like modern stream deposits in some places. In general, outwash tends to be coarser and less weathered, and alluvium is most often finer than medium sand and contains variable amounts of weathered material.

Outwash deposits are found not only in the area covered by the ice field but sometimes far beyond it. Meltwater streams ran off the top of the glacier, in crevices in the ice, and under the ice. In some places, the cobble-gravel-sand filling of the bed of a stream that flowed in the ice is preserved as a sinuous ridge called an **esker**. Some eskers in Illinois are made up of sandy to silty deposits and contain mass wasted diamicton material. Cone-shaped mounds of coarse outwash, called **kames**, were formed where meltwater plunged through crevasses in the ice or into ponds on the glacier.

The finest outwash sediments, the clays and silts, formed bedded deposits in the ponds and lakes that filled glacier-dammed stream valleys, the sags of the till plains, and some low, moraine-diked till plains. Meltwater streams that entered a lake rapidly lost speed and also quickly dropped the sands and gravels they carried, forming deltas at the edge of the lake. Very fine sand and silts were commonly redistributed on the lake bottom by wind-generated currents, and the clays, which stayed in suspension longest, slowly settled out and accumulated with them.

Along the ice front, meltwater ran off in innumerable shifting and short-lived streams that laid down a broad, flat blanket of outwash that formed an **outwash plain**. Outwash was also carried away from the glacier in valleys cut by floods of meltwater. The Mississiippi, Illinois, and Ohio Rivers occupy valleys that were major channels for meltwaters and were greatly widened and deepened during times of the greatest meltwater floods. When the floods waned, these valleys were partly filled with outwash far beyond the ice margins. Such outwash deposits, largely sand and gravel, are known as **valley trains**. Valley train deposits may be both extensive and thick. For instance, the long valley train of the Mississippi Valley is locally as much as 200 feet thick.

Loess, Eolian Sand and Soils

One of the most widespread sediments resulting from glaciation was carried not by ice or water but by wind. **Loess** is the name given to windblown deposits dominated by silt. Most of the silt was derived from wind erosion of the valley trains. Wind action also sorted out **eolian sand** which commonly formed **sand dunes** on the valley trains or on the adjacent uplands. In places, sand dunes have migrated up to 10 miles away from the principle source of sand. Flat areas between dunes are generally underlain by eolian **sheet sand** that is commonly reworked by water action. On uplands along the major valley trains, loess and eolian sand are commonly interbedded. With increasing distance from the valleys, the eolian sand pinches out, often within one mile.

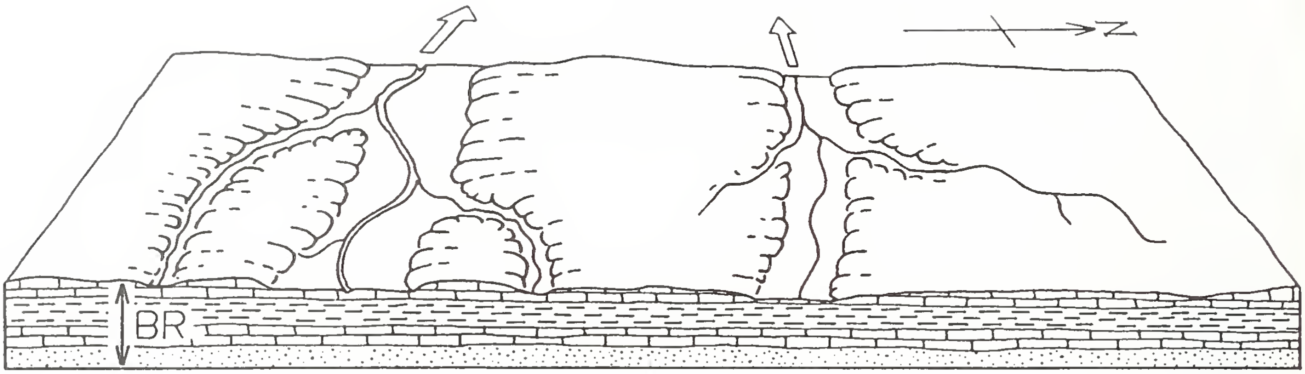
Eolian deposition occurred when certain climatic conditions were met, probably in a seasonal pattern. Deposition could have occurred in the fall, winter or spring season when low precipitation rates and low temperatures caused meltwater floods to abate, exposing the surfaces of the valley trains and permitting them to dry out. During Pleistocene time, as now, west winds prevailed, and the loess deposits are thickest on the east sides of the source valleys. The loess thins rapidly away from the valleys but extends over almost all the state.

Each Pleistocene glaciation was followed by an interglacial stage that began when the climate warmed enough to melt the glaciers and their snowfields. During these warmer intervals, when the climate was similar to that of today, drift and loess surfaces were exposed to weather and the activities of living things. Consequently, over most of the glaciated terrain, soils developed on the Pleistocene deposits and altered their composition, color, and texture. Such soils were generally destroyed by later glacial advances, but some were buried. Those that survive serve as “key beds,” or stratigraphic markers, and are evidence of the passage of a long interval of time.

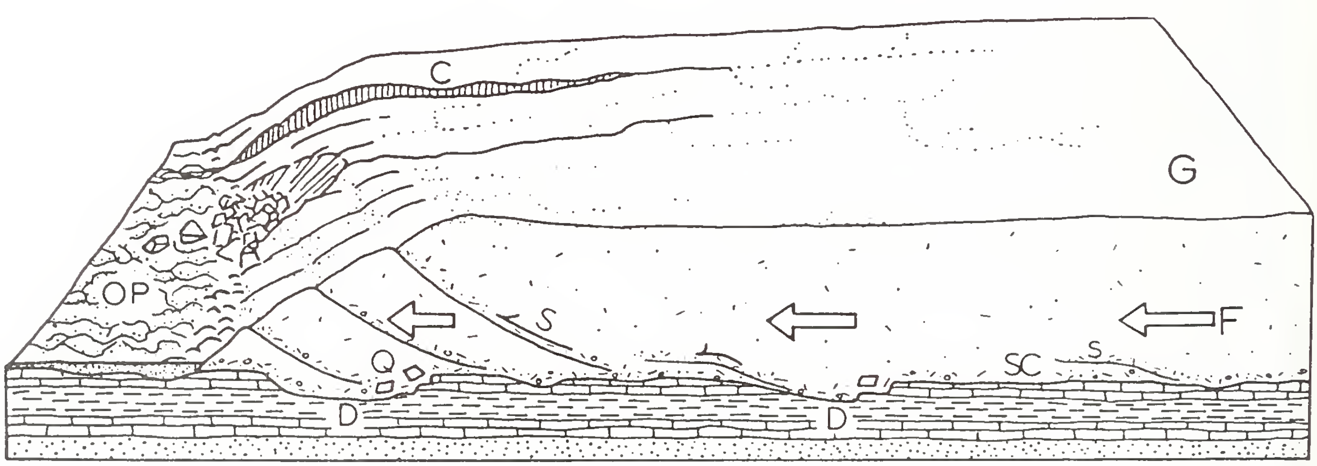
Glaciation in a Small Illinois Region

The following diagrams show how a continental ice sheet might have looked at various stages as it moved across a small region in Illinois. They illustrate how it could change the old terrain and create a landscape like the one we live on. To visualize how these glaciers looked, geologists study the landforms and materials left in the glaciated regions and also the present-day mountain glaciers and polar ice caps.

