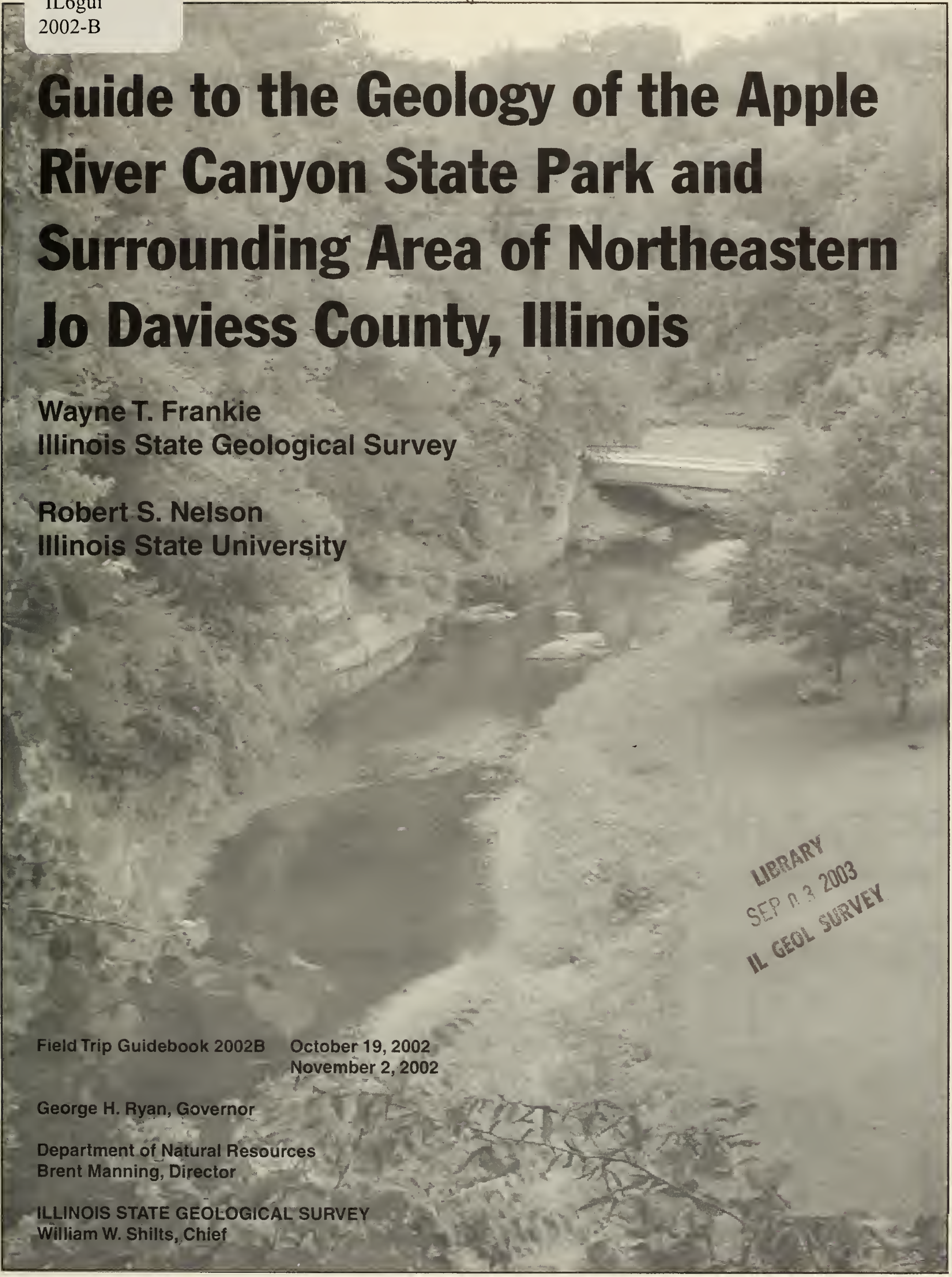

Guide to the Geology of the Apple River Canyon State Park and Surrounding Area of Northeastern Jo Daviess County, Illinois

Wayne T. Frankie
Illinois State Geological Survey

Robert S. Nelson
Illinois State University

Field Trip Guidebook 2002B October 19, 2002
November 2, 2002

George H. Ryan, Governor

Department of Natural Resources
Brent Manning, Director

ILLINOIS STATE GEOLOGICAL SURVEY
William W. Shilts, Chief

Cover photo: Apple River Canyon State Park (photo by W. T. Frankie).

Geological Science Field Trips 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. We ask, however, that grade school students be accompanied by at least one parent or guardian for each five students. 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 Geoscience Outreach Coordinator, Illinois State Geological Survey, Natural Resources Building, 615 East Peabody Drive, Champaign, IL 61820-6964. Telephone: 217-244-2427 or 217-333-4747. This information is on the ISGS home page: http://www.isgs.uiuc.edu.

Six USGS 7.5-Minute Quadrangle maps (Apple River, Elizabeth Northeast, Scales Mound East, Scales Mound West, Shullsburg, and Warren) provide coverage for this field trip area.

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ILLINOIS DEPARTMENT OF NATURAL RESOURCES
ISGS Illinois State Geological Survey

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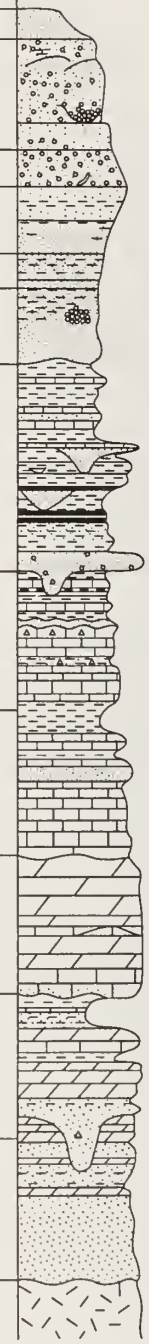
CONTENTS

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	1.8 m	Glacial till, glacial outwash, gravel, sand, silt, lake deposits of clay and silt, loess and sand dunes; covers nearly all of state except north-west corner and southern tip
		Tertiary 0-500'	Pliocene	[5.3 m 33.7 m]	Chert gravel, present in northern, southern and western Illinois
			Eocene	54.8 m	Mostly micaceous sand with some silt and clay; presently only in southern Illinois
			Paleocene	65.0 m	Mostly clay, little sand; present only in southern Illinois
MESOZOIC "Middle Life"	Age of Reptiles	Cretaceous 0-300'		[144 m 290 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")		323 m	Largely shale and sandstone with beds of coal, limestone, and clay
		Mississippian 0-3,500'		354 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'		417 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'		443 m	Principally dolomite and limestone
		Ordovician 500-2,000'		490 m	Largely dolomite and limestone but contains sandstone, shale, and siltstone formations
		Cambrian 1,500-3,000'		543 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.

INTRODUCTION

The Apple River Canyon State Park area is located in the unglaciated area of northwestern Illinois in Jo Daviess County in the northeastern part of the Wisconsin Driftless Section of Illinois. This natural division is part of the highly significant North American geobiological feature, the "Driftless Area." First described in 1823 by geologist W. H. Keating, it is world renowned for its isolation from direct glacial impacts during the Pleistocene Epoch. High hills, sharp ridges, sweeping slopes, and narrow valleys form some of the most picturesque topography in the state.

The area's rugged surface was formed mainly by the differential erosion of Ordovician and Silurian sedimentary strata consisting primarily of *dolomite*[1] and shale and some *limestone* (see generalized geologic column on facing page). Ridges and large mounds are upheld by resistant dolomite caps, and sweeping slopes are developed on soft shale. Steep-walled valleys are incised into lower, older, resistant dolomite strata. The trails along the tops of the towering bluffs of Apple River Canyon State Park offer spectacular views of the Apple River and the surrounding scenic topography of the county. This geological science field trip will acquaint you with the *geology*, landscape, and mineral resources for part of Jo Daviess County, Illinois.

Stockton, with a population of 1,926, is the largest city within the field trip area. Apple River Canyon State Park is 20 miles east and slightly north of Galena and approximately 135 miles west of Chicago, 190 miles north of Springfield, 285 miles north of East St. Louis, and 420 miles north of Cairo.

Jo Daviess County was named after Col. Joseph Hamilton Daveiss, a prominent Kentucky lawyer and Indian fighter who died in 1811 while leading a charge against Native Americans at the Battle of Tippecanoe in Indiana. Interestingly, an early clerical error led to the spelling of Daveiss with an "ie" rather than "ei."

Kentucky, Indiana, and Missouri also have a Daviess County, named after the same man, but without the first name added. Many visitors ask about the correct pronunciation. In most parts of the county Daviess is pronounced the same as "Davis" with a short "i." One often hears, however, particularly from those who have not grown up in the county, the long "e," as in "Davees."

When first established, Jo Daviess County included most of northwestern Illinois, including all or parts of the following counties: Carroll, Stephenson, Winnebago, Whiteside, Ogle, Lee, Henry, Bureau, and Rock Island.

GEOLOGIC FRAMEWORK

Precambrian Era (3.8 BY to 543 MY)

Through several billion years of geologic time, the area surrounding the Apple River Canyon State Park, like the rest of present-day Illinois, has undergone many changes throughout the hundreds of millions of years of geologic time. 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.

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[1] Words in italics (except for fossil names) 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, the present names of places and geologic features are used because they provide clear reference points for describing the ancient landscape.

The depth to the Precambrian rocks in Jo Daviess County range from 2,000 to 2,500 feet. In southern Illinois, the depth to the Precambrian rocks is greater than 20,000 feet in the deepest part of the Illinois *Basin*. From these samples, however, we know that these ancient rocks consist mostly of granitic and rhyolitic *igneous rocks* and possibly *metamorphic*, crystalline rocks formed about 1.5 to 1.0 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, forming a barren landscape that was probably quite similar to the topography of the present Missouri Ozarks. There is no rock record (*sediments*) in Illinois that represents the long interval of *weathering* and erosion that lasted from the time the Precambrian rocks were formed until the first Cambrian age sediments accumulated on the eroded Precambrian rocks. This interval of weathering and erosion is almost as long as the time from the beginning of the Cambrian *Period* to the present.

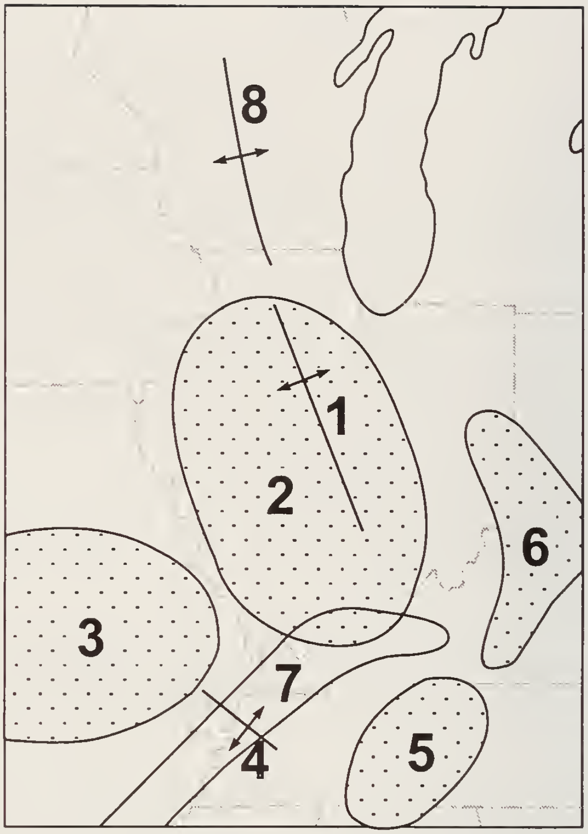


Figure 1 Location of some of the major structures in the Illinois region: (1) La Salle Anticlinorium, (2) Illinois Basin, (3) Ozark Dome, (4) Pascola Arch, (5) Nashville Dome, (6) Cincinnati Arch, (7) Rough Creek Graben–Reelfoot Rift, and (8) Wisconsin Arch.

Because geologists cannot see the Precambrian basement rocks in Illinois except as cuttings and cores from boreholes, other various techniques, such as measurements of Earth's gravitational, and magnetic fields, and seismic exploration, are used to map the regional characteristics of the basement complex. The evidence collected from these various exploratory techniques indicates that southernmost Illinois, near what is now the historic Kentucky–Illinois Fluorspar Mining District, consisted of *rift* valleys similar to those in eastern Africa. These Illinois Basin rift valleys formed as movement of crustal plates (plate *tectonics*) began to rip apart the Precambrian North American continent. These rift valleys have been named the Rough Creek Graben and the Reelfoot Rift (fig. 1).

Paleozoic Era (543 MY to 248 MY)

After the beginning of the Paleozoic Era, about 520 million years ago in the late Cambrian Period, the rifting stopped, and the hilly Precambrian landscape began to sink slowly on a broad regional scale, allowing the invasion of a shallow sea from the south and southwest. During the following 280 million years of the Paleozoic Era, the area that is now called the Illinois Basin continued to accumulate sediments that were deposited in the shallow seas that repeatedly covered this subsiding basin. The region continued to sink until at least 20,000 feet of sedimentary strata were deposited in the deepest part of the basin, located in the Rough Creek Graben and Reelfoot Rift areas of southeastern Illinois and western Kentucky. At various times during this era, the seas withdrew, and deposits were weathered and eroded. As a result, there are gaps (called a *hiatus)* in the sedimentary rock record in Illinois.

These deposited sediments, when compacted and hardened (*indurated*), constitute the *bedrock* succession. Bedrock refers to the indurated or lithified rock units that underlie the soils or other relatively loose, crumbly, materials near Earth's surface.

In the field trip area, bedrock strata range in age from more than 490 million years (the Cambrian Period) to less than 420 million years old (the Silurian Period). Jo Daviess County is underlain by as much as 2,500 feet of Paleozoic sedimentary strata. 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. The oldest Paleozoic rocks exposed in the area are Ordovician in age. These rocks formed from sediments that accumulated from about 490 up to 443 million years ago in an ancient sea.

DEPOSITIONAL HISTORY

Paleozoic Era (543 MY to 248 MY)

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.

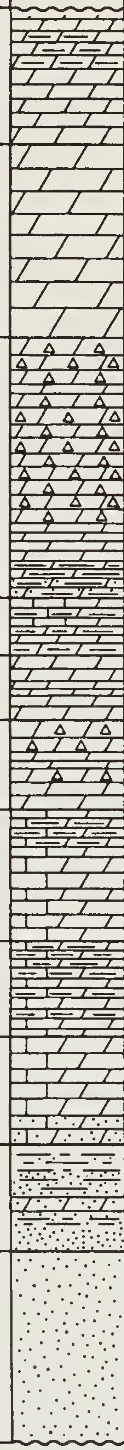
These inland seas connected with the open ocean to the south during much of the Paleozoic, and the area that is now southern Illinois was an embayment. The southern part of Illinois and adjacent parts of Indiana and Kentucky sank more rapidly than the areas to the north, allowing more sediment to accumulate. During the Paleozoic and Mesozoic, the Earth's thin crust was periodically flexed and warped in places as stresses built up in response to the tectonic forces associated with the collision of continental and oceanic plates and mountain building. These movements caused repeated invasions and withdrawals of the seas across the region. The former sea floors were thus periodically exposed to erosion, which removed some sediments from the rock record.

Stratigraphic Units and Contacts Sedimentary rock, such as limestone, sandstone, shale, or combinations of these and other rock types, commonly occur in units called formations. A formation is a body of rock that has a distinctive lithology, or set of characteristics, and easily recognizable top and bottom boundaries. It is also thick enough to be readily traceable in the field and sufficiently widespread to be represented on a map. Most formation names contain modifiers, such as St. Peter Sandstone or Scales Shale, which are usually derived from geographic names and predominant rock types. In cases where no single rock type is characteristic, the word Formation becomes a part of the name (for example, Dubuque Formation). A group, such as the Galena Group or the Maquoketa Group, is a vertical lumping together of adjacent formations having many similarities. A member, or *bed*, is a subdivision of a formation that is too thin to be classified as a formation or that has minor characteristics setting it apart from the rest of the formation.

Many of the sedimentary units, called formations, have conformable contacts—that is, no significant interruption in deposition occurred as one formation was succeeded by another (figs. 2 and 4). In some instances, even though the composition and appearance of the rocks change significantly at the contact between two formations, the *fossils* in the rocks and the relationships between the rocks at the contact indicate that deposition was virtually continuous. In contrast, in some places, the top of the lower formation was at least partially eroded before the next formation began to be deposited. In these instances, fossils and other evidence within or at the boundary between the two formations indicate 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

SYSTEM	SERIES	GROUP	FORMATION Thickness, ft	LITHOLOGY	DESCRIPTION
SILURIAN	NIAGARAN		Racine 300		Dolomite, pure, gray, thin-bedded to massive; local reef structures; local areas of brownish gray, argillaceous dolomite.
			Marcus 35-45		Dolomite, very pure, buff, vesicular, massive; contains *Pentamerus* in great abundance in lower 5-15 ft.
	ALEXANDRIAN		Sweeney 45-55		Dolomite, pure, pinkish gray; in thin wavy beds with green shale partings; corals abundant; 3-5 ft cherty zone near middle contains *Microcardinalia* and *Pentamerus*.
			Blanding 25-35		Dolomite, pure, brownish gray; contains many layers of white chert; silicified corals abundant; lower 3-5 ft slightly argillaceous.
			Tete des Morts 15-20		Dolomite, light gray, slightly cherty, thick-bedded medium to fine-grained, relatively pure.
			Mosalem 0-100		Dolomite, gray, cherty; medium-bedded; lower part is very argillaceous dolomite grading to dolomitic shale at base.
ORDOVICIAN	CINCINNATIAN	Maquoketa	Brainard 0-50		Shale, greenish gray, dolomitic; interbedded with fine- to medium-grained, argillaceous dolomite; abundant and diverse fauna consisting largely of brachiopods and bryozoans.
			Fort Atkinson 0-10		Dolomite, yellowish gray, fine-grained, argillaceous, thin-bedded; interbedded with greenish gray shale.
			Scales 125		Shale, gray, dolomitic; conchoidal fractures; *Isotelus* common in upper part; dark brown, carbonaceous, laminated shale in lower 15 ft; one or two beds of brown argillaceous dolomite at base containing depauperate fauna, pyrite, and phosphatic pebbles.