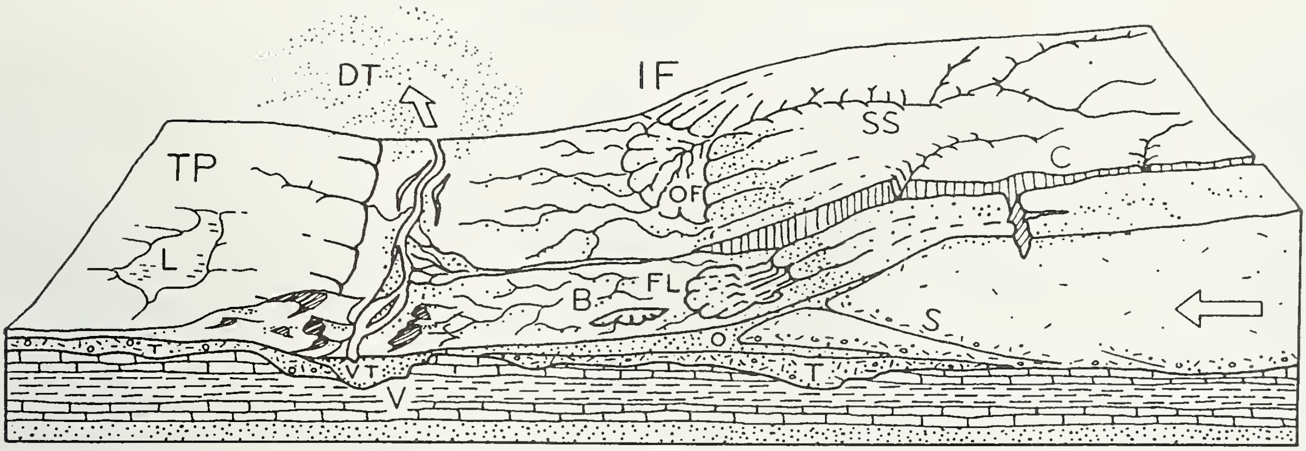
The block of land in the diagrams is several miles wide and about 10 miles long. The vertical scale is exaggerated—layers of material are drawn thicker and landforms higher than they ought to be so that they can be easily seen.



1. **The Region Before Glaciation** — Like most of Illinois, the region illustrated is underlain by almost flat-lying beds of sedimentary rocks—layers of sandstone ( ), limestone ( ), and shale ( ). Millions of years of erosion have planed down the bedrock (BR), creating a terrain of low uplands and shallow valleys. A residual soil weathered from local rock debris covers the area but is too thin to be shown in the drawing. The streams illustrated here flow westward and the one on the right flows into the other at a point beyond the diagram.



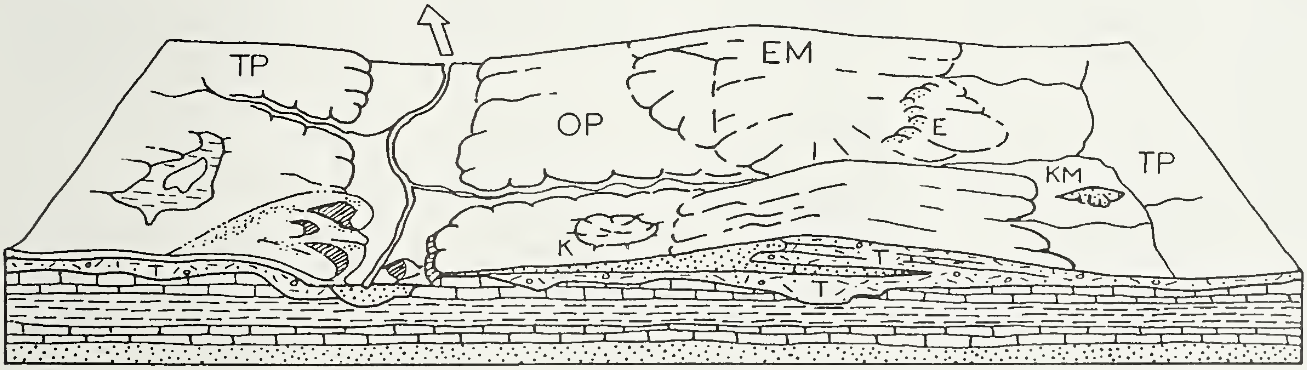
2. **The Glacier Advances Southward** — As the Glacier (G) spreads out from its ice snowfield accumulation center, it scours (SC) the soil and rock surface and quarries (Q)—pushes and plucks up—chunks of bedrock. The materials are mixed into the ice and make up the glacier's "load." Where roughnesses in the terrain slow or stop flow (F), the ice "current" slides up over the blocked ice on innumerable shear planes (S). Shearing mixes the load very thoroughly. As the glacier spreads, long cracks called "crevasses" (C) open parallel to the direction of ice flow. The glacier melts as it flows forward, and its meltwater erodes the terrain in front of the ice, deepening (D) some old valleys before ice covers them. Meltwater washes away some of the load freed by melting and deposits it on the outwash plain (OP). The advancing glacier overrides its outwash and in places scours much of it up again. The glacier may be 5000 or so feet thick, and tapers to the margin, which was probably in the range of several hundred feet above the old terrain. The ice front advances perhaps as much as a third of a mile per year.



3. **The Glacier Deposits an End Moraine** — After the glacier advances across the area, the climate warms and the ice begins to melt as fast as it advances. The ice front (IF) is now stationary, or fluctuating in a narrow area, and the glacier is depositing an end moraine.

As the top of the glacier melts, some of the sediment that is mixed in the ice accumulates on top of the glacier. Some is carried by meltwater onto the sloping ice front (IF) and out onto the plain beyond. Some of the debris slips down the ice front in a mudflow (FL). Meltwater runs through the ice in a crevasse (C). A supraglacial stream (SS) drains the top of the ice, forming an outwash fan (OF). Moving ice has overridden an immobile part of the front on a shear plane (S). All but the top of a block of ice (B) is buried by outwash (O).

Sediment from the melted ice of the previous advance (figure 2) remains as a till layer (T), part of which forms the till plain (TP). A shallow, marshy lake (L) fills a low place in the plain. Although largely filled with drift, the valley (V) remains a low spot in the terrain. As soon as the ice cover melts, meltwater drains down the valley, cutting it deeper. Later, outwash partly refills the valley: the outwash deposit is called a valley train (VT). Wind blows dust (DT) off the dry floodplain. The dust will form a loess deposit when it settles. Sand dunes (D) form on the south and east sides of streams.



4. **The Region after Glaciation** — As the climate warms further, the whole ice sheet melts, and glaciation ends. The end moraine (EM) is a low, broad ridge between the outwash plain (OP) and till plains (TP). Run-off from rains cuts stream valleys into its slopes. A stream goes through the end moraine along the channel cut by the meltwater that ran out of the crevasse in the glacier.

Slopewash and vegetation are filling the shallow lake. The collapse of outwash into the cavity left by the ice block's melting has made a kettle (K). The outwash that filled a tunnel draining under the glacier is preserved in an esker (E). The hill of outwash left where meltwater dumped sand and gravel into a crevasse or other depression in the glacier or at its edge is a kame (KM). A few feet of loess covers the entire area but cannot be shown at this scale.

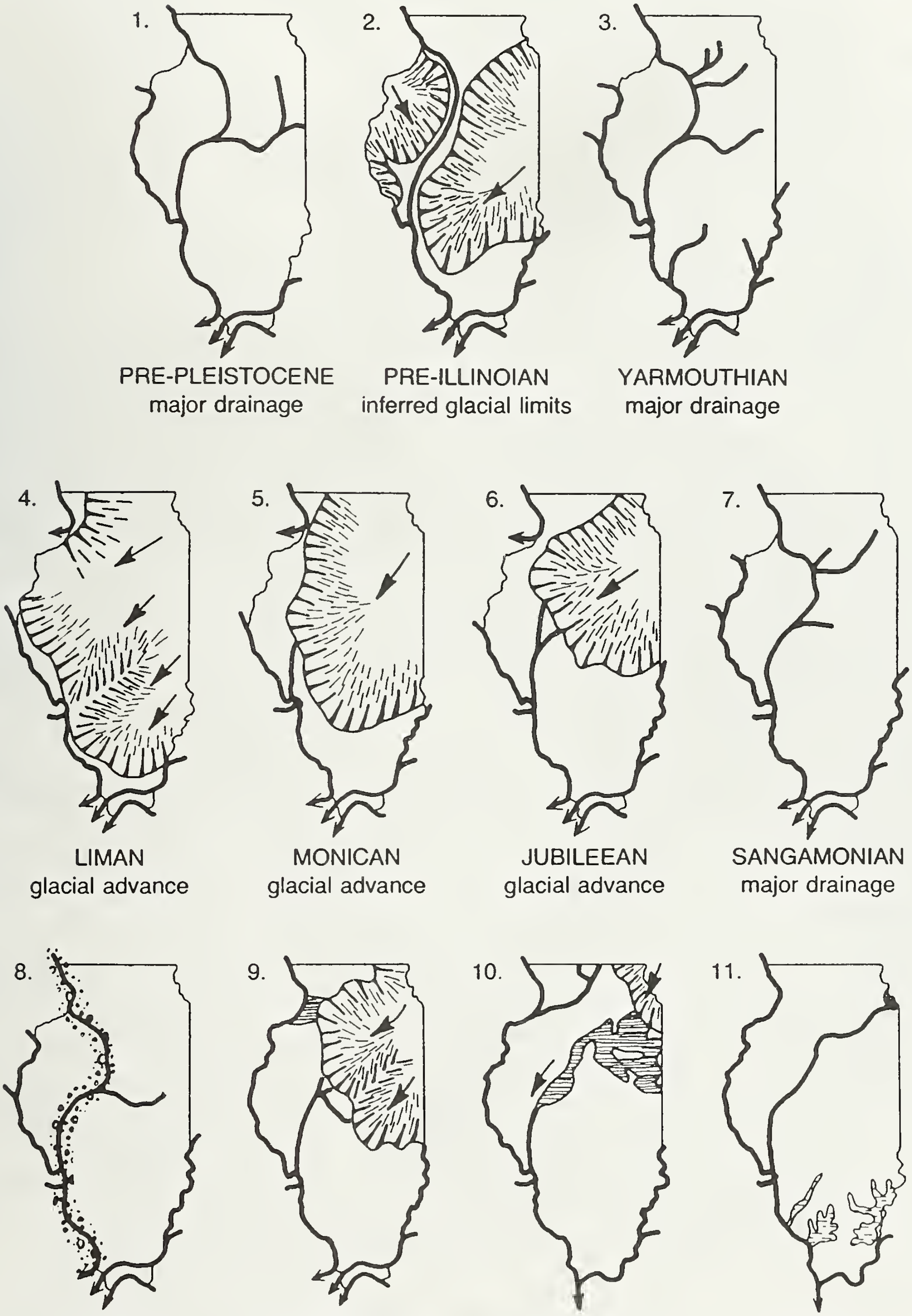
TIME TABLE OF PLEISTOCENE GLACIATION

			STAGE		SUBSTAGE	NATURE OF DEPOSITS	SPECIAL FEATURES
QUATERNARY			HOLOCENE (interglacial)		Years Before Present	Soil, youthful profile of weathering, lake and river deposits, dunes, peat	
					10,000		
	Pleistocene		WISCONSINAN (glacial)	late	Valderan	Outwash, lake deposits	Outwash along Mississippi Valley
					11,000		
				late	Twocreekan	Peat and alluvium	Ice withdrawal, erosion
					12,500		
				late	Woodfordian	Drift, loess, dunes, lake deposits	Glaciation; building of many moraines as far south as Shelbyville; extensive valley trains, outwash plains, and lakes
					25,000		
				mid	Farmdalian	Soil, silt, and peat	Ice withdrawal, weathering, and erosion
					28,000		
				early	Altonian	Drift, loess	Glaciation in Great Lakes area, valley trains along major rivers
					75,000		
			SANGAMONIAN (interglacial)			Soil, mature profile of weathering	Important stratigraphic marker
					125,000		
			ILLINOIAN (glacial)		Jubileean	Drift, loess, outwash	Glaciers from northeast at maximum reached Mississippi River and nearly to southern tip of Illinois
					Monican	Drift, loess, outwash	
					Liman	Drift, loess, outwash	
					300,000?		
			YARMOUTHIAN (interglacial)			Soil, mature profile of weathering	Important stratigraphic marker
					500,000?		
		Pre-Illinoian	KANSAN* (glacial)			Drift, loess	Glaciers from northeast and northwest covered much of state
					700,000?		
			AFTONIAN* (interglacial)			Soil, mature profile of weathering	(hypothetical)
					900,000?		
			NEBRASKAN* (glacial)			Drift (little known)	Glaciers from northwest invaded western Illinois
					1,600,000 or more		

*Old oversimplified concepts, now known to represent a series of glacial cycles.

(Illinois State Geological Survey, 1973)

SEQUENCE OF GLACIATIONS AND INTERGLACIAL DRAINAGE IN ILLINOIS



1. PRE-PLEISTOCENE major drainage
2. PRE-ILLINOIAN inferred glacial limits
3. YARMOUTHIAN major drainage
4. LIMAN glacial advance
5. MONICAN glacial advance
6. JUBILEEAN glacial advance
7. SANGAMONIAN major drainage
8. ALTONIAN glacial advance
9. WOODFORDIAN glacial advance
10. WOODFORDIAN Valparaiso ice and Kankakee Flood
11. VALDERAN drainage

(Modified from Willman and Frye, "Pleistocene Stratigraphy of Illinois," ISGS Bull. 94, fig. 5, 1970.)