Figure 2 Generalized stratigraphic column from the top of the Niagaran (middle Silurian) to the base of the Champlainian (middle Ordovician) in the field trip area (modified from Kolata and Buschbach 1976). Figure continues on the next page.

SYSTEM	SERIES	GROUP	FORMATION Thickness, ft	LITHOLOGY	DESCRIPTION
ORDOVICIAN	CHAMPLAINIAN	Galena	Dubuque 30-45		Dolomite, argillaceous, light gray to buff, fine- to medium-grained, thin- to medium-bedded; brown shale partings.
			Wise Lake 70-80		Dolomite, pure, light gray to buff, medium-grained, thick-bedded to massive; abundant molluscan fauna; *Receptaculites* abundant near middle.
			Dunleith 130		Dolomite, gray to buff, medium-grained, thin- to thick-bedded; white to dark gray chalky and vitreous chert, particularly in upper part; *Receptaculites* abundant. Lower part argillaceous, sandy, fossiliferous, with green shale partings.
			Guttenberg 2-15		Dolomite and limestone, argillaceous, gray to brown, fine- to medium-grained, thin-bedded; reddish brown shale partings; abundant and diverse fauna.
		Platteville	Quimbys Mill 12		Dolomite, slightly argillaceous, light gray to buff, fine-grained, thin- to medium-bedded.
			Nachusa 20		Dolomite, pure, light gray to buff, thick-bedded, medium-grained, vuggy, fucoidal; white to light gray chert.
			Grand Detour 15-45		Dolomite and limestone, light gray to buff, thin- to medium-bedded, fine-grained; reddish brown shale partings; fossiliferous.
			Mifflin 15-25		Dolomite and limestone, argillaceous, light gray to buff, thin-bedded, fine-grained; greenish gray to blue-gray shale partings; fossiliferous.
			Pecatonica 20-30		Dolomite and limestone, light gray to buff, thin- to medium-bedded, fine-grained; brownish gray shale partings; corrosion surface at top; well-rounded sand grains in lower part.
		Ancell	Glenwood 5-20		Shale, sandstone, and dolomite, greenish gray; poorly sorted, fine- to coarse-grained sand.
			St. Peter 50-200		Sandstone, white, fine-grained, well-rounded, well-sorted, friable, thick-bedded to massive.

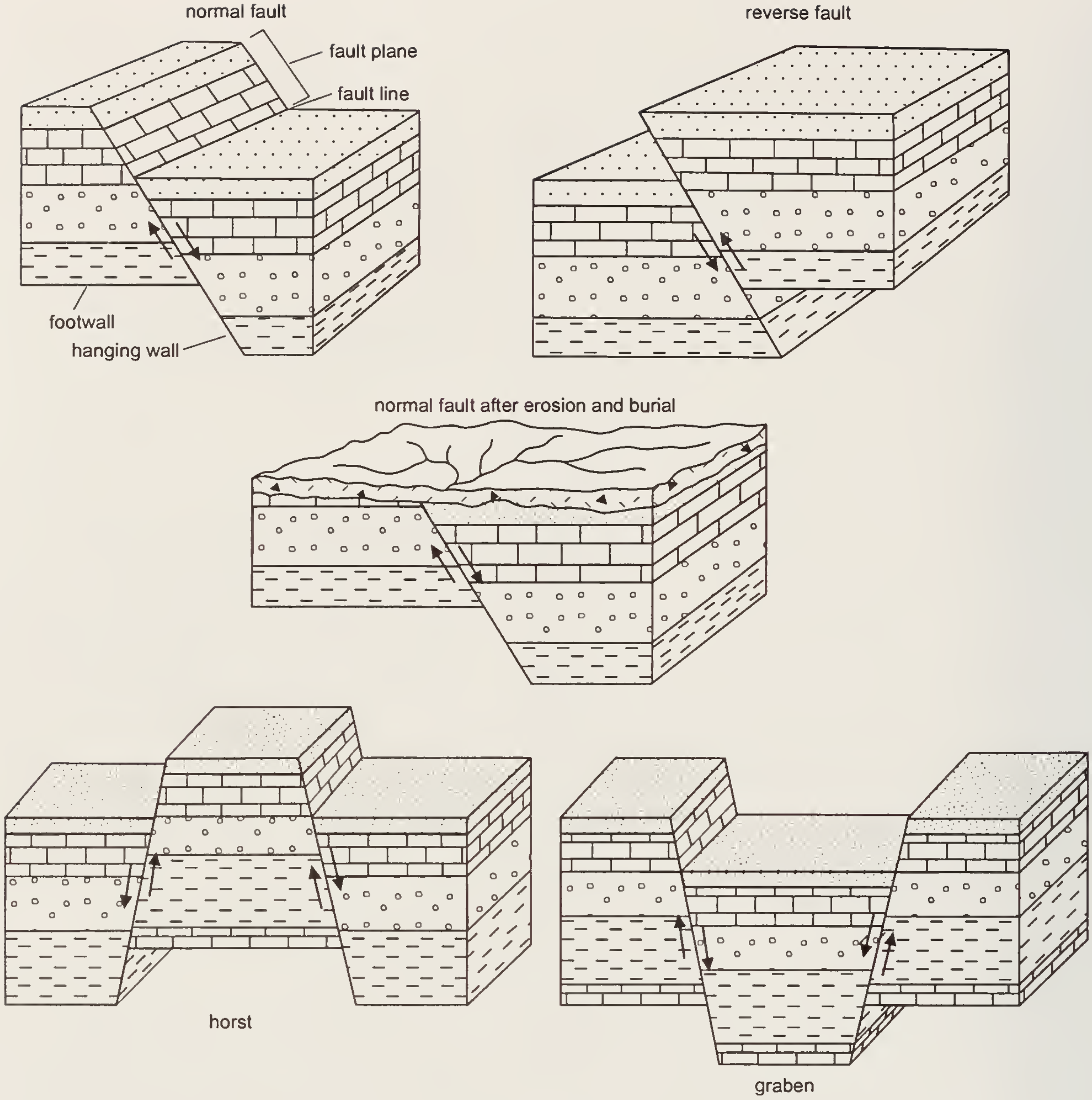


Figure 3 Diagrammatic illustrations of fault types that may be present in the field trip area. A fault is a fracture in the Earth's crust along which there has been relative movement of the opposing blocks. A fault is usually an inclined plane, and when the hanging wall (the block above the plane) has moved up relative to the footwall (the block below the fracture), the fault is a reverse fault. When the hanging wall has moved down relative to the footwall, the fault is a normal fault.

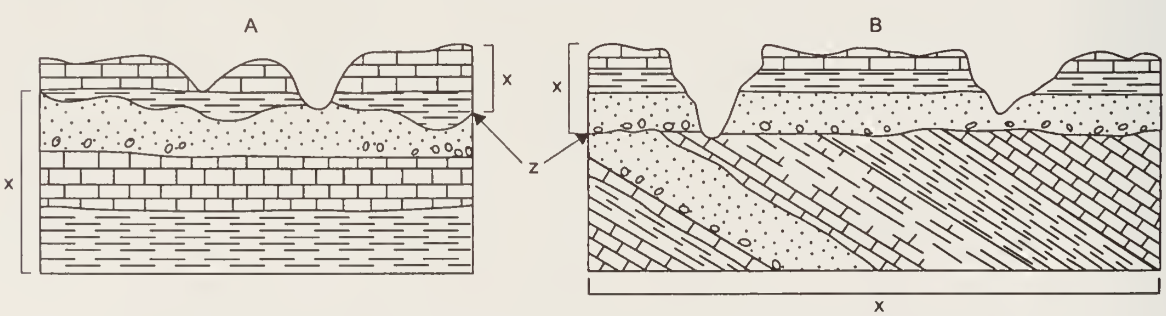


Figure 4 Schematic drawings of (A) a disconformity and (B) an angular unconformity (x represents the conformable rock sequence, and z is the plane of unconformity).

below an unconformity are parallel, the unconformity is called a *disconformity.* However, if the lower beds were tilted and eroded prior to deposition of overlying beds, the contact is called an *angular unconformity.*

Unconformities occur throughout the Paleozoic rock record and are shown as wavy lines in the generalized stratigraphic column (fig. 2). 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 complex structure has smaller structures such as *domes*, *anticlines*, and *synclines* superimposed on the broad upwarp of the anticlinorium. Further gradual arching continued through the Pennsylvanian Period. Because the youngest Pennsylvanian strata are absent from the area of the anticlinorium (either because they were not deposited or because they were 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.

Mesozoic Era (248 MY to 65 MY)

During the Mesozoic Era, the rise of the Pascola Arch (figs. 1 and 5) in southeastern Missouri, northeastern Arkansas, and western Tennessee produced a structural barrier that helped form the current shape of the Illinois Basin by closing off the embayment and separating it from the open sea to the south. The Illinois Basin is a broad, subsided region covering much of Illinois, southwestern Indiana, and western Kentucky (fig. 1). Development of the Pascola Arch, in conjunction with the earlier sinking of the deeper portion of the basin north of the Pascola Arch in southern Illinois, 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, windblown, and surface materials were removed.

Younger rocks of the latest Pennsylvanian and perhaps the Permian (the youngest rock systems of the Paleozoic) may have at one time covered the southern and northern portions of Illinois. Mesozoic and Cenozoic rocks (see the generalized geologic column at the front of the guidebook) might also 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 1.5 miles (7,920 feet) of latest Pennsylvanian and younger rocks once covered southern Illinois.

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. 8).

Later, during the Ice Age, the topographic *relief* was reduced by repeated advances and melting back of continental *glaciers* that scoured and scraped the bedrock surface. This glacial erosion affected all of the formations exposed at the bedrock surface in Illinois. The final melting of the glaciers left behind the non-lithified deposits in which our Modern Holocene soil has developed.

ANCIENT ENVIRONMENTAL HISTORY

The sediments that form the bedrock that underlies northwestern Illinois were laid down in a warm, tropical sea that covered the Midwest approximately 450 million years ago during the

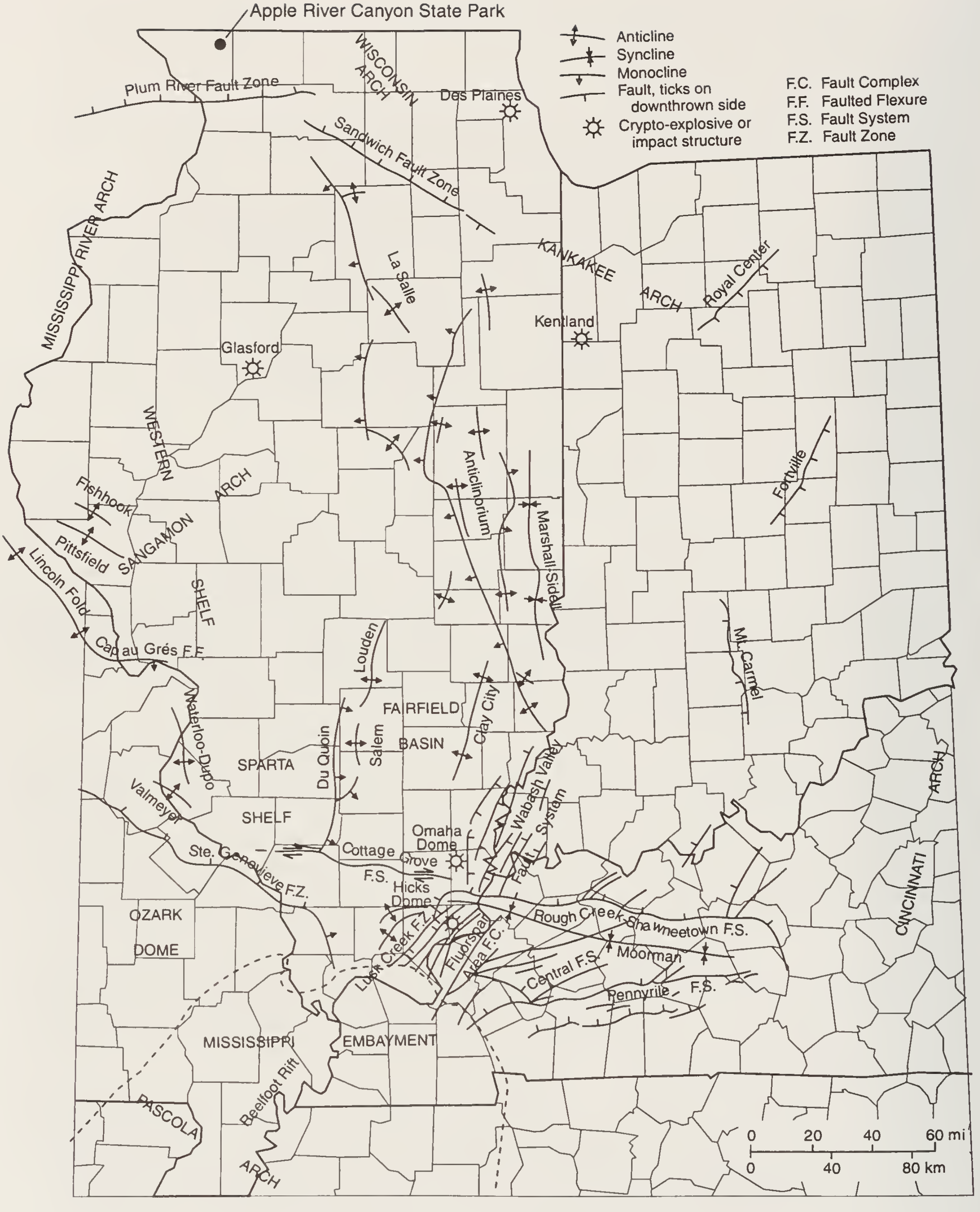


Figure 5 Structural features of Illinois (modified from Buschbach and Kolata 1991).

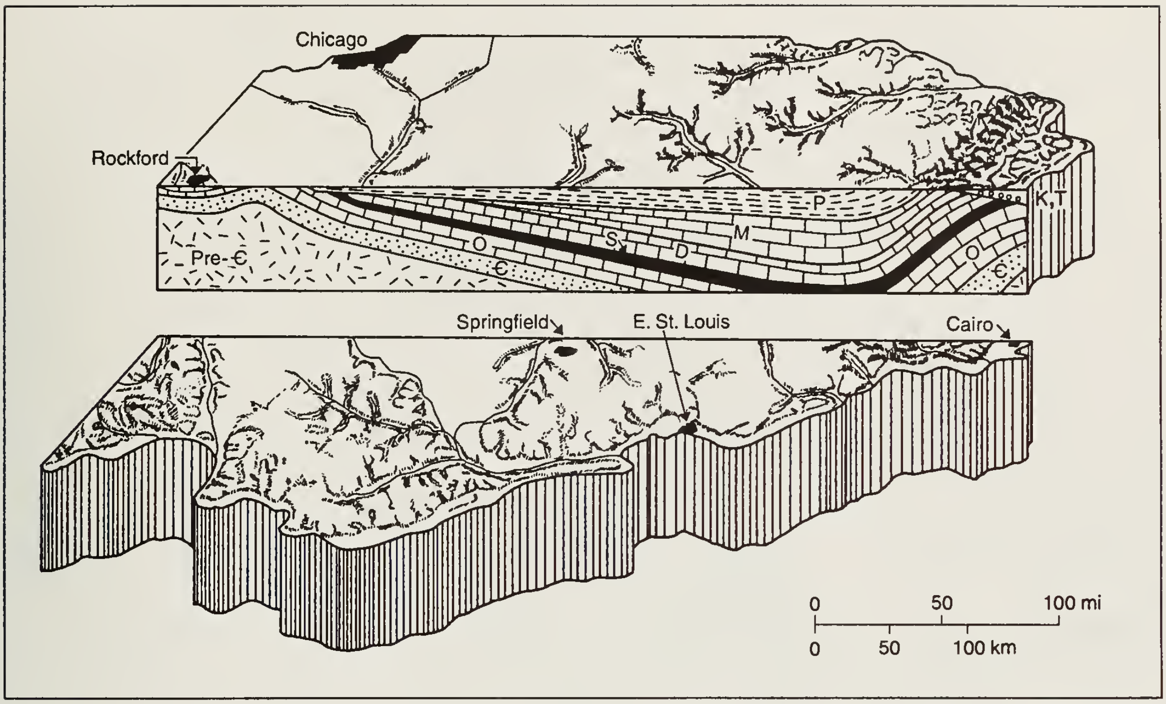


Figure 6 Stylized north-south cross section shows the structure of the Illinois Basin. To show detail, the thickness of the sedimentary rocks has been greatly exaggerated and younger, unconsolidated surface deposits have been eliminated. The oldest rocks are Precambrian (Pre-C) granites. They form a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

Ordovician Period. The environment was probably similar to that in the present Bahama Islands. The nearest land was situated about 500 miles to the north in Canada. During Ordovician time, North America straddled the equator, and northern Illinois was positioned at about 25 degrees South latitude (fig. 9). The prevailing wind direction during the Ordovician was out of the southeast (southeast trade winds) in contrast to the present, prevailing westerly wind direction. Occasionally, winds would carry clouds of fine ash into the area from explosive volcanic eruptions that occurred in the region of Alabama and Georgia. Those constituted some of the largest volcanic eruptions known on Earth. Two- to three-inch thick volcanic ash beds can be seen in several rock quarries in northwestern Illinois.