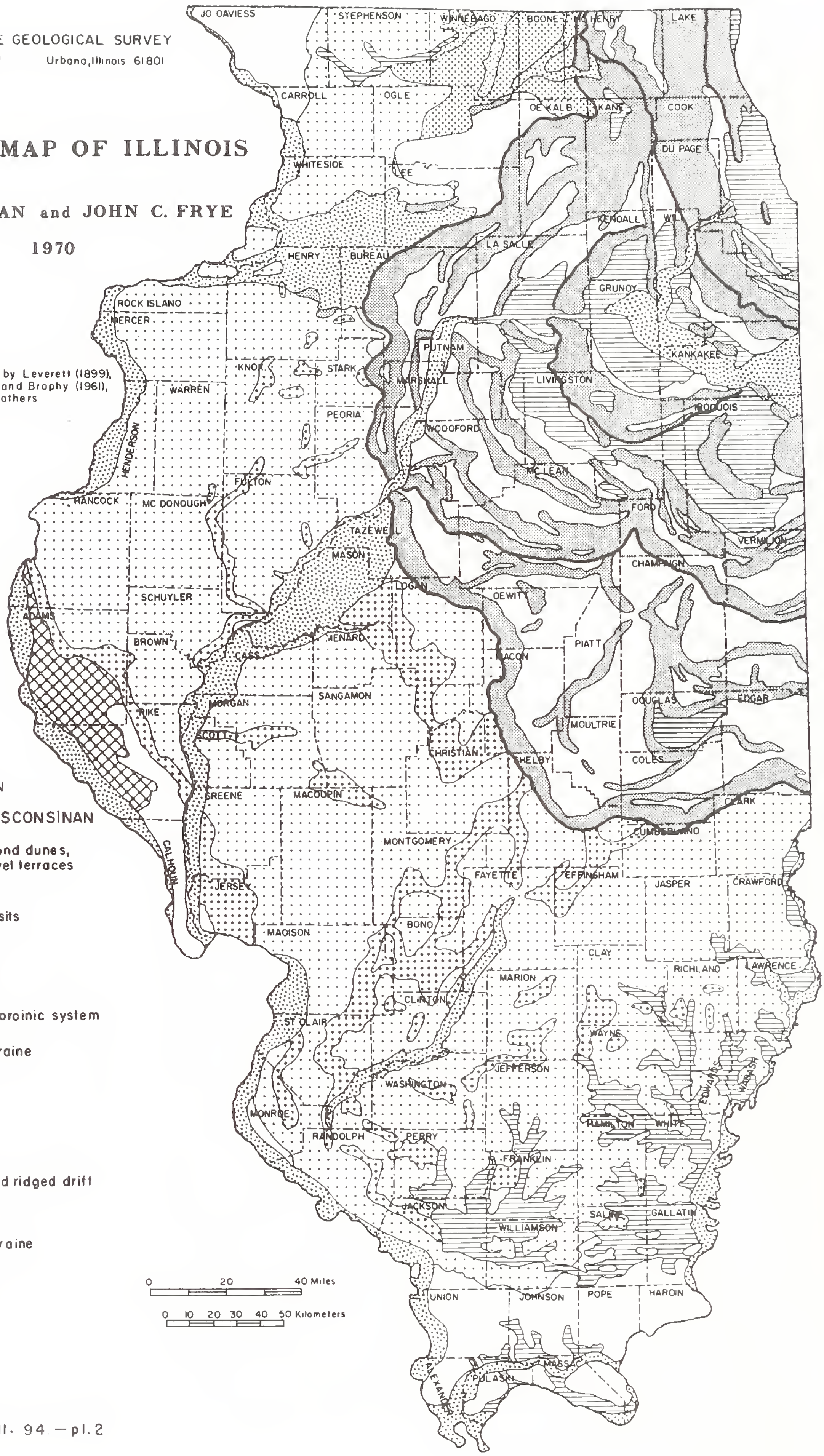
ILLINOIS STATE GEOLOGICAL SURVEY
John C Frye, Chief   Urbana, Illinois 61801

GLACIAL MAP OF ILLINOIS

H.B. WILLMAN and JOHN C. FRYE

1970

Modified from maps by Leverett (1899), Ekblaw (1959), Leighton and Brophy (1961), Willman et al. (1967), and others



EXPLANATION

HOLOCENE AND WISCONSINAN

Alluvium, sand dunes, and gravel terraces

WISCONSINAN

Lake deposits

WOODFORDIAN

Moraine

Front of morainic system

Groundmoraine

ALTONIAN

Till plain

ILLINOIAN

Moraine and ridged drift

Groundmoraine

KANSAN

Till plain

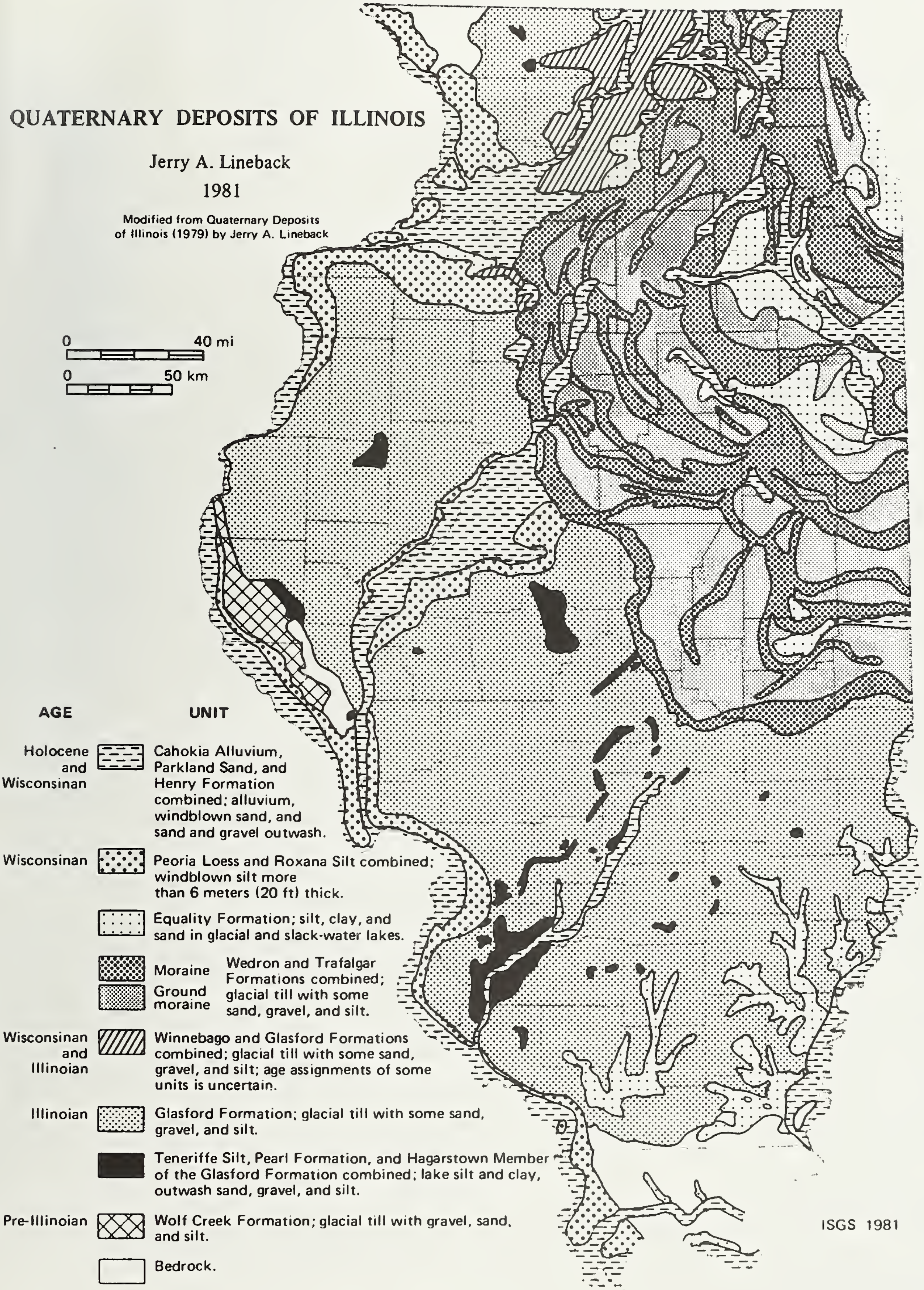
DRIFTLESS

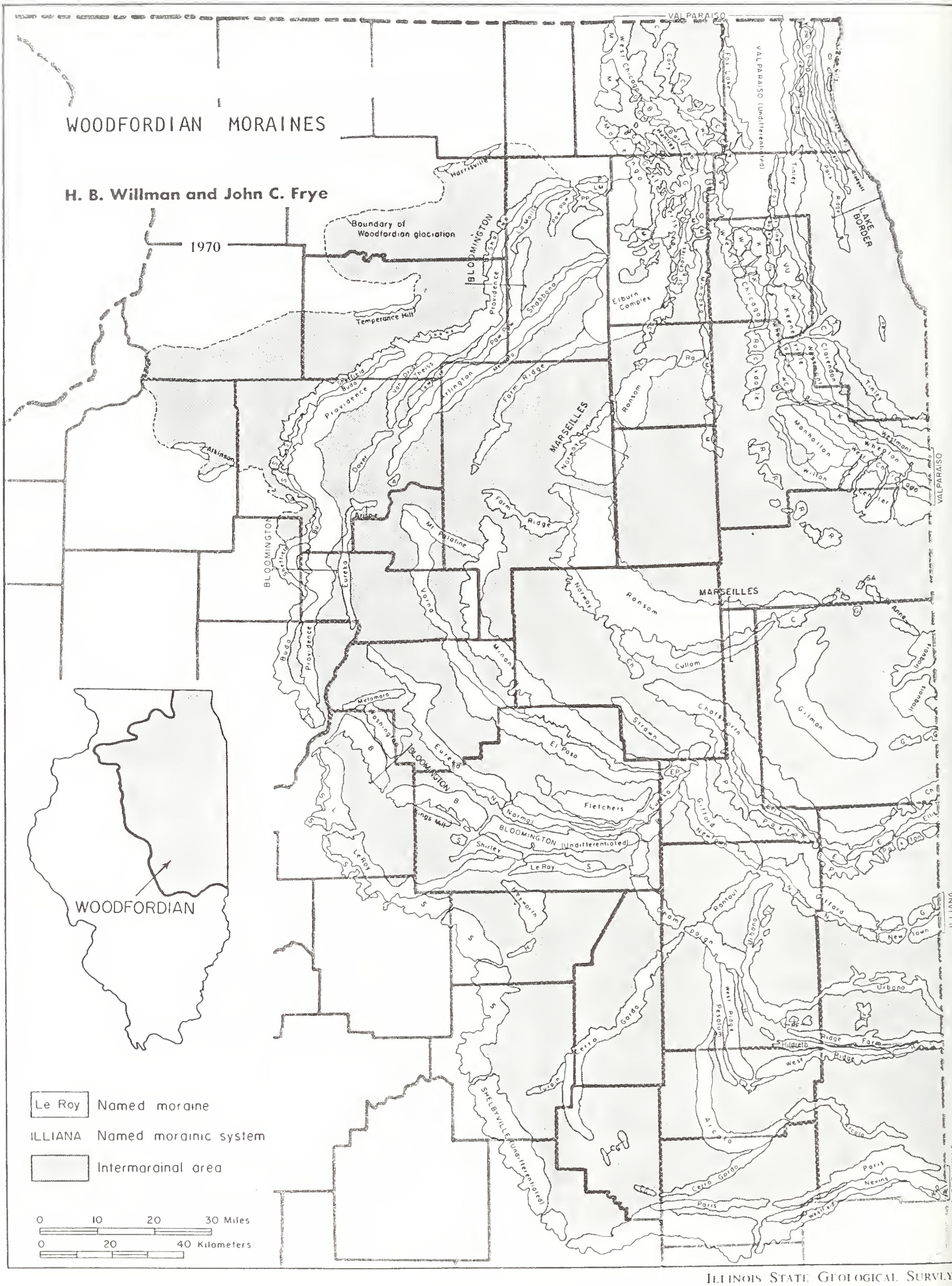
Modified from Bull. 94.—pl. 2

QUATERNARY DEPOSITS OF ILLINOIS

Jerry A. Lineback
1981

Modified from Quaternary Deposits of Illinois (1979) by Jerry A. Lineback




WOODFORDIAN MORAINES
H. B. Willman and John C. Frye
1970
Boundary of Woodfordian glaciation
VALPARAISO
VALPARAISO (Undifferentiated)
LAKE BORDER
BLOOMINGTON
BLOOMINGTON (Undifferentiated)
MARSEILLES
ILLIANA
SHELBYVILLE
SHELBYVILLE (Undifferentiated)
Harrisville
Temperance Hill
Atkinson
Providence
Shabbona
Paw Paw
Farm Ridge
Elburn Complex
Ransom
Normal
Mt Palatine
Varna
Eureka
Minonk
Cullom
Chatsworth
Gilman
Iroquois
El Paso
Strawn
Fletchers
Gifford
Newtown
Le Roy
Shirley
Heyworth
Rantoul
Champaign
Urbana
Cerro Gordo
Pesotum
West Ridge
Arcola
Paris
Nevins
Westfield
Tuscola
Metamora
Washington
Kings Mill
Dover
Arispe
Buda
Sheffield
Tinley
Manhattan
Wilton
Westmont
Clarendon
Keeneyville
Chicago
Rollingdale
WOODFORDIAN
Le Roy — Named moraine
ILLIANA — Named morainic system
Intermorainal area
0 10 20 30 Miles
0 20 40 Kilometers

ILLINOIS STATE GEOLOGICAL SURVEY
Urbana, Illinois 61801

GEOGRAM 5
October 1975

ANCIENT DUST STORMS IN ILLINOIS

Myrna M. Killey

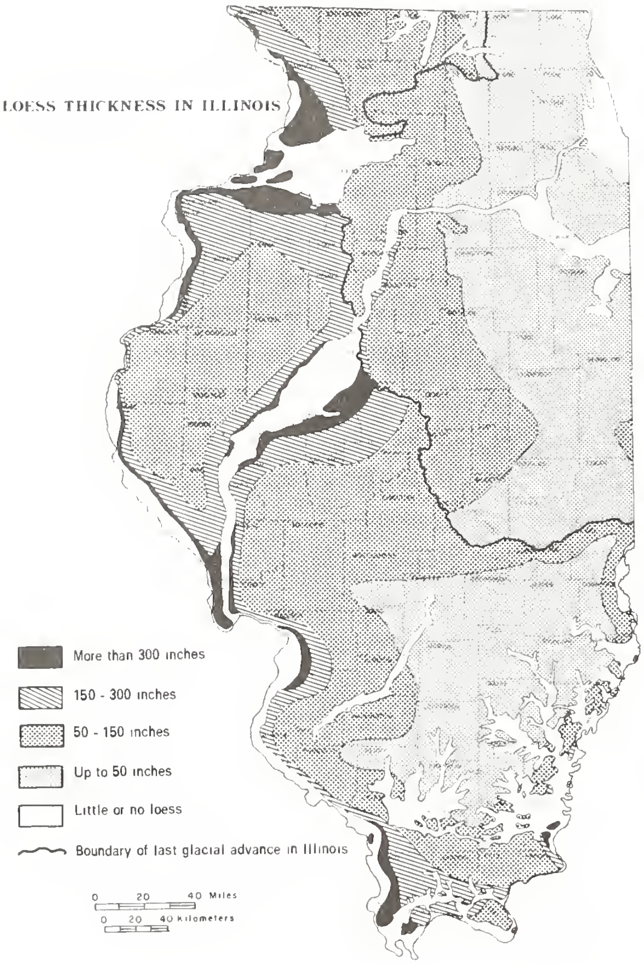
Fierce dust storms whirled across Illinois long before human beings were here to record them. Where did all the dust come from? Geologists have carefully put together clues from the earth itself to get the story. As the glaciers of the Great Ice Age scraped and scoured their way southward across the 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.

MISSISSIPPIAN ROCKS IN ILLINOIS

Janis D. Treworgy
1997

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.