The flat, featureless, sea floor was teeming with invertebrate animals and algae. Shells of animals including trilobites, brachiopods, bryozoans, crinoids, snails, and clams accumulated on the sea floor along with mud formed from very fine calcium carbonate crystals secreted by algae. The carbonate mud and shells were slowly buried and, with time, began to solidify, producing beds of limestone. After several million years, numerous limestone beds were formed and stacked one on another. Evidence suggests that perhaps as much as a mile of sedimentary rocks (limestone, shale, and sandstone) were deposited in the region after the limestones formed. Hot groundwater containing dissolved salts and metals began to move slowly through the deeply buried limestone altering the rock to the mineral dolomite. Later fluid migration, approximately 270 million years ago, during the Permian Period, formed the galena (lead ore) lead and (sphalerite (zinc ore) zinc deposits in northwestern Illinois and southwestern Wisconsin. The galena deposits in northwestern Illinois have been radioisotope dated at 270 million years, the same date as the fluorspar deposits of

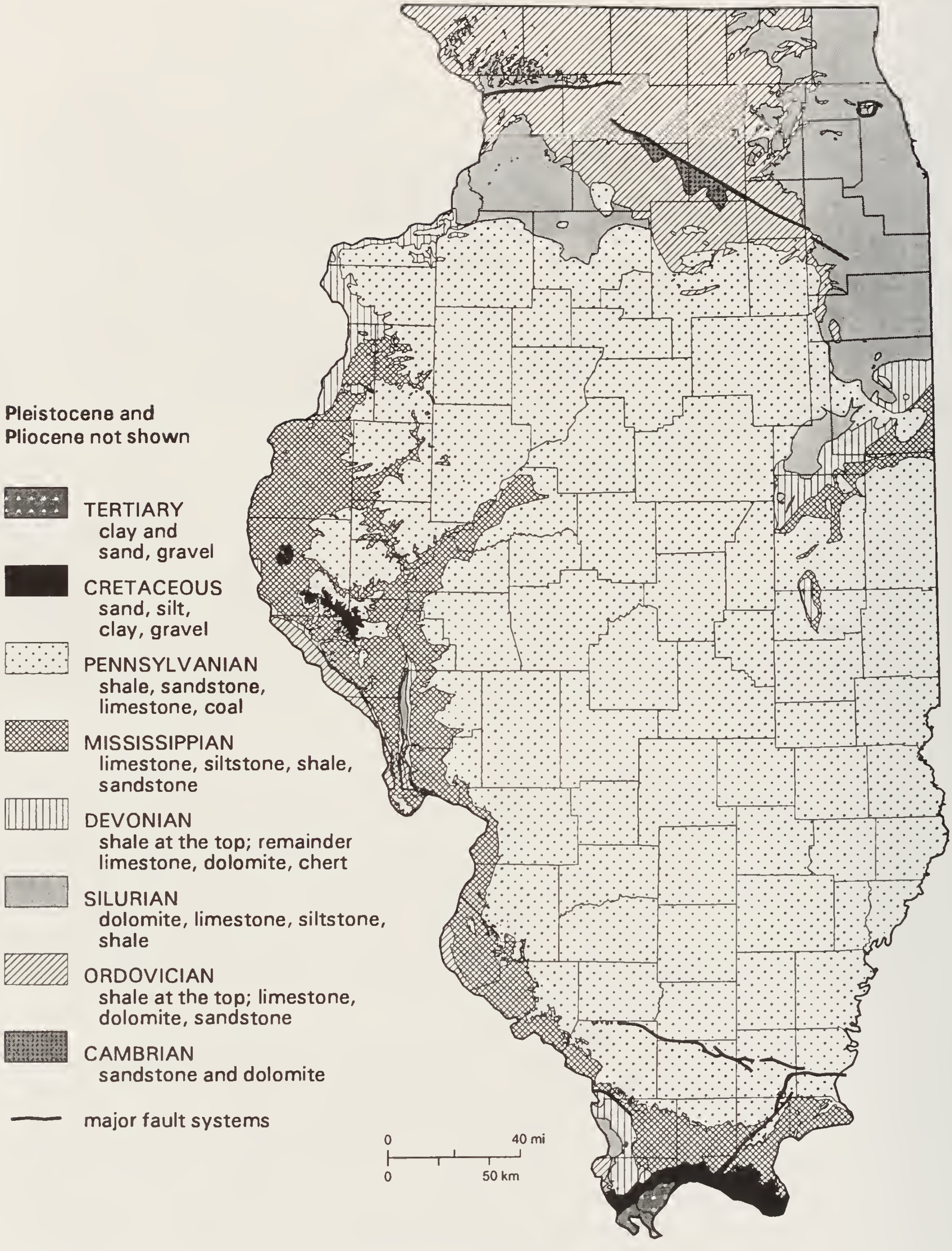


Figure 7 Bedrock geology beneath the surficial deposits in Illinois.

Figure 8 Bedrock valleys of Illinois (modified from Piskin and Bergstrom 1975).

southeastern Illinois. The fluid migration path was from the north to the south (D. Kolata and S. Nelson, personal communication 2002). Hot brines found their way through fractures in the limestone and dolomite, rose to the surface, cooled, and precipitated sulfide minerals, including galena (PbS) and sphalerite (ZnS).

About 250 million years ago, the seas withdrew from the region, and a long period of erosion began that continues today. The mile thick layer of sedimentary rocks slowly eroded away, exposing the ancient and now petrified sea floor with its abundant fossils. Outstanding specimens of trilobites, crinoids, starfish, and other rare fossils have been collected from the bedrock in northwestern Illinois. A large number of Ordovician and other fossil specimens are on exhibit at the Burpee Museum of Natural History in downtown Rockford.

STRATIGRAPHY

Bedrock Names

The Ordovician dolomite bedrock in northeastern Illinois is about 400 feet thick. It is divided into two major units called the Platteville Group (oldest) and the Galena Group (fig. 2). These are further subdivided into numerous subunits based mainly on the relative amount of shale, presence or absence of *chert*, and fossil content. Knowledge of the subtle subdivisions is useful in finding and producing crushed stone products; siting large construction sites such as bridges, dams, and power plants; and identifying potentially fossiliferous exposures of bedrock. The Platteville Group is underlain by the Glenwood Formation and the St. Peter Sandstone of the Ancell Group (fig. 2).

Ordovician Period The oldest rock exposed on the field trip is the middle Ordovician dolomite of the Galena Group (fig. 2), which formed from sediments deposited in the embayment that encompassed present-day Illinois about 468 million years ago. Most of the Galena Group strata are dolomite (calcium magnesium carbonate, or $CaMg(CO_3)_2$) that was originally deposited as limestone ($CaCO_3$) in the shallow seas of the embayment that covered what is now Illinois and adjoining states. The limestone was later altered to dolomite.

The total thickness of the Galena Group is about 270 feet. Except for a small amount of limestone, oil rock, and shale at the base and a few limestone layers and shaley partings near the top, the Galena Group consists of dolomite. It is crystalline, coarse grained, porous, and weathers into exceedingly rough, irregular forms. Hand specimens show small cavities, many of which are lined with dolomite or calcite crystals. The rock weathers into a coarse yellow dolomite sand. The Galena is crisscrossed with numerous joints and crevices. At nearly all of the places where these rocks are exposed, they are broken by cracks, which cross the strata at all possible angles and trend in various directions. The upper Ordovician Maquoketa Shale Group unconformably overlies the Galena Group. The mud that produced the shale was flushed into shallow areas from nearby low-lying land areas. These shales are the youngest Ordovician rocks and are about 200 feet thick.

Silurian Period The underlying Ordovician Maquoketa Shale was partially eroded before early Silurian sediments accumulated in shallow seas covering what is now referred to as the Driftless Area. Nearby low-lying lands generally did not contribute much sediment to the seas covering the region from 443 to about 417 million years ago. Most of the sediment deposited during this period consisted of limestone formed primarily from the shells of living organisms, both animals and plants. Early Silurian dolomite, which is the resistant caprock (top layer of rock) of the high ridges and mounds in the field trip area, reaches a maximum thickness of about 140 feet. Silurian strata may once have been thicker across the area, but subsequent erosion has removed it. Furthermore,

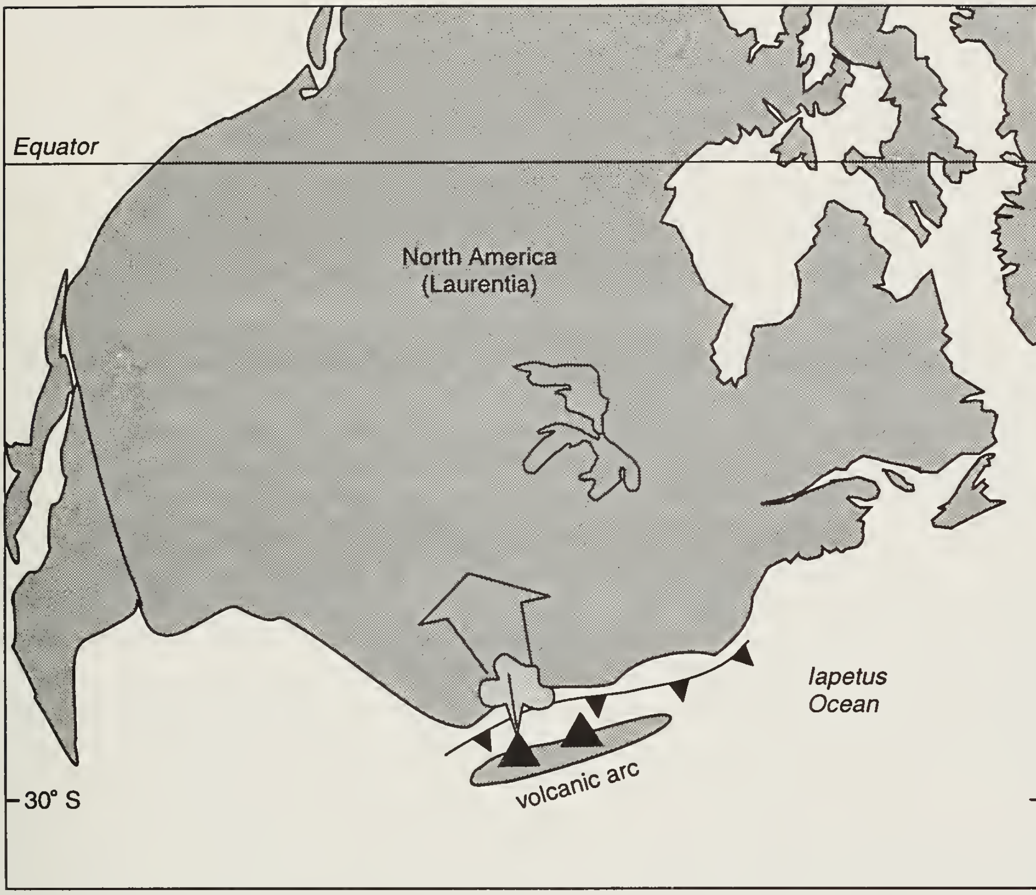


Figure 9 Middle Ordovician paleogeographic map of North America.

still younger rocks may also have been present, but long periods of erosion may have removed them as well.

Silurian formations constitute the upper part of the bedrock in the field trip area (fig. 2). Throughout the area where it only caps the knobs and ridges, the Silurian dolomite seldom is more than 75 feet thick and generally is much thinner. Because of a regional southward dip, the Silurian strata thicken to as much as 300 feet in the southern part of the Driftless Area (Kolata and Buschbach 1976). The contact between the underlying Maquoketa Shale is marked by an erosional unconformity.

The Mosalem Formation at the base is largely argillaceous, medium to dark gray, partly cherty dolomite that ranges from only a few feet to as much as 100 feet thick where it fills channels in the underlying Maquoketa Group (fig. 2). It weathers to yellow to brown. Although the formation is largely nonfossiliferous, fossils are present locally.

The overlying Tete des Morts Formation is a relatively pure, fine- to medium-grained, massive, slightly cherty, light gray dolomite that is 15 to 20 feet thick (fig. 2). It forms conspicuous cliffs at or near the top of the Silurian exposures in the ridges and knobs north of Hanover. South of Hanover it thins rapidly and disappears. The Tete des Morts dolomite is generally thicker-bedded with many pits or vesicles in it and looks different from the underlying Mosalem dolomite. Except for corals, particularly *Favosites*, fossils are scarce.

The uppermost units exposed often exhibit a weathered profile called *"geest"* (also called "residuum" or "terra rossa"). This typical red clay layer underlies thick deposits of loess where present, and overlies dolomite and limestone formations in northwestern Illinois. No glacial materials have been found in the geest deposits. The presence of geest directly overlying an erosional surface suggests that at least a major part of the geest deposits are Tertiary. The abundance of smooth, brown iron-stained coatings on deposits of white chert (on a fresh broken surface) in the geest and the presence of white chert in the underlying Silurian dolomite indicate that the geest on the highest erosional surfaces is largely residuum from solution of the underlying dolomite.

Regionally, the bedrock strata essentially are flat-lying, although there is a slight tilt of about 15 to 20 feet per mile to the southwest away from the Wisconsin Arch (figs. 1 and 5). The upland slopes are underlain by the Ordovician Maquoketa Shale. The ridge tops are capped by Silurian dolomite, which is quite resistant to erosion and, therefore, protects the underlying Maquoketa Shale. The lower elevation flats and stream valley walls consist of Ordovician dolomite.

The area's major structural features consist of low-amplitude northeast-southwest–trending synclines (downward arches) formed by a northwest-southeast compressive force. An east-west, preexisting joint system seems to have dissipated the shearing component of the northwest-southeast compressive force by yielding along fracture zones that were later favorable for ore deposition. Bradbury (1960) postulated that the staggered *(en echelon)* arrangement of north-northwest–trending smaller synclines and ore bodies may have formed as a result of a set of localized forces, such as might be created by a strike-slip (horizontal displacement) fault in the basement rocks.

STRUCTURAL SETTING

The Apple River Canyon State Park field trip area is located northwest of the Illinois Basin on the southwestern flank of the regional, broad, and gently sloping Wisconsin Arch (figs. 1 and 5). Paleozoic bedrock strata in the field trip area have a regional dip of 15 to 20 feet per mile to the southwest, except where it is affected by local structure.

Wisconsin Arch

The Wisconsin Arch (fig. 1) is a broad, positive area that separates the Michigan Basin on the east from the Forest City Basin on the west (basins not shown). The northern end of the Wisconsin Arch, termed the Wisconsin Dome, is a region where Precambrian rocks outcrop in northern Wisconsin. The rest of the arch is overlapped by Cambrian, Ordovician, and Silurian sedimentary rocks. The southeastern end of the Wisconsin Arch connects with the Kankakee Arch (fig. 5), which separates the Michigan and Illinois Basins (Nelson 1995). The Illinois Basin is the major structural depression between the Ozark Dome to the west, the Cincinnati Arch to the east, the Kankakee Arch to the north, and the Pascola Arch to the south (fig. 5).

The Wisconsin Arch apparently began to emerge late in the St. Croixan Epoch (Cambrian) and was well established by the middle of the Ordovician Period. It may have been covered by seas in the late Ordovician through middle Silurian time, but rose again in late Silurian or Devonian time (Nelson 1995).

PREGLACIAL HISTORY OF NORTHWESTERN ILLINOIS

The topography of northwestern Illinois has had a long history of development. Since the last Paleozoic sea withdrew from the midcontinent at the end of the Pennsylvanian Period some 290 million years ago, or possibly as late as the end of the Permian Period nearly 248 million years ago, the Upper Mississippi Valley region was uplifted and has remained a land area. During this long interval of erosion, many hundreds of feet of Paleozoic strata have been stripped away.

Erosion Surfaces During the 1890s investigators observed two apparent erosion surfaces in far northwestern Illinois: an upper surface at elevations of 1,000 to 1,150 feet on isolated mounds of Silurian dolomite and a lower surface at elevations of 900 to 1,000 feet on the top of the Ordovician age Galena dolomite. The upper surface was called the Dodgeville Peneplain, and the lower was called the Lancaster Peneplain (fig. 10). Both were named for towns in southwestern Wisconsin. Peneplaination was the "hot idea" at the end of the nineteenth and beginning of the twentieth centuries. As envisioned by William Morse Davis in a series of publications between 1896 and 1922, a *peneplain* is a surface of very low relief representing the final stage of an erosion cycle. The surface should be independent of bedrock structure and stratigraphic influence. At that time, peneplains were recognized at numerous locations on most continents. The best examples of peneplains in the United States occur along the Atlantic Coast and in the Appalachian and the Rocky Mountains. Multiple peneplains indicated cycles of uplift, dissection and downcutting by streams, and development of low relief surfaces, each erosion cycle taking millions of years.

The Dodgeville and the Lancaster Surfaces appear to be stratigraphically controlled and do not have deep regoliths. Because peneplains are supposed to truncate different stratigraphic units and have deep regoliths, an alternate interpretation for the the Dodgeville and Lancaster Surfaces is warranted. After the last Paleozoic sea withdrew from the midcontinent at the end of the Paleozoic, the Upper Mississippi Valley remained a land area, even during the Cretaceous highstand of sea level. Erosion dissected the region, and several topographic surfaces (five in Wisconsin) developed as successive stratigraphic units were partially removed. Each of these surfaces is on a relatively resistant unit (dolomite or sandstone) overlain by a relatively week unit (shale). Although these surfaces are not peneplains, the names Dodgeville and Lancaster are still useful to convey the sense of topography for the region. The Dodgeville Surface on Silurian dolomite is 350 to 400 feet above the modern valley floors, and the Lancaster Surface on the top of the Galena Dolomite is 150 to 200 feet above the modern valley floors. Relatively gentle slopes are present on the Maquoketa Shale. Steeper slopes and mounds are present on the Silurian dolomite formations above the Maquoketa and the Ordovician formations below the Maquoketa.

The present-day relief of the bedrock surface topography is closely related to the establishment of the Mississippi Valley through the region during the earliest pre-Illinois glacial episode. The Mississippi Valley probably was eroded to its maximum depth by meltwater during the latter stages of the pre-Illinois glacial episode. After that, the valley was alternately *aggraded* (built up) by

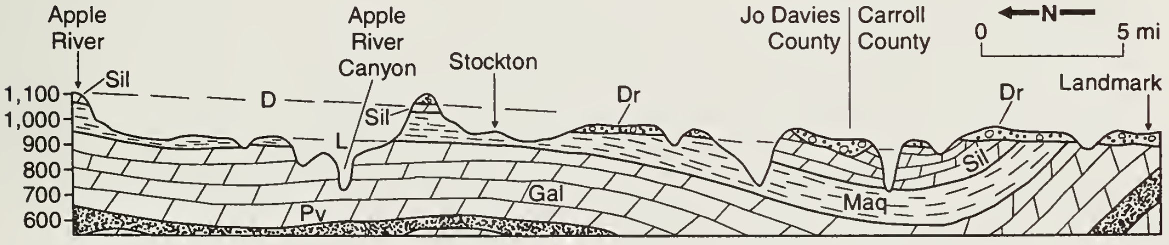


Figure 10 Cross section showing the Dodgeville (D) and Lancaster (L) erosion surfaces in northwestern Illinois and their relationship to the bedrock structure. The line of the section is from Apple River to Stockton to Lanark. Dr, glacial drift; Sil, Silurian dolomite; Maq, Maquoketa shale; Gal, Galena dolomite; and Pv, Platteville dolomite.

outwash and re-excavated during subsequent glacial and interglacial intervals. In the glaciated area to the east and south, till and outwash were deposited on the bedrock surface during the Illinois Glacial Episode. Loess was deposited on the uplands throughout the Upper Mississippi Valley region during the Illinois and Wisconsin Glacial Episodes. Deposition of a thick valley train in the Mississippi Valley during the late Wisconsin Woodfordian and Valderan Glacial Episodes aggraded the valley to a level approximately 30 feet above its present floodplain. This aggradation also resulted in alluviation of the tributary valleys. Since the last glacier melted away, the Mississippi River and its tributaries have been deepening their valleys into the Wisconsin alluvial deposits.

GLACIAL HISTORY OF ILLINOIS

Pleistocene Epoch (1.8 MY to 0.01 MY)

The Driftless Area was never overrun by the Pleistocene glaciers of the "Ice Age" (fig. 11). Nevertheless, the region has been profoundly affected by the events of the glacial period. As previously stated, preglacial erosion left a network of deep valleys carved into the bedrock surface (fig. 8). The present *topography* of Illinois is significantly different from the topography of the preglacial bedrock surface, which is largely hidden from view by glacial deposits except along the major streams and in the driftless areas of northwestern and southern Illinois (fig. 12). In many areas, the glacial drift is thick enough to completely mask the underlying bedrock surface. Studies of mine shafts, water-well logs, and other drill hole information and of scattered bedrock exposures in some stream valleys and road cuts show that the present land surface of the glaciated areas of Illinois do not reflect the underlying bedrock surface. The topography of the preglacial bedrock surface has been significantly modified by glacial erosion and is subdued by glacial deposits.

During the past 1.8 million years, during the Pleistocene *Epoch* of the Quaternary Period (also known as the Ice Age), much of northern North America was repeatedly covered by huge glaciers (see fig. 11). These continent-size masses of ice formed in eastern and central Canada as a result of climatic cooling. Their advances into the central lowland of the United States altered the landscape across much of the Midwest.

During an early part of the Pleistocene Epoch, glaciers advanced out of centers of ice accumulation both east and west of the Hudson Bay area in Canada (fig. 11, a and b). These centers are referred to in this guidebook as northeastern and northwestern source areas because Illinois lies to the south of and between these centers of accumulation. Glaciers flowing out of these centers into Illinois carried along rock debris incorporated into the ice as they advanced; the material was dropped out as the ice melted. The number and timing of these early episodes of glaciation are uncertain at present and are therefore unnamed, but, because they precede the first named glacial episode (the Illinois Episode; Hansel and Johnson 1996), they are called simply pre-Illinois glacial episodes (figs. 13 and 14). The pre-Illinois glacial episodes ended about 425,000 years ago.

A long interglacial episode, called the Yarmouth, followed the last of the pre-Illinois glacial advances (figs. 13 and 14). The Yarmouth interglacial episode is estimated to have lasted approximately 125,000 years, and deep soil formation took place during that long interval (Yarmouth Geosol). On the parts of the landscape that were generally poorly drained, fine silts and clays that slowly accumulated (accreted) in shallow, wet depressions formed what are called accretion gleys, which are characterized by dark gray to black, massive, and dense *gleyed* clays.

Approximately 300,000 years ago, the Illinois Episode of glaciation began. It lasted for about 175,000 years, and, during this interval, the ice advanced three times out of the northeastern center of accumulation (figs. 11c and 13). During the Illinois Episode, North American continental glaciers

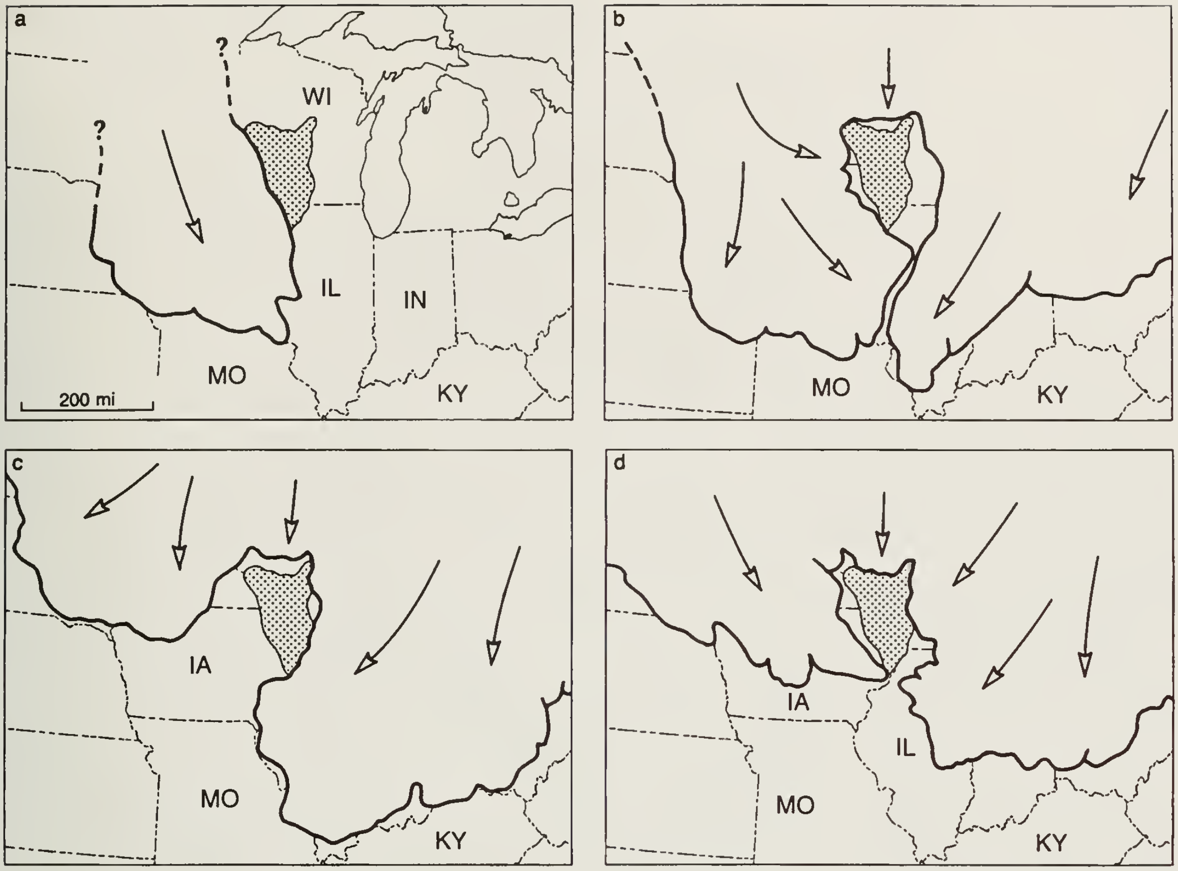


Figure 11 Maximum extent of (a) early pre-Illinois glacial episode (1,000,000 + years ago); Driftless Area shown by stippled pattern; arrows indicate direction of ice movement; (b) late pre-Illinois glacial episode (600,000 + years ago); (c) Illinois Glacial Episode (250,000 + years ago); and (d) late Wisconsin Glacial Episode (22,000 years ago).

reached their southernmost position in the northern part of Johnson County (fig. 12). Locally the glacier stopped approximately 3 miles east of the Apple River State Park. A line indicating the westernmost advance of the Illinois glacier can be drawn from just east of Warren to the east edge of Stockton. During the first of these advances, ice of this episode reached westward across Illinois and into Iowa, south of the Driftless Area (fig. 11c).

Another long interglacial episode, called the Sangamon (figs.13 and 14), followed the Illinois Episode and lasted about 50,000 years. Although shorter than the Yarmouth, this interglacial interval's length was long enough for another major soil, called the Sangamon Geosol, to develop. The Sangamon Geosol exhibits both well-drained and poorly drained soil profiles; although accretion gleys are not as pronounced as they are in the Yarmouth Soil, their occurrence is common across the Sangamon landscape, and they are easily identified by the same characteristics as the Yarmouth accretion gleys.

The Wisconsin Episode of glaciation began about 75,000 years ago (figs. 11d, 13, and 14). Ice from the early and middle parts of this episode did not reach into Illinois. Although late Wisconsin ice did advance across northeastern Illinois beginning about 25,000 years ago, it did not reach southern or western Illinois (figs.11d and 12). The late Wisconsin glaciation is represented in the field trip area by the windblown silts (*loess*) that blanket the landscape and compose the parent

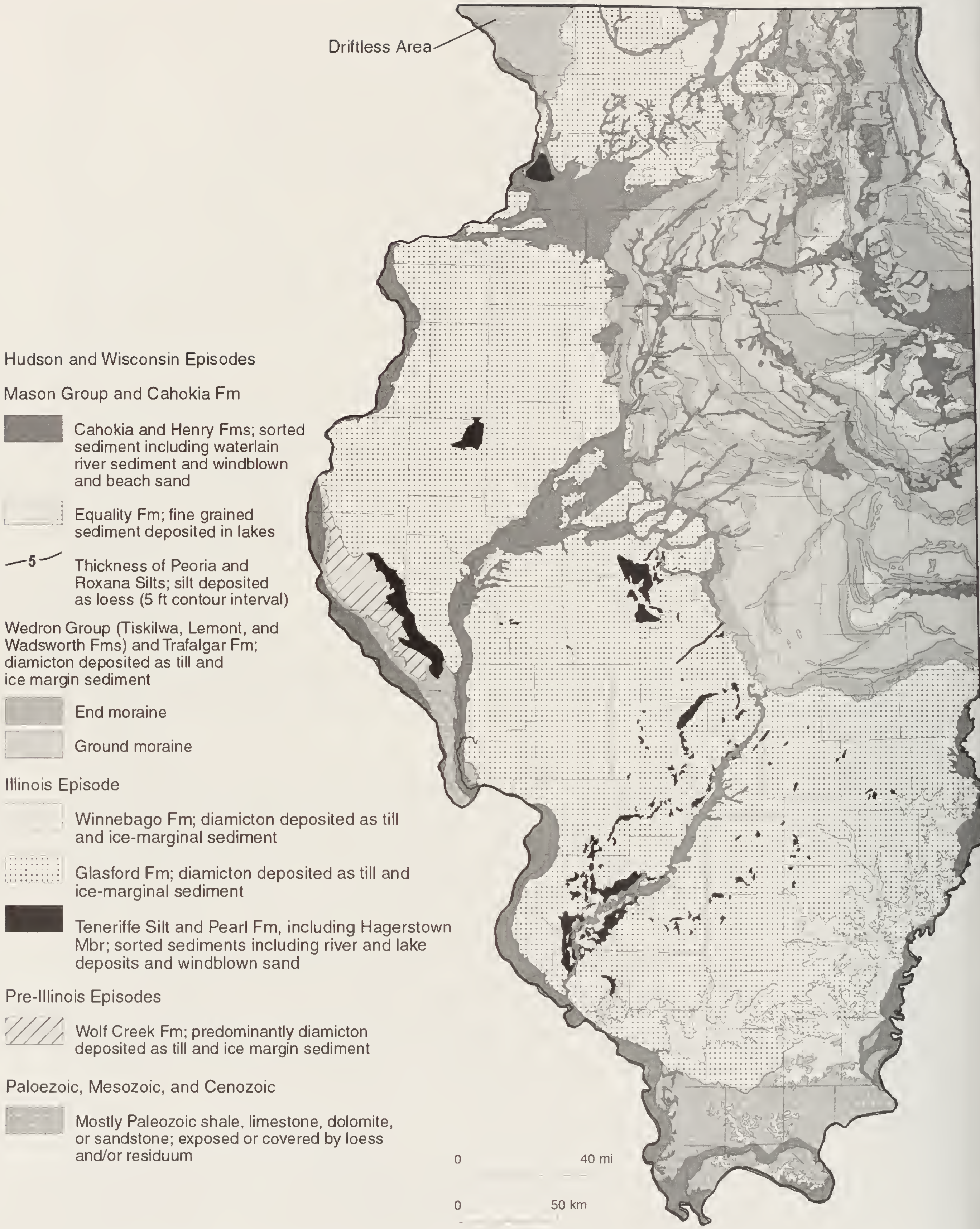


Figure 12 Generalized map of the glacial deposits in Illinois (modified from Willman and Frye 1970).

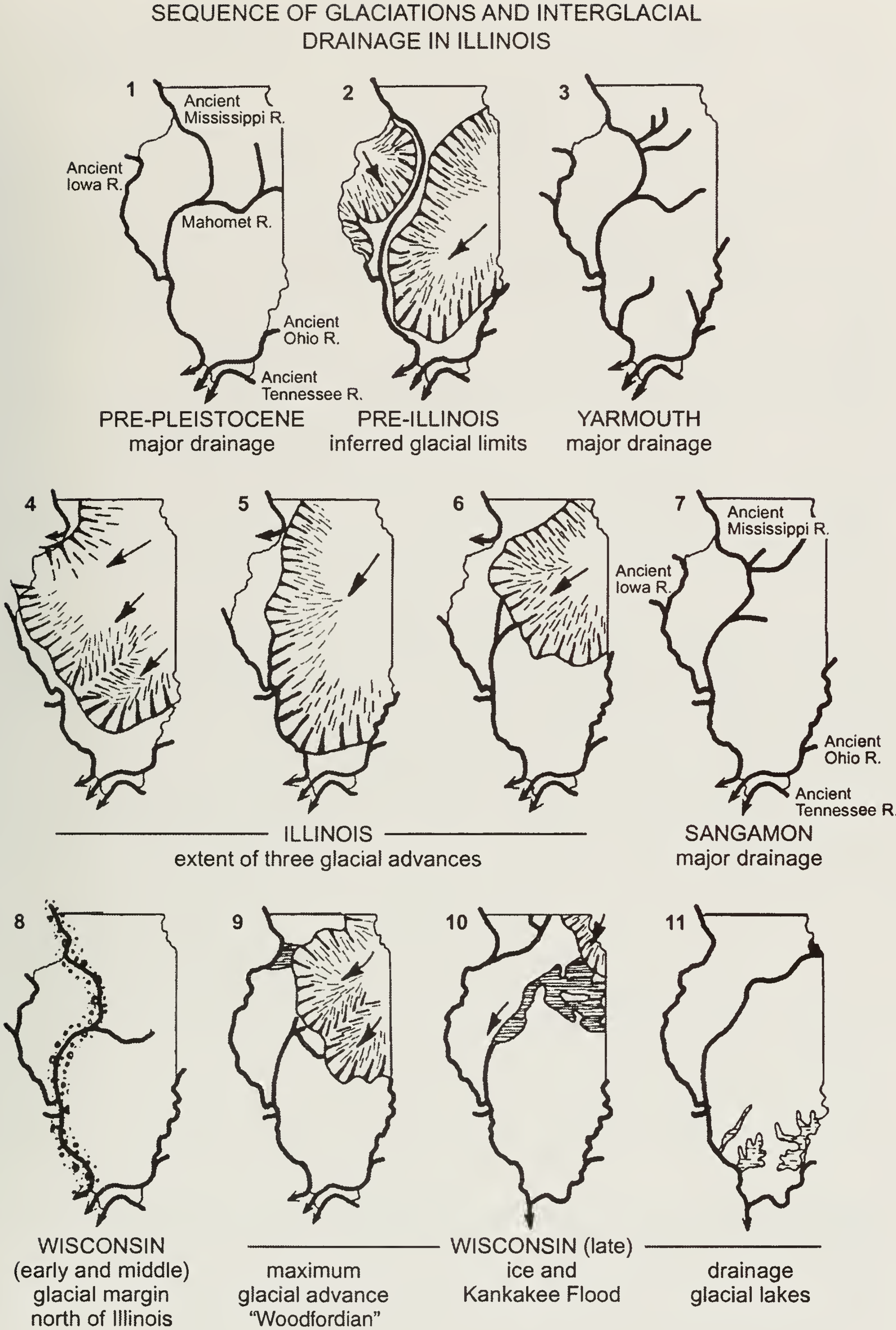


Figure 13 The sequence of glaciations and interglacial drainage in Illinois.