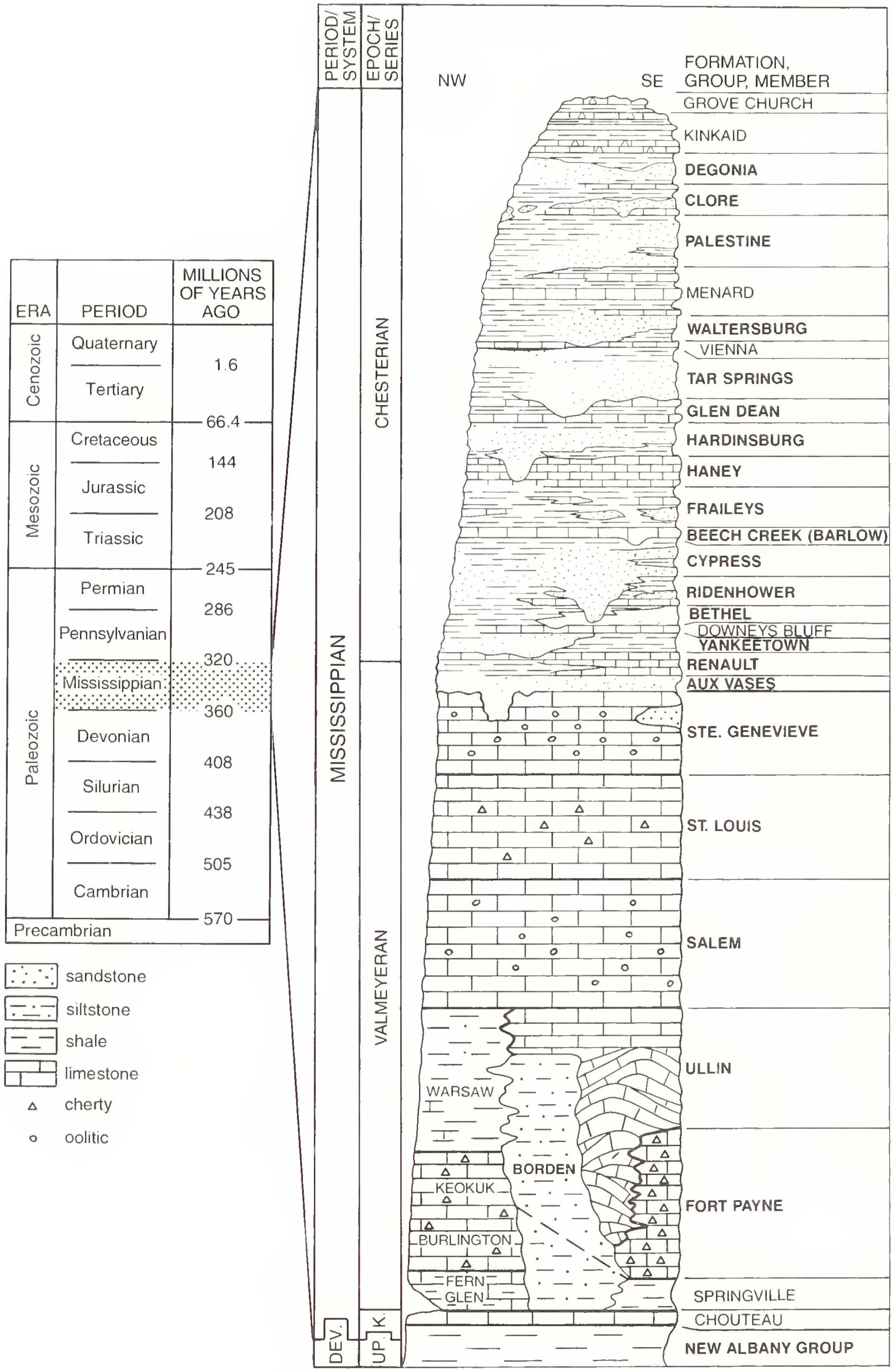


Figure 1 Mississippian rock units in Illinois. Units that have produced oil are shown in bold type. The base of the Fort Payne is approximately equivalent in time to the base of the Keokuk (dashed line). Dev = Devonian, UD = Upper Devonian, and K = Kinderhookian.

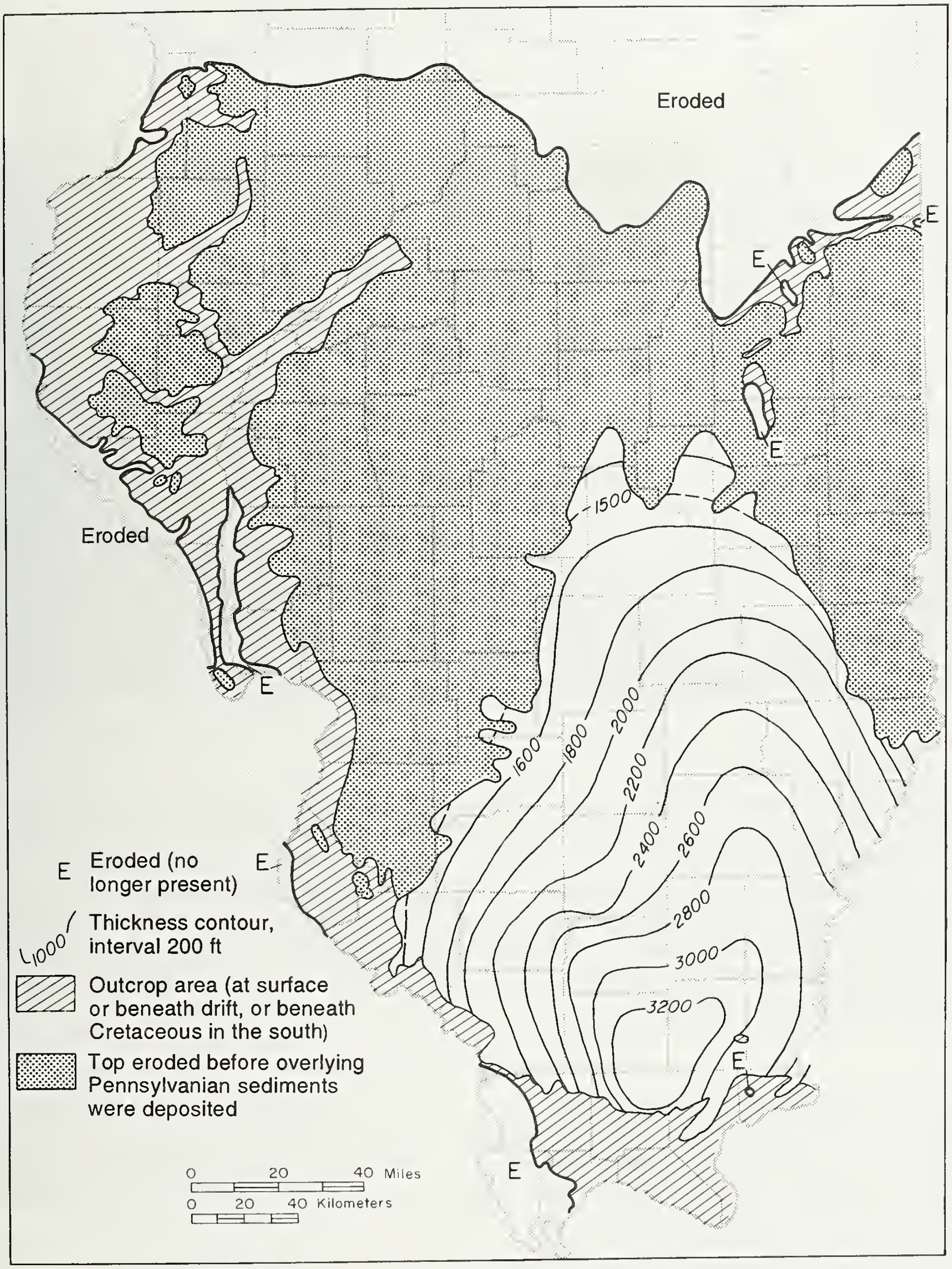


Figure 2 Distribution and thickness of the Mississippian rocks in Illinois. Thickness contours are shown where upper Chesterian rocks are present (modified from Atherton et al. 1975).