Years before present	Time-distance diagram Interglacial and glacial episodes	Sediment record	Dominant climate conditions Dominant land forming and soil forming events
HOLOCENE	interglacial episode	River, lake, wind, and slope deposits.	Warm; stable landscape conditions. Formation of modern soil; running water, lake, wind, and slope processes.
PLEISTOCENE EPOCH (not to scale) 10,000	WISCONSIN (late) glacial episode; glacial ice	Till and ice-marginal deposits; outwash and glacial lake deposits; loess. 6	Cold; unstable landscape conditions. Glacial deposition, erosion, and landforming processes (e.g., formation of end moraines, outwash plains, valley trains, proglacial lakes, kettles), plus running water, lake, wind, and slope processes.
25,000	WISCONSIN (early and middle) glacial margin north of Illinois	Loess; river, lake, and slope deposits. 5	Cool; stable. Weathering, soil formation (Farmdale Soil and minor soils); wind and running water processes.
75,000	SANGAMON interglacial episode	River, lake, wind, and slope deposits. 4	Warm; stable. Weathering, soil formation (Sangamon Geosol); running water, lake, wind, and slope processes.
125,000	ILLINOIS glacial episode	Till and ice-marginal deposits; outwash and glacial lake deposits; loess. 3	Cold; unstable. Glacial deposition, erosion, and landforming processes, plus proglacial running water, lake, wind, and slope processes; possible minor soil formation.
300,000	YARMOUTH interglacial episode	River, lake, wind, and slope deposits. 2	Warm; stable. Long weathering interval with deep soil formation (Yarmouth Geosol); running water, lake, wind, and slope processes.
425,000 – 1,600,000 and older	? PRE-ILLINOIS glacial and ? interglacial episodes	Till and ice-marginal deposits; outwash and glacial lake deposits; loess plus nonglacial river, lake, wind, and slope deposits. 1	Alternating stable and unstable intervals of uncertain duration. Glacial deposition, erosion, and landforming processes, plus proglacial and interglacial running water, lake, wind, and slope processes; interglacial weathering and soil formation.

Figure 14 Timetable illustrating the glacial and interglacial events sediment record, and dominant climate conditions of the Ice Age in Illinois (modified from Killey 1998).

materials for our modern Holocene Epoch soils. The maximum thickness of the later Wisconsin Episode glaciers was about 2,000 feet in the Lake Michigan Basin, but only about 700 feet over most of the Illinois land surface (Clark et al. 1988). The last of these glaciers melted from northeastern Illinois about 13,500 years ago.

Wisconsin Episode moraines were deposited in Illinois from approximately 25,000 to 13,500 years ago (fig. 12). Although Illinois Episode glaciers probably built morainic ridges similar to those of the later Wisconsin Episode glaciers, the Illinois Episode moraines apparently were not as numerous and have been exposed to weathering and erosion for approximately 280,000 years longer than their younger Wisconsin Episode counterparts. For these reasons, Illinois Episode glacial features generally are not as conspicuous as the younger Wisconsin Episode features.

In general, glacial deposits consist primarily of (1) *till*—pebbly clay, silt, and sand, deposited directly from melting glaciers; (2) outwash—mostly sand and gravel, deposited by the rapidly flowing meltwater rivers; (3) *lacustrine deposits—silt* and clay that settled out in quiet-water lakes and ponds; and (4) loess—windblown sand and silt.

Although glaciers did not advance over the field trip area or completely surround it at any one time during the major ice advances (fig.11), outwash deposits of silt, sand, and gravel were dumped along the Mississippi Valley. When these deposits dried out during the winters, strong prevailing winds from the west (the westerlies) winnowed out the finer materials, such as fine sand and silt, and carried them eastward across the unglaciated terrain.

The loess (pronounced "luss") that mantles the bedrock and glacial drift throughout the field trip area was laid down by the wind during all of the glacial episodes, from the earliest pre-Illinois glacial episode (approximately 1.6 million years ago) to the last glacial episode, the Wisconsin Episode (which occurred approximately 25,000 to 13,500 years ago). This yellowish brown silt occurs on the uplands and mantles the bedrock throughout the field trip area. The loess is generally between 20 to 25 feet thick, but erosion has completely removed the loess in scattered areas, especially atop the bluffs along the Mississippi River valley. In general, the thickness of the loess decreases to the east. The loess, which covers most of Illinois, is up to 15 feet thick along the Illinois River valley and is more than 50 feet thick, in some localities, along the east edge of the Mississippi River valley.

GEOMORPHOLOGY

Wisconsin Driftless Section

Physiography is a general term used for describing landforms; a physiographic province is a region in which the relief or landforms differs markedly from those is adjacent regions. The field trip area is located in the Wisconsin Driftless Section of the Central Lowland Physiographic Province (fig.15). This unglaciated area covers about 10,000 square miles and extends northward into southwestern Wisconsin and northwestward into northeastern Iowa and southeastern Minnesota. The easternmost part of the field trip parallels the Rock River Hill Country of the Till Plains Section.

The Wisconsin Driftless Section, or "Driftless Area" as it is commonly called, has some of the most rugged topography in Illinois. The Driftless Area is a submaturely, deeply dissected, low plateau bounded by the outwash-filled valley of the Upper Mississippi River to the west and the margin of the Illinois Glacial Episode on the east and southeast. The high hills and sharp ridges are underlain by dolomitic strata, and the sweeping slopes and wide valleys are generally eroded into the less resistant underlying shales. Only loess, in which the modern soils developed, mantles the deeply dissected bedrock surface. Remnants of the former upland surface remain, but most of the

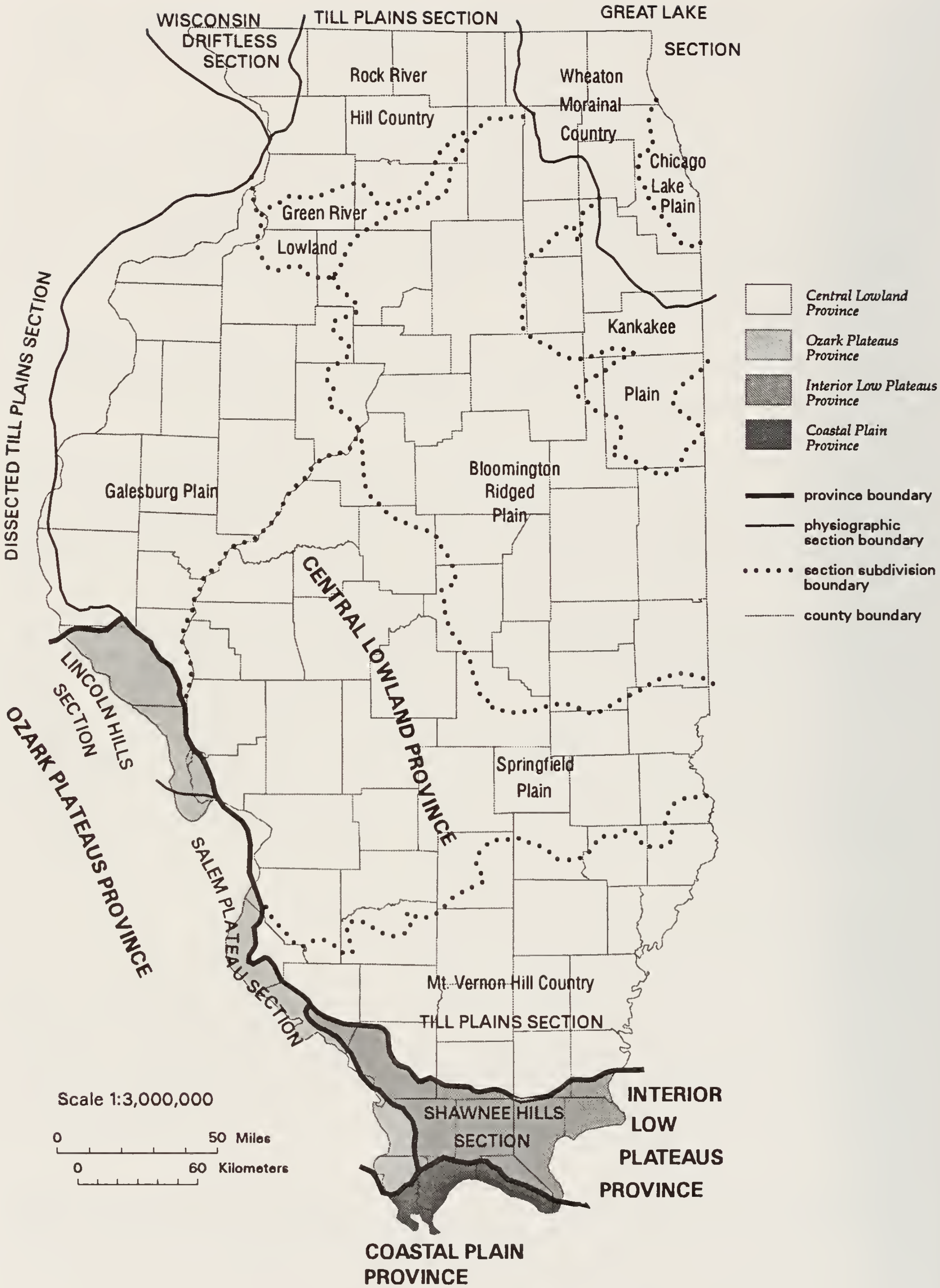


Figure 15 Physiographic divisions of Illinois (modified from Leighton et al. 1948).

area is in slopes that dip rather steeply toward the streams. The major streams are flowing in rather broad, steep-walled valleys, and relatively flat upland areas still remain. Except for the major streams, most drainage is via a system of V-shaped, steep-walled, relatively short tributaries with steep *gradients* (longitudinal bottom slope). Some of the minor tributaries have incised *meanders*. Major streams flow from a central upland westward to the Mississippi River and eastward and southward to the Rock River. Alluvium, relatively modern deposits along the streams, has been eroded, leaving terraced remnants along the valley walls. *Sinkholes* (depressions caused by dissolution of underlying dolomite) and other karst features, although present, are not conspicuous. Topography in the adjacent glaciated area of the Rock River Hill Country (fig. 15) is more subdued than in the Driftless Area. Here the thin Illinois glacial deposits—which barely mask the irregularities of the major uplands and valleys formed by pre-Illinois erosion of the bedrock—have produced a rolling landscape.

Rock River Hill Country

The Rock River Hill Country is characterized by subdued, rolling hill lands in the stage of late youth to early maturity. It includes the eroded Illinois glacial drift plain north of the Bloomington Moraine and Meredosia Valley and a fringe of early Wisconsin drift, which lies west of Marengo Ridge.

The Illinois glacial drift is thin throughout most of the district and is not known to be underlain by older till. Thus, the major uplands and valleys are determined primarily by the bedrock surface. The Illinois glacial drift is without marked ridging, and constructional forms are very localized. In the western part of the district, where it borders the Mississippi Valley, thick deposits of loess and fine sand occur as broad ridges, *paha,* and dunes on the Illinois glacial till plain.

The major streams flow radially from a central upland into the Mississippi River on the west and the Rock River on the east and south. Their valleys are relatively broad and steep walled and have terrace remnants of alluvial fill. The Mississippi River and the upper part of the Rock River occupy large alluviated valleys. Below the mouth of Kishwaukee River, sometime after the Illinois Glacial Episode, the Rock River has cut a rock gorge that extends south to the Green River Lowland. Numerous smaller rock gorges are also present along tributaries that locally are superimposed on spurs of the bedrock upland. Most of the minor streams are narrow and V-shaped.

NATURAL DIVISIONS AND GEOLOGY

Glacial history has played an important role in shaping Illinois topography by eroding the preglacial landscape and depositing glacial sediments. Topography influences the diversity of plants and animals (biota) of Illinois by strongly influencing the diversity of habitats. Geological processes form, shape, and create the topography on all of the Earth's surface. Specifically, geology not only determines the composition of the parent material of soils, but geological processes also form soils through the weathering of parent materials. Thus, the geology of a region is the foundation of its habitats.

Natural Divisions

The state has been divided into 14 different Natural Divisions. These divisions are distinguished according to differences in significant aspects of topography, glacial history, bedrock geology, soils, aquatic habitats, and distribution of plants and animals (flora and fauna). A strong relationship exists between the Physiographic Divisions of Illinois and the Natural Divisions of Illinois because the geologic factors used to determine the Physiographic Divisions were important elements used to define the boundaries of the Natural Divisions. The following descriptions of the Natural Divisions are modified from Schwegman (1973).

Wisconsin Driftless Division

The Wisconsin Driftless Division is part of an area extending from northwestern Illinois into Wisconsin, Iowa, and Minnesota that escaped Pleistocene glaciation. This division is one of the most maturely developed land surfaces in Illinois and is characterized by rugged terrain and a dissected pattern of wooded ridges; the division includes such prominent features as canyons, ravines, bluffs, and palisades. Originally most of the area was forested. The area has the coldest climate in the state and contains several distinctive plants of northern affinity and some species that may represent relicts of the pre-Ice Age flora. In Illinois, algific slopes—north-facing rocky slopes that retain subsurface ice through most of the year—occur only in the Driftless Area. The cold microclimate created on the surface of the slope supports relict northern and Pleistocene biota, including many endangered, threatened, and rare species.

- ***Bedrock*** The Wisconsin Driftless Division is a maturely dissected upland of Ordovician and Silurian limestone, dolomite, and shale. Bedrock crops out along the major watercourses. Promi nent "mounds" capped with the more resistant dolomite are common. A mineralized zone containing deposits of lead and zinc is an important feature. Caves are known in the dolomite.

- ***Topography*** The topography of the division is one of rolling hills and great relief, particularly along interior stream canyons. High erosional remnants are prominent features. There are loess-capped bluffs and palisades along the Mississippi River valley and ravines and bluffs throughout the division.

- ***Soils*** The soils of this division have developed from loess or, on steeper slopes, from loess on bedrock. The loess soils are derived from thick deposits and are weakly to moderately developed. The soils on bedrock are thin to moderately thick and well drained.

Drainage The Mississippi River is the major drainageway in northwestern Illinois. The main tributary in the field trip area is Apple River, which flows southwest to the master stream. The larger tributaries include Clear Creek, Kentucky Creek, Mud Run, Hell's Branch, and Mill Creek. The major streams have flat floodplain areas, and stream channels in the major valleys generally meander freely. A well-developed network of smaller, V-shaped, steep-gradient tributaries has grown headward into the upland remnants. Considerable subsurface drainage occurs through small caves and solution channels that have developed in the dolomite bedrock.

Relief Relief is defined as the vertical difference in elevation between the hilltops or mountain summits and the lowlands or valley bottoms of a particular area. The highest point along the field trip route is Charles Mound (the highest point in Illinois) at 1,241 feet above mean sea level (msl), located northeast of the community of Scales Mound just south of the Wisconsin state line. The lowest elevation on the route is 763 feet msl at the intersection of North Hammer Road and North Mill Creek Road (NW/4, Sec. 18, T28N, R3E). Therefore, the relief along the route is slightly more than 478 feet, and local relief of 150 to 200 feet is fairly common, especially along the bluffs bordering the Apple River.

NATURAL RESOURCES

Mineral Production

The field trip area is located within the eastern part of the Zinc and Lead District of northwestern Illinois. Areas of mineralization in Illinois, Iowa, and Wisconsin make up the Upper Mississippi Valley District. The Illinois portion of the district has a history of lead mining that dates from Native American mines from the late 1700s. The last commercial zinc and lead operation in Illinois closed in 1973.

The total value of all minerals extracted, processed, and manufactured in Illinois during 1998 was $1,950,000,000. Extracted minerals accounted for 86.4% of this total. Coal continued to be the leading commodity, followed by construction stone (limestone and dolomite), sand and gravel, and oil. The 2001 Illinois production data for stone and sand and gravel was $547,000,000. Illinois ranked 5th among coal-producing states, 13th among the 31 oil-producing states, and 16th among the 50 states in total production of nonfuel minerals but continues to lead all other states in production of industrial sand and tripoli. Jo Daviess County mineral production is currently limited to dolomitic stone and sand and gravel deposits.

Groundwater

Few of us are likely to think of groundwater as a mineral resource when we consider the natural resource potential of an area. Yet the availability of groundwater is essential for orderly economic and community development. More than 48% of the state's 11 million citizens and 97% of those who live in rural areas depend on groundwater for their water supply.

The source of groundwater is precipitation that infiltrates the soil and percolates into the groundwater system lying below the water table in the zone of saturation. Groundwater is stored in and transmitted through saturated earth materials called aquifers. An *aquifer* is any body of saturated earth materials that will yield sufficient water to serve as a water supply for some use. Pores and other void spaces in the earth materials of an aquifer must be permeable; that is, they must be large enough and interconnected so that water can overcome confining friction and move readily toward a point of discharge such as a well, spring, or seep. Generally, the water-yielding capacity of an aquifer can be evaluated by constructing wells into it. The wells are then pumped to determine the quantity and quality of groundwater available for use.

Thick permeable sand and gravel deposits occur locally in the Mississippi Valley, and some may be found in the major tributaries, especially in the lower parts of their valleys. Electrical earth resistivity surveys (a geophysical method for characterizing buried sand and gravel deposits) can be useful in locating groundwater supplies in these valleys.

Silurian and Ordovician dolomite units are creviced and water-bearing. Most domestic water wells in the area get their water from these creviced formations at depths of less than 250 feet and are susceptible to bacterial pollution, particularly where the formation is overlain by less than 35 feet of *overburden* (soil and/or unconsolidated materials above the formation). Open crevices provide little filtering action, and polluted water may travel long distances through these openings with little loss of pollutants.

Future of Mineral Industries in Illinois For many years, the mineral resources of the midcontinent have been instrumental in the development of the nation's economy. The mineral resource extraction and processing industries continue to play a prime role in our economy and in our lives, and they will continue to do so in the future.

The prime mission of the ISGS is to map the geology and mineral resources of the state, conduct field mapping, collect basic geologic data in the field and in the laboratory, and interpret and compile these data on maps and in reports for use by industry, the general public, and the scientific community. Over the years, maps of the geology of the state have been published at various scales. Recently, more detailed maps and reports covering particular regions have been completed. To meet growing demands for detailed geologic information to guide economic development and environmental decision-making, the ISGS is conducting a program to geologically map the 1,071 Illinois 7.5-minute quadrangles of Illinois.

Scattered throughout Jo Daviess County are some farming practices that are not so common elsewhere in Illinois. Crops, which are planted in strips following the contour around the hills and along slopes, appear like a patchwork quilt. This practice minimizes erosion on the steep slopes in this region. In some cases, ridges have been constructed following the contour around the hills, and the crops are planted in the flatter areas behind the ridge crest. This practice helps conserve moisture by reducing run-off from the field. In some locations, you see grass strips from high up on the slopes heading downslope—these are grass-waterways. Thick, coarse grass is established to minimize downcutting of surface run-off. The result is that you see very few gullies here compared with the number you see elsewhere in the state, despite the steepness of the slopes and the easily eroded shale that underlies the loessal soils.

GUIDE TO THE ROUTE

We will start the field trip at the Apple River Canyon State Park, at the Devil's Hollow Picnic Area Shelter (SW, NE, SW, Sec. 4, T28N, R4E, 4th P.M., Elizabeth NE 7.5-minute Quadrangle, Jo Daviess County). Mileage will start at the entrance to the shelter's parking lot. Set your odometer to 0.0.

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!
- Stay off of all mining equipment.
- Parents must closely supervise their children at all times.

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 (Apple River, Elizabeth NE, Scales Mound East, Scales Mound West, Shullsburg, and Warren) provide coverage for this field trip area.

START: The field trip will begin with a hike along the Primrose Nature Trail in Apple River Canyon State Park (SW, NE, SW, Sec. 4, T28N, R4E, 4th P.M., Elizabeth NE 7.5-minute Quadrangle, Jo Daviess County).

Miles to next point	Miles from start	
0.0	0.0	Exit parking lot and TURN LEFT onto West Canyon Road and cross bridge over the North Fork of the Apple River.
0.1	0.1	Pass the trail head for the Primrose Nature Trail on the left.
0.1	0.2	STOP (one-way). T-intersection (West Canyon Road and North Canyon Park Road). TURN LEFT. Begin the ascent out of the Apple River Canyon.
0.05	0.25	YIELD SIGN. Y-intersection (North Canyon Park Road and East Canyon Road). BEAR LEFT onto North Canyon Park Road.
0.1	0.35	Entrance to Canyon River Campground on the left. CONTINUE AHEAD.
0.35	0.7	Road flattens out as you cross the north edge of Apple River Canyon.
0.25	0.95	Road curves 90 degrees to the left.
0.25	1.2	Road curves 90 degrees to the right.
0.5	1.7	Road curves 90 degrees to the left. T-intersection (North Canyon Park Road and Sweet Home Road). TURN LEFT and follow North Canyon Park Road. NOTE: No stop sign at the intersection.
0.25	1.95	Cross a small creek, an unnamed tributary of Apple River. The road immediately curves 90 degrees to the right.
1.05	3.0	Crossroad intersection (North Canyon Park Road and East Twin Bridges Road). TURN RIGHT onto East Twin Bridges Road. The large mound northwest of the intersection is Squirrel Grove Mound. This mound is capped by Silurian dolomitic bedrock.
0.3	3.3	Cross unnamed tributary of Clear Creek.
1.2	4.5	Cross first bridge over Clear Creek. Immediately past bridge, on the left, is the entrance to an abandoned quarry.

STOP 1: Rutherford's Quarry and Dolomite Prairie (SW, SW, NE, Sec. 27, T29N, R4E, 4th P.M., Elizabeth NE 7.5-minute Quadrangle, Jo Daviess County). On the day of the field trip, we will park along the road.

0.0	4.5	Leave Stop 1. Retrace your route back to Twin Bridges Road.
0.1	4.6	Entrance to abandoned quarry. TURN LEFT onto Twin Bridges Road (heading east).

0.05	4.65	Cross bridge over the east fork of Clear Fork. Notice the gray clayey soil in the ditch along the road just past the bridge. This soil is characteristic of soils developed in a wetland.
0.15	4.8	T-intersection from the right (Bausman Road). CONTINUE AHEAD. Road makes a series of 90 degrees turns to the left and then to the right.
0.6	5.4	Road heading east.
0.45	5.85	T-intersection from the left (Slaughter House Road). CONTINUE AHEAD.
0.25	6.1	Road curves 90 degrees to the right.
0.25	6.35	Road curves 90 degrees to the left. Looking to the northeast, you can see the city of Warren, population 1,595. Warren was started by two entrepreneurs, Capt. Alexander Burnett and Freeman A. Tisdel. The town is named after Capt. Burnett's first son. The Warren Cheese Plant, the home of Apple Jack Cheese, produces 4.5 million pounds of cheese a year.
0.25	6.6	STOP (one-way). T-intersection (North Fiedler Road and East Twin Bridges Road). TURN RIGHT onto North Fiedler Road heading south.
0.05	6.65	Angle intersection from the left (East Hicks Road). CONTINUE AHEAD.
0.8	7.45	Road curves 45 degrees to the right.
0.25	7.7	T-intersection from the right (Sweet Home Road). CONTINUE AHEAD on North Fiedler Road. We are traveling across the relatively flat Dodgeville Surface. This erosional surface represents the top of the Ordovician age, Galena Dolomite.
0.6	8.3	T-intersection from the left (Mahoney Road). CONTINUE AHEAD.
1.0	9.3	Note the stand of native birch trees on the right. The Driftless Area of Illinois is one of the few places in Illinois where native birch trees can be found.
0.1	9.4	STOP (two-way). Crossroad intersection (East Canyon Road and North Fiedler Road). CONTINUE AHEAD. **USE CAUTION: Dangerous intersection.**
0.2	9.6	Y-intersection (North Kuppersmith Road and East Fiedler Road). BEAR LEFT onto North Kuppersmith Road (heading south). Note: The main road (East Fiedler Road) curves 45 degrees to the right.
0.75	10.35	Road jogs to the right and then back to the left. Note the outcrop of Galena dolomite on the left. The high ridge to the south is Benton Mound, which is capped by Silurian dolomitic bedrock.

0.45	10.8	Cross the South Fork of the Apple River. STOP (two-way) immediately south of bridge. Crossroad intersection (Rush Town Road and North Kuppersmith Road). CONTINUE AHEAD. The South Fork of the Apple River currently flows to the northwest. Prior to the Illinois Glacial Episode, the pre-glacial river that occupied this valley flowed to the southeast and eventually emptied into the ancient Pecatonica River, which flowed into the ancient Rock River. The South Fork of the Apple River is an underfit stream with respect to the size of the valley it occupies.
0.6	11.4	View of Youngbluth Quarry on the left.
0.2	11.6	Cross narrow bridge over a small unnamed branch to Mud Run Creek. Weight limit is 3 tons. Road immediately curves 90 degrees to the left. Although unmarked, the road changes name at the curve; you are now on Chelsea Road.
0.15	11.75	Cross the narrow bridge over Mud Run Creek.
0.15	11.9	Stop 2. Entrance to Youngbluth Quarry is on the left. TURN LEFT into quarry and park on the quarry floor.

STOP 2: Youngbluth Quarry (NE, NW, NW, Sec. 23, T28N, R4E, 4th P.M., Elizabeth NE 7.5-minute Quadrangle, Jo Daviess County). Pull into the quarry and park on the bed of the quarry. Please wait for instructions from your field trip leaders before you attack the outcrop.

0.0	11.9	Leave Stop 2 and retrace your route back to the quarry entrance.
0.5	12.4	At the exit of the quarry, TURN LEFT onto Chelsea Road.
0.3	12.7	Cross Mud Run Creek.
0.2	12.9	T-intersection from the left (Rush Town Road). CONTINUE AHEAD. Intersection is unmarked.
0.25	13.15	STOP (two-way). Crossroad intersection (Chelsea Road and Stockton Road). TURN RIGHT onto Stockton Road. Intersection is unmarked. Road ascends hill and immediately begins to drop down into a large valley eroded by Mud Run Creek. There is a view of Benton Mound to the southwest.
1.05	14.2	Cross bridge (unnamed branch of Mud Creek). STOP (two-way). Crossroad intersection on the south side of the bridge (Stockton Road and Greenvale Road). TURN RIGHT onto Greenville Road. Intersection is unmarked. This intersection is in the middle of the old paleo drainage channel where the Apple River used to flow from the northwest to the southeast. Looking to the southeast, you can see a low in the landscape, which marks the position of the buried paleo-channel. Looking to the northwest, you can follow the low in the

landscape where Mud Creek is flowing today. This valley marks the position of an ancient river that once flowed to the southeast. The drainage through this area has reversed. Today Mud Run Creek is flowing to the northwest. Prior to glaciation, the drainage was to the southeast through this valley. The low ridge to the east marks the margin of the Illinois Glacial Episode deposits.

0.7	14.9	Cross Mud Run creek. CONTINUE AHEAD.
0.45	15.35	Old abandoned quarry on the left. The quarry is in the Galena dolomite, Wise Lake Formation. The old stone foundation on the right is made from the Galena dolomite.
0.85	16.2	Road curves 90 degrees to the left.
0.1	16.3	Road curves 90 degrees to the right. The road is now paralleling the southern edge of Benton Mound, a Silurian bedrock capped mound.
0.4	16.7	Small lane on the left side of the road. Sign on tree says "Trail's End." The "911" emergency address pole is Number 9041.

STOP 3: Benton Mound (SW, NW, NE, Sec. 28, T28N, R4E, 4th P.M., Elizabeth NE 7.5-minute Quadrangle, Jo Daviess County). Several of the Silurian capped mounds are visible from this vantage point to the north and northwest.

0.0	16.7	Leave Stop 3. CONTINUE AHEAD.
0.15	16.85	STOP (one-way). T-intersection (East Greenville Road and North Canyon Park Road). TURN RIGHT.
0.75	17.6	T-intersection from the left (East Upmann Road). CONTINUE AHEAD.
0.4	18.0	Crossroad intersection (Rush Town Road). CONTINUE AHEAD. On the southeast corner of the intersection is the Rush Township Hall. This building was once the one-room Rush Center Schoolhouse.
1.2	19.2	T-intersection from the right (East Fiedler Road). CONTINUE AHEAD.
0.6	19.8	Begin the descent into Apple River Canyon.
0.3	20.1	Enter Apple River Canyon State Park boundary.
0.2	20.3	Cross bridge on the South Fork of the Apple River. TURN LEFT onto West Canyon Road on the north side of the bridge.
0.2	20.5	Cross the bridge on the North Fork of the Apple River and immediately enter the Devil's Hollow Picnic Area shelter parking lot.

STOP 4: Lunch (SW, NE, SW, Sec. 4, T28N, R4E, 4th P.M., Elizabeth NE 7.5-minute Quadrangle, Jo Daviess County). After lunch, reset the odometer at the entrance to the shelter parking lot to 0.0.

0.0	0.0	Exit parking lot. TURN RIGHT. Road begins ascent out of Apple River Canyon.
0.9	0.9	T-intersection from the left (Bouroquin Road). CONTINUE AHEAD.
0.1	1.0	Note the view of an unnamed mound on right side of the road. The mound is capped by Silurian dolomite. The slope between the top of the mound and the road is underlain by the Ordovician Maquoketa Shale. Locally the mound is known as Sigafus Mound.
1.0	2.0	STOP (one-way). T-intersection (West Canyon Road and Broadway Road). TURN RIGHT. Unmarked intersection.
0.15	2.15	Stone house on the right is made from locally quarried Ordovicain dolomite. Historically, this building was used as a one-room school called Brown School. Locally it is known as the old Broadway School.
0.15	2.3	Good view of unnamed Silurian capped mound on the right.
0.4	2.7	T-intersection from the left (East Dotzel Road). CONTINUE AHEAD.
0.5	3.2	Road curves to the right.
0.2	3.4	Road begins its descent into the valley cut by the North Fork of the Apple River.
0.2	3.6	Cross bridge. Dolomite bluffs are visible along Apple River on the right.
0.3	3.9	Directly ahead is an unnamed Silurian capped mound.
0.3	4.2	Road curves to the left.
0.2	4.4	T-intersection from the right (Twin Bridges Road). CONTINUE AHEAD.
0.6	5.0	Good view of Squirrel Mound, a Silurian capped mound to the left.
0.1	5.1	Cross creek.
0.65	5.75	STOP (one-way). T-intersection (North Broadway and Stage Coach Road). TURN LEFT and enter community of Apple River, population 472.
0.45	6.2	Apple River School is on the left. CONTINUE AHEAD. Road begins its descent into the valley cut by Kentucky Creek

0.3	6.5	Cross Kentucky Creek, a tributary of Apple River.
0.2	6.7	T-intersection from the left (North Scout Camp Road). TURN LEFT onto North Scout Camp Road. St. Joseph Cemetery is on the southwest corner of the intersection. The low area on the left is the valley cut by Kentucky Creek.
0.8	7.5	Pass guard rail on the left side of the road. Entrance road to Cox Quarry on the left. TURN LEFT. The "911" emergency address sign is marked as 8045. Follow road to the Cox Quarry.
0.3	7.8	Entrance to Cox Quarry

STOP 5: Cox Quarry (NW, NE, NE, Sec.25, T29N, R3E, 4th P.M., Elizabeth NE 7.5-minute Quadrangle, Jo Daviess County). Pull into the quarry and park on the bed of the quarry. Please wait for instructions from your field trip leaders before you attack the outcrop.

0.0	7.8	Leave Stop 5. Retrace your route back to North Scout Camp Road.
0.2	8.0	Entrance road to the quarry. TURN LEFT onto North Scout Camp Road (heading south).
0.6	8.6	Cross Apple River. Kentucky Creek is flowing into the Apple River on the left and northeast of the bridge.
0.6	9.2	Good view of Mount Sumner mound to the right at curve in road.
0.8	10.0	Mount Sumner straight ahead.
0.4	10.4	T-intersection from the right in the middle of curve (North Scout Camp and East Mount Sumner Road). TURN RIGHT onto East Mount Sumner Road.
0.1	10.5	T-intersection from the right (South Hodgin Road). CONTINUE AHEAD. Large mound directly north of the intersection is Squirrel Grove Mound. Road begins ascent up Mount Sumner mound.
0.3	10.8	Road curves around the south side of the mound.
0.1	10.9	Good view to the south of the topography of Jo Daviess County.
0.4	11.3	View of mound to the northwest is Hudson Mound.
1.0	12.3	STOP (one-way). T-intersection (East Mount Sumner Road and North Lake No.1 Road). TURN LEFT onto North Lake No. 1 Road (heading south).
0.7	13.0	Road curves 90 degrees to the right.
0.8	13.8	View of Apple Canyon Lake to the left.