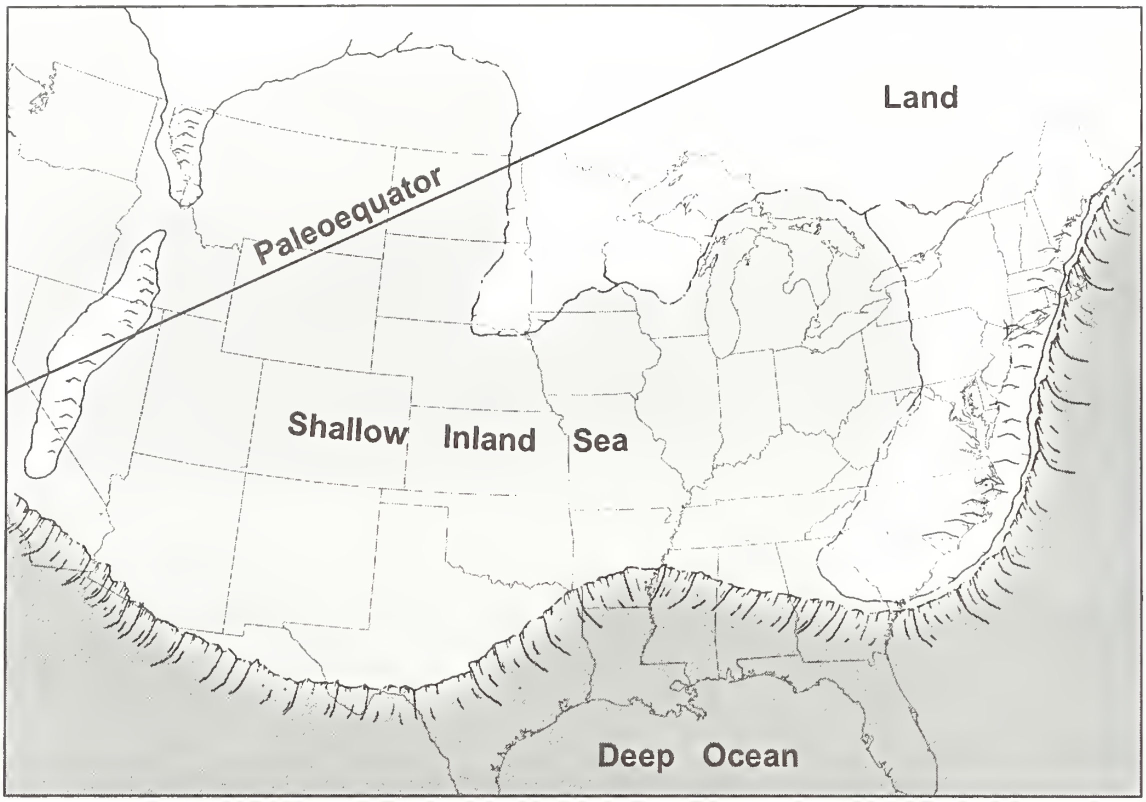


Figure 3 Position of much of the United States and general paleogeography during the Mississippian Period, approximately 350 million years ago.

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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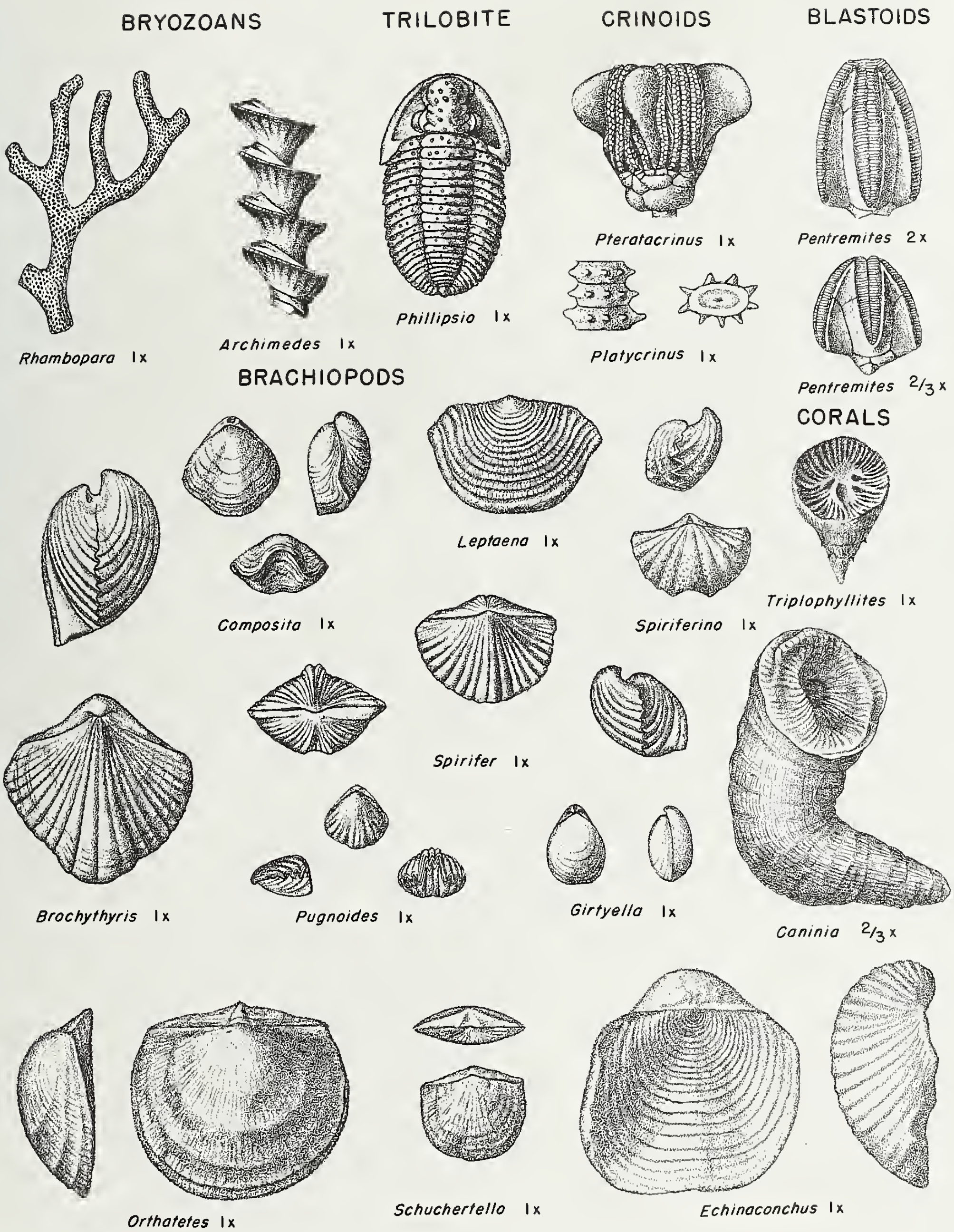


PLATE A Typical Mississippian fossils.