0.1	13.9	T-intersection from the left (North Apple Canyon Road and North Lake No.1 Road). CONTINUE AHEAD and cross bridge over Hell's Branch. Road changes to West Canyon Road at the bridge. Local historical archives state that in the early days a large family of rough characters named Daves settled on a branch of the Apple River, which was subsequently named Hell's Branch. There is a good view of Apple Canyon Lake from the middle of the bridge to the left. The lake was formed by damming Hell's Branch. Certainly one "hell" of a way to make a lake.
0.2	14.1	T-intersection from the right (Fair Oaks Road). CONTINUE AHEAD on West Apple Canyon Road.
0.4	14.5	Crossroad intersection (West Apple Canyon Road and Blue Gray Drive). TURN RIGHT onto Blue Gray Drive.
0.1	14.6	STOP (one-way). T-intersection (Blue Gray and Pea Ridge Road). TURN RIGHT onto Pea Ridge Road and immediately TURN LEFT onto East Fox Road at the Y-intersection (East Fox Road and Pea Ridge Road). East Fox Road immediately begins to ascend up a hill.
0.2	14.8	Pass bee hives on the right side of the road.
0.1	14.9	Silurian outcrop on the right side of the road.
0.5	15.4	STOP (one-way). T-intersection (East Fox road and Hammer Road). Unmarked intersection. TURN LEFT onto Hammer Road.
0.5	15.9	Y-intersection (North Anderson Road and North Hammer Road). BEAR RIGHT onto North Hammer Road.
0.5	16.4	Entrance to old abandoned quarry in the Galena dolomite on the right.
0.2	16.6	Road begins its descent to the valley cut by Mill Creek.
0.2	16.8	There is a great view of Mill Creek Valley on your right.
0.5	17.3	STOP (one-way). T-intersection (North Mill Creek Road and North Hammer Road). TURN RIGHT on North Mill Creek Road.
0.6	17.9	Cross an unnamed creek. Mill Creek is on the left side of the road. The road follows the contact between the alluvium on left and the colluvium on the right.
1.1	19.0	Cross the unnamed creek, a branch to Mill Creek.
0.3	19.3	A good view of entrenched meanders can be seen to the left of the road within the Mill Creek floodplain.

0.2	19.5	Cross the small bridge over the branch of Mill Creek.
0.1	19.6	Entrance to Wenzel Mound Quarry. TURN RIGHT.

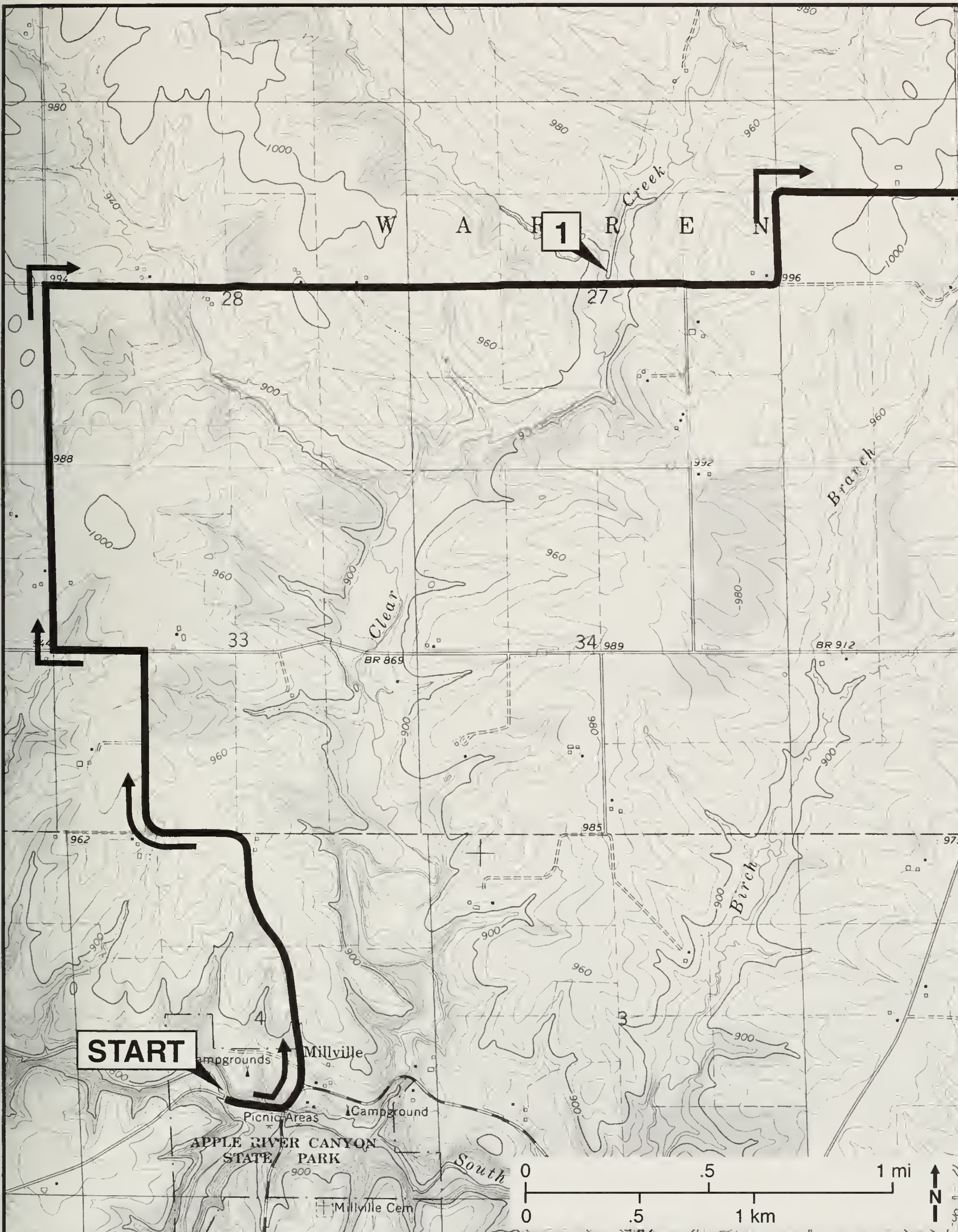
STOP 6: Wenzel Mound Quarry (SW, SW, NE, Sec. 2, T28N, R2E, 4th P.M., Scales Mound East 7.5-minute Quadrangle, Jo Daviess County). Pull into the quarry and park on the bed of the quarry. Please wait for instructions from your field trip leaders before you attack the outcrop.

0.0	19.6	Leave Stop 6. Exit the quarry and retrace your route back to Mill Creek Road.
0.25	19.85	Exit to the Quarry.
		The following road log will get you back to Apple River Canyon State Park or other destinations. Reset your odometer to 0.0 at the exit of the quarry and TURN RIGHT onto Mill Creek Road.

Miles to next point	Miles from start	
0.0	0.0	STOP (one-way). T-intersection (North Mill Creek Road and North Elizabeth/Scales Mound Road).
		To head back toward Apple River State Park or Galena TURN RIGHT heading toward Scales Mound.
		To head toward Elizabeth and U.S. Route 20, TURN LEFT and follow the Elizabeth/Scales Mound Road.
		The following road log is ONLY for those who TURNED RIGHT.
1.1	1.2	STOP (one-way). Crossroad intersection (Elizabeth/Scales Mound Road and Stage Coach Trail). TURN RIGHT onto Stage Coach Trail heading toward the communities of Apple River and Warren. The community of Scales Mound, population 381, is directly ahead of this intersection. The Silurian capped Scales Mound is to the left. Note: If you TURN LEFT onto Stage Coach Trail, it will take you to Galena.
0.4	1.6	The large high Silurian capped mound to the left is Charles Mound, the highest point in Illinois, with an elevation of 1,241 feet.
9.25	10.85	Entering community of Apple River, population 472.
1.85	12.7	The sign for Apple River Canyon State Park is on the right.

0.1	12.8	T-intersection from the right (North Canyon Park Road). TURN RIGHT onto North Canyon Park Road. This road will take you to Apple River Canyon State Park. Note: If you continue ahead on Stage Coach Road, it will take you to the community of Warren and Illinois Route 78.
3.7	16.5	Apple River Canyon State Park.

End of Trip! Have a Safe Journey Home.



W A R R E N
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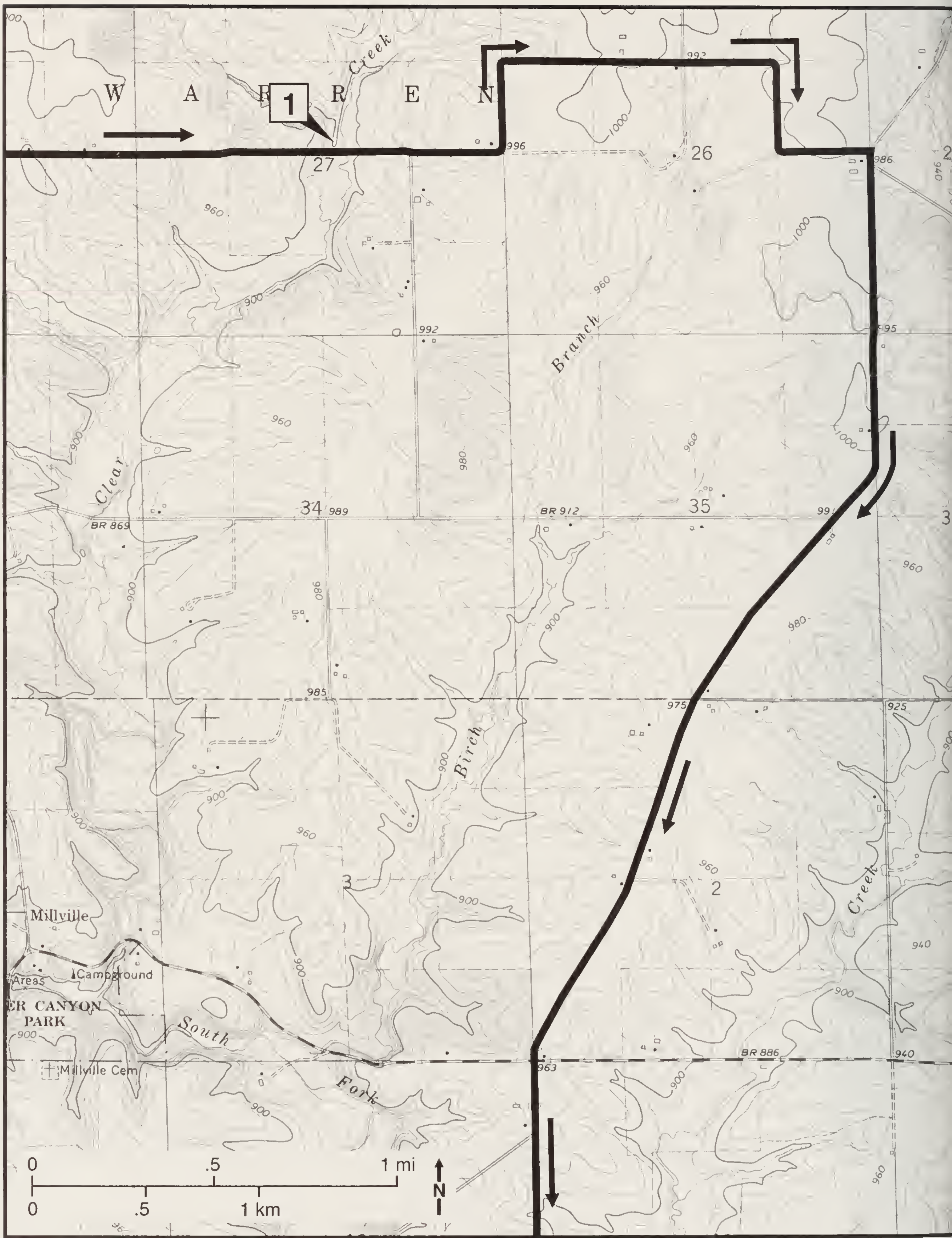
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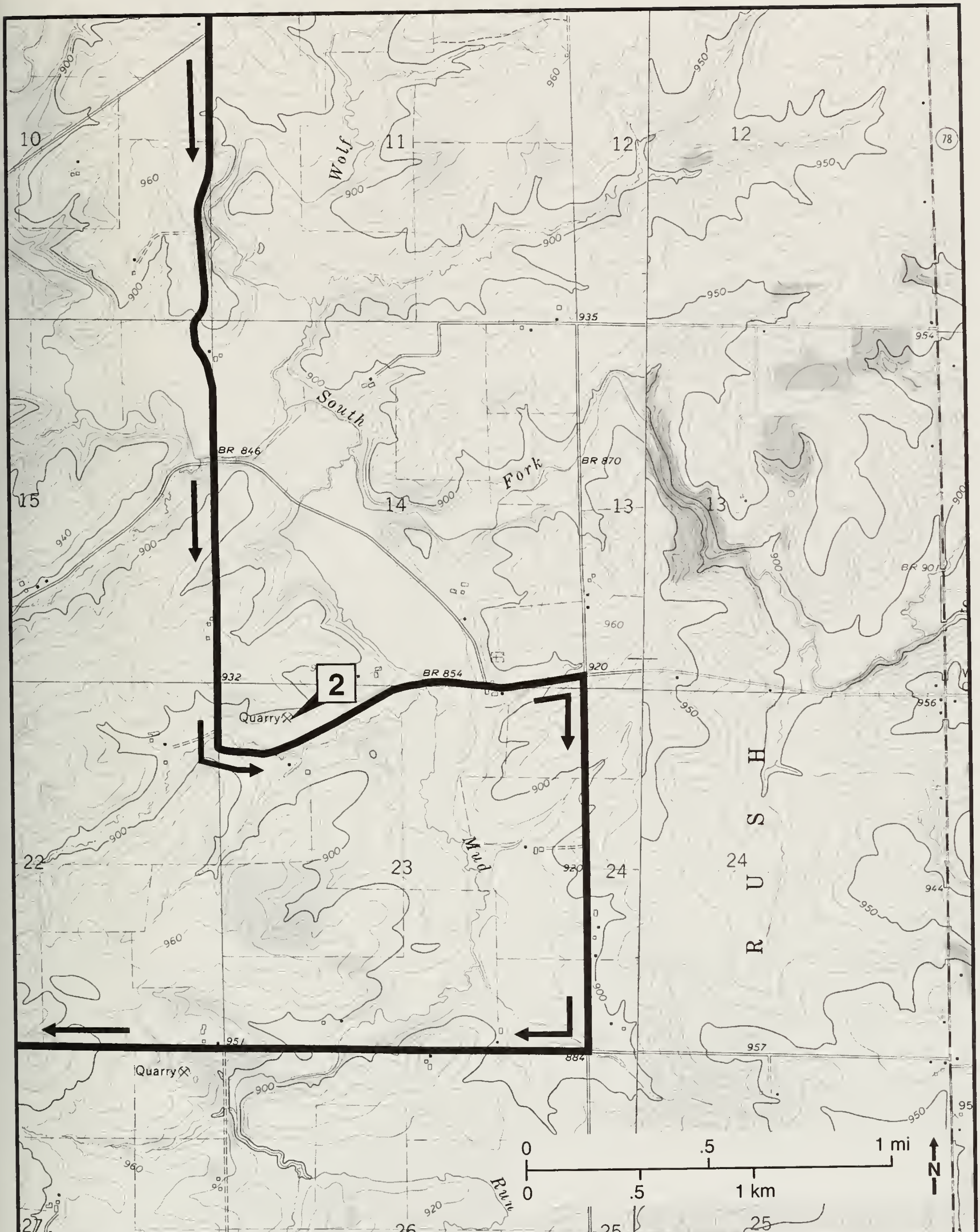
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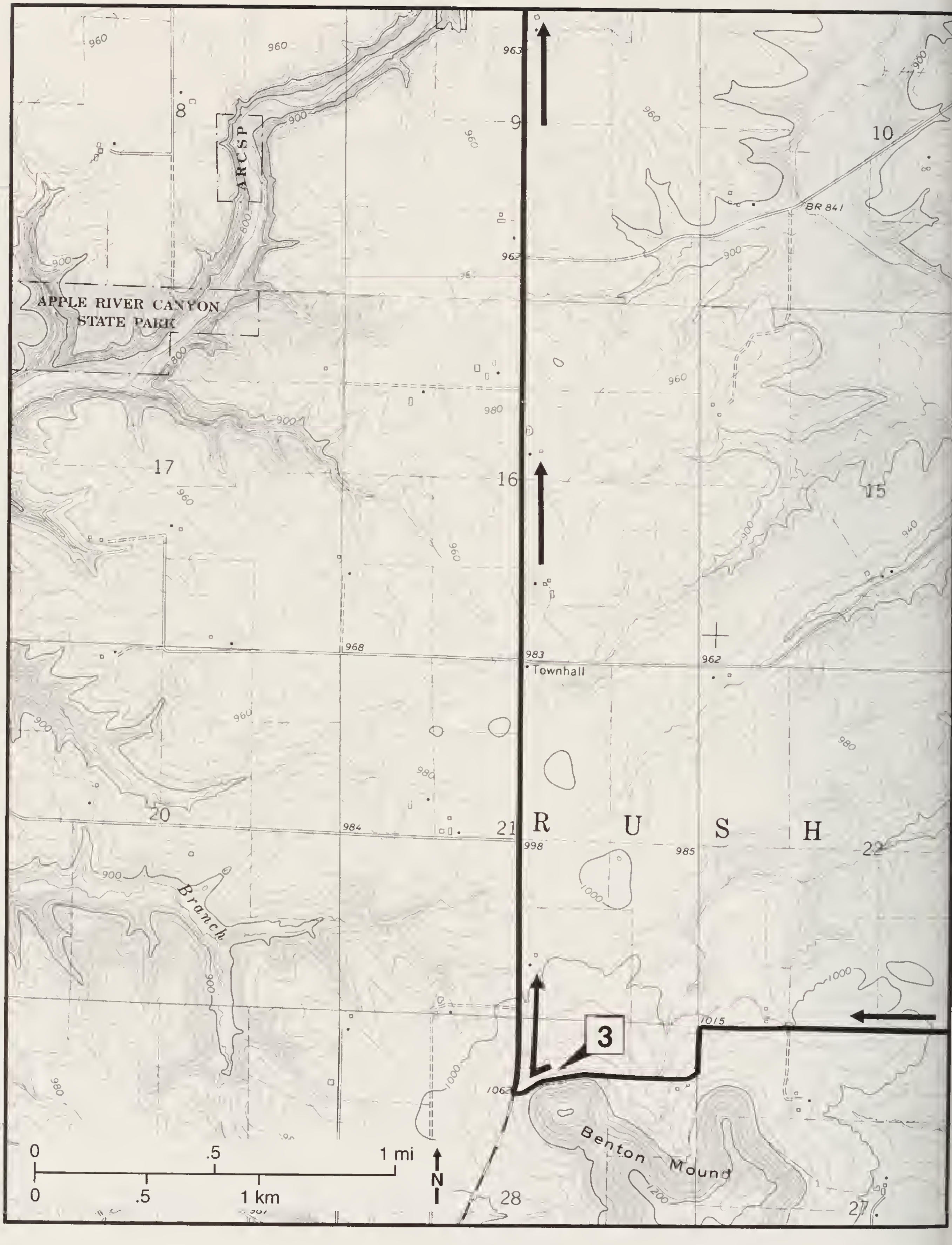