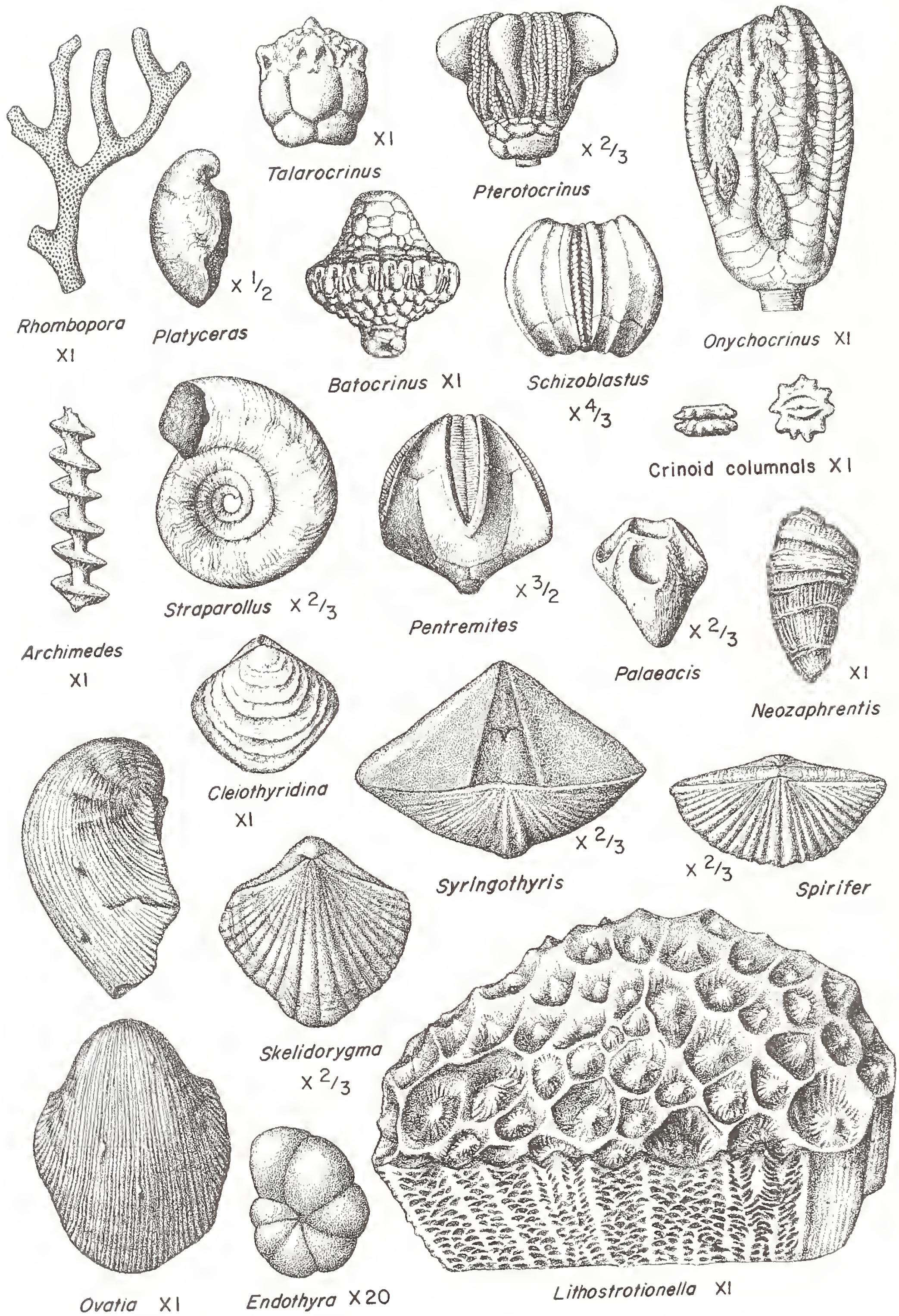
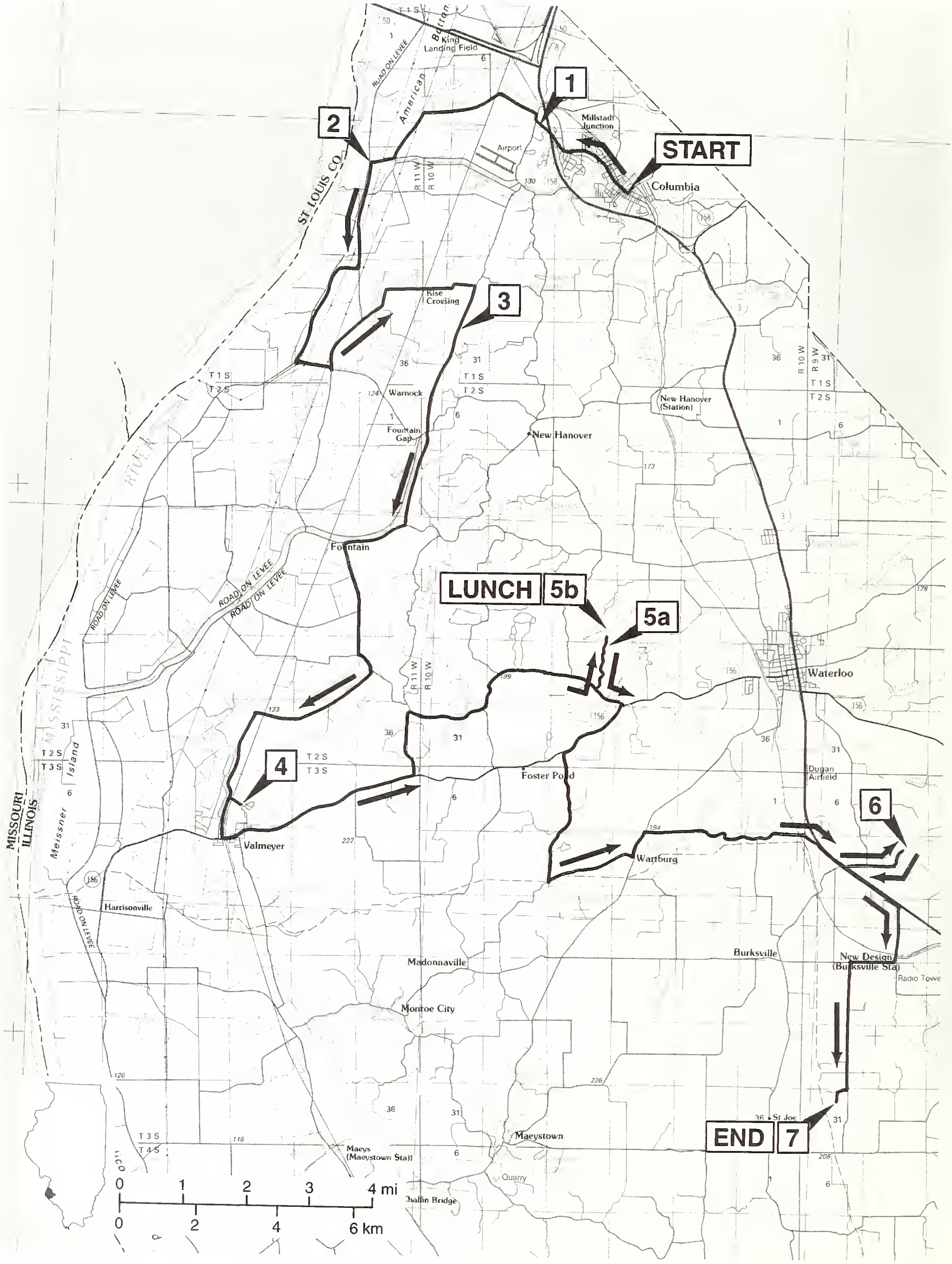


PLATE B Typical Mississippian fossils.



START
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LUNCH
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Columbia
Millstadt Junction
Airport
King Landing Field
American Bottom
ROAD ON LEVEE
ST LOUIS CO
Rise Crossing
Warnock
Fountain Gap
New Hanover
New Hanover (Station)
Fountain
RIVER
MISSISSIPPI
Waterloo
Foster Pond
Valmeyer
Wartburg
Dugan Airfield
Harrisonville
Meissner Island
MISSOURI
ILLINOIS
Burksville
New Design (Burksville Sta)
Radio Towe
Madonnaville
Monroe City
Maeystown
Maeys (Maeystown Sta)
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