APPLE RIVER CANYON STATE PARK
ARCSP
BR 841
Townhall
R U S H
Branch
Benton Mound
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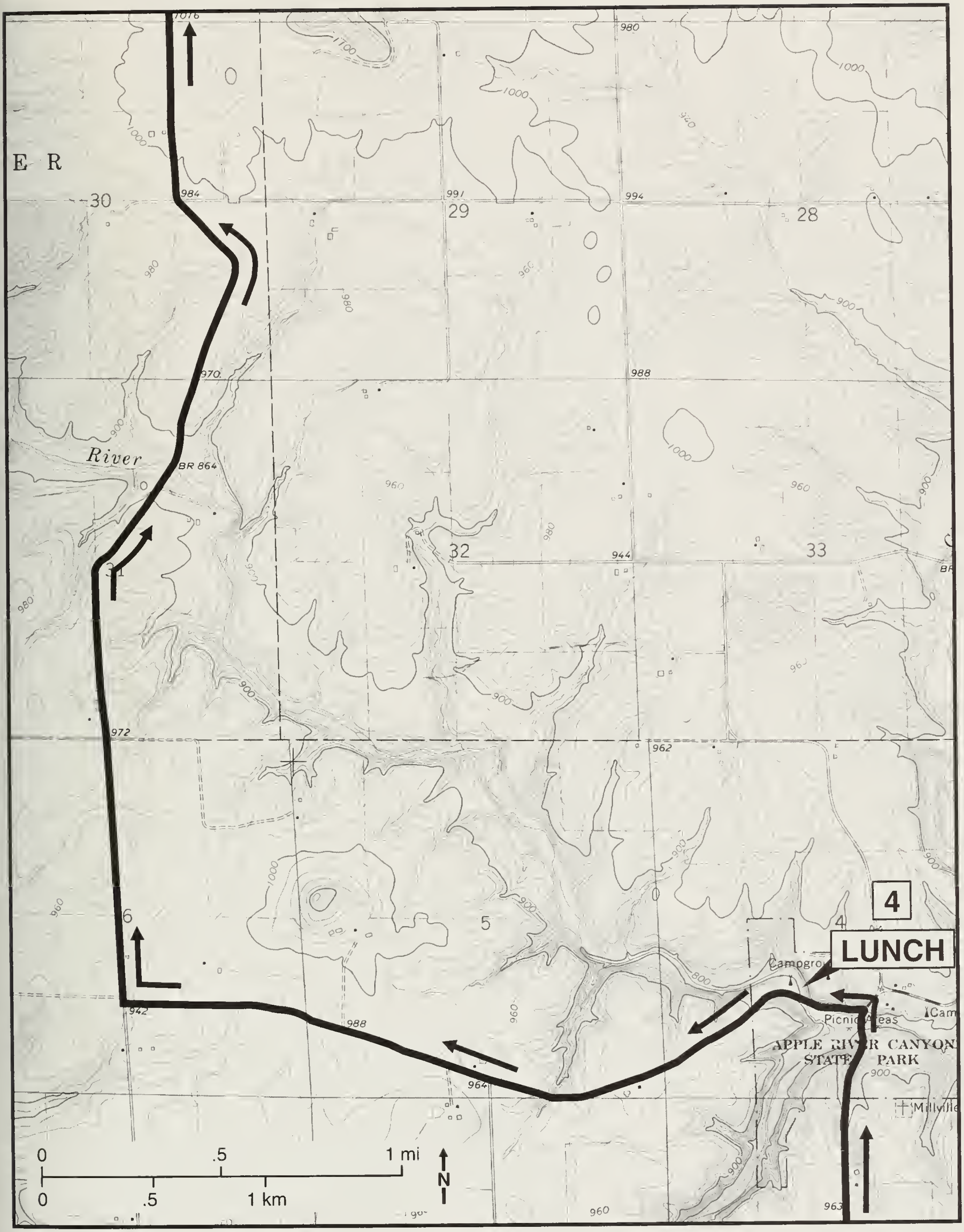

E R
River
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30
29
28
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4
LUNCH
Campground
Picnic Areas
APPLE RIVER CANYON STATE PARK
Millville
984
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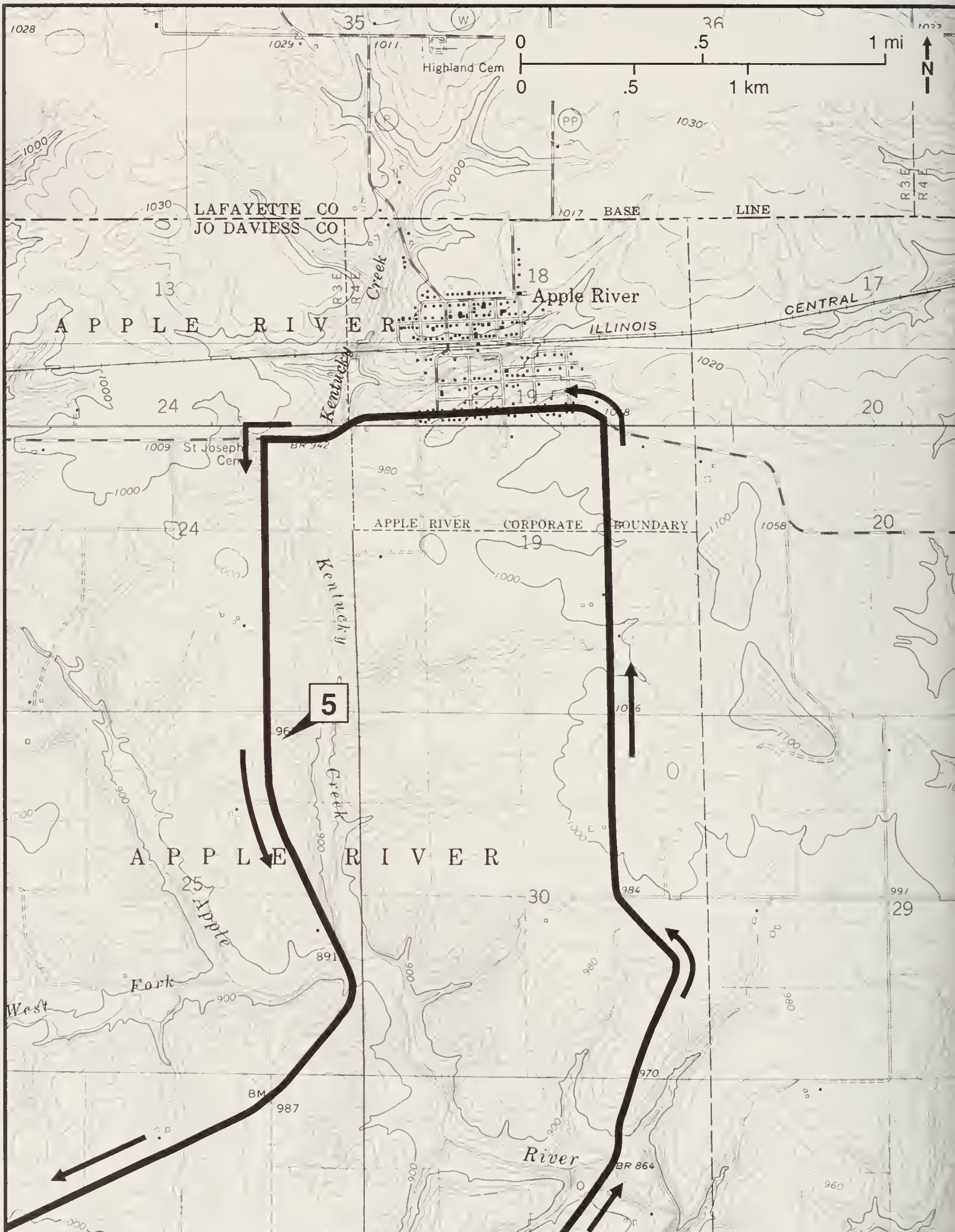

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APPLE RIVER CORPORATE BOUNDARY
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River
BR 942
BR 864
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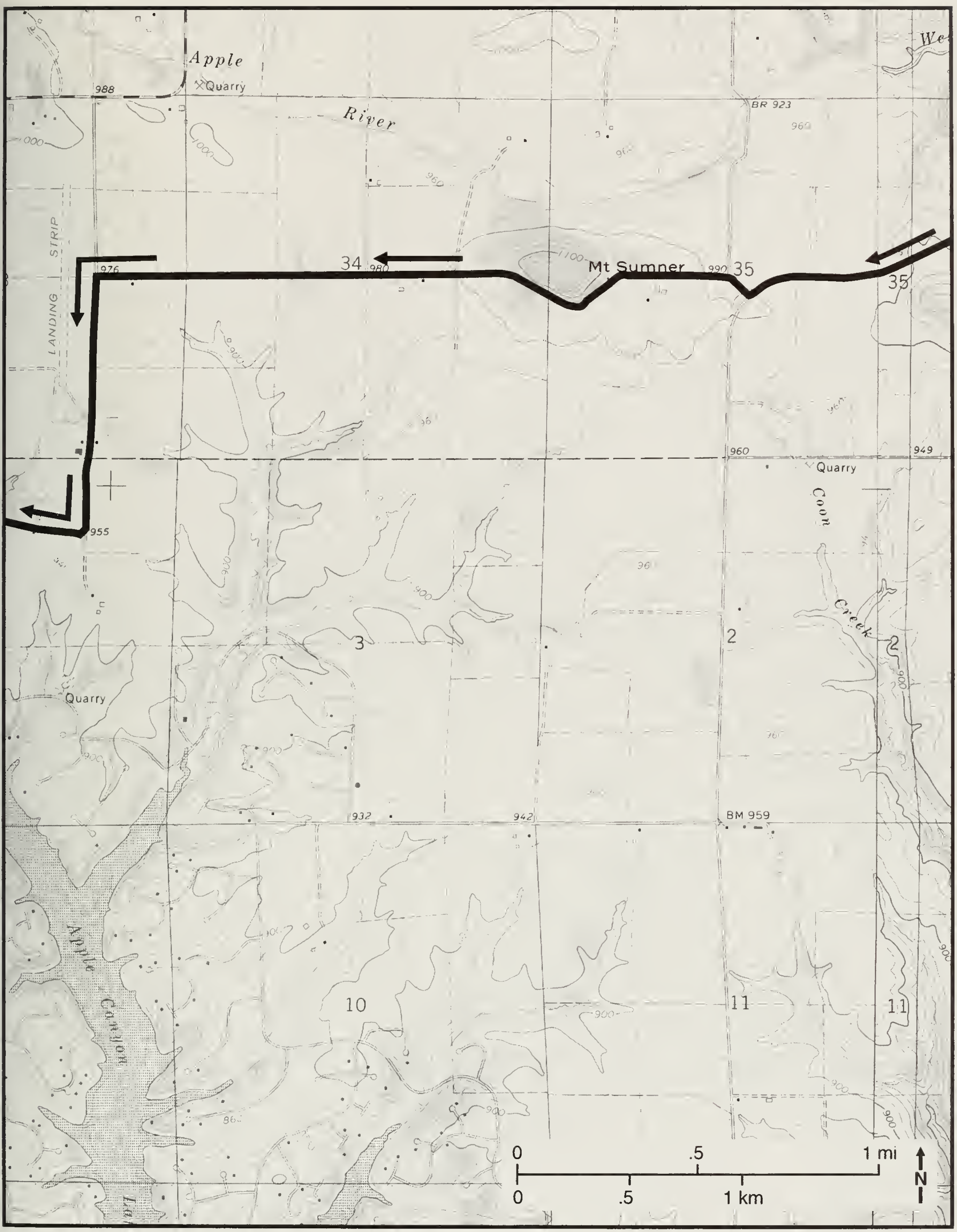
Apple
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LANDING STRIP
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976
980
Mt Sumner
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Quarry
Coon
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Creek
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Apple Canyon
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31
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33
LANDING STRIP
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Branch
1120
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BR 814
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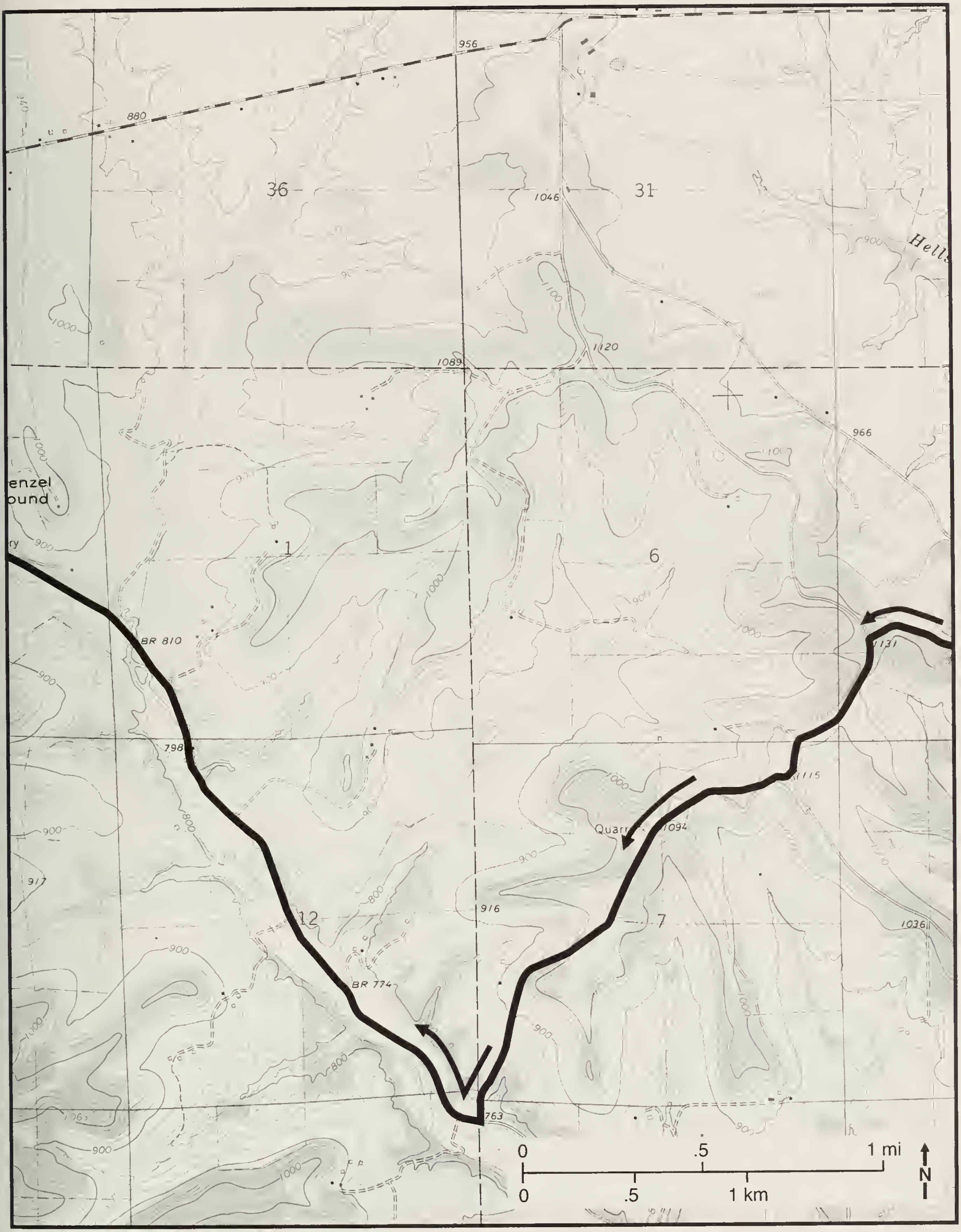
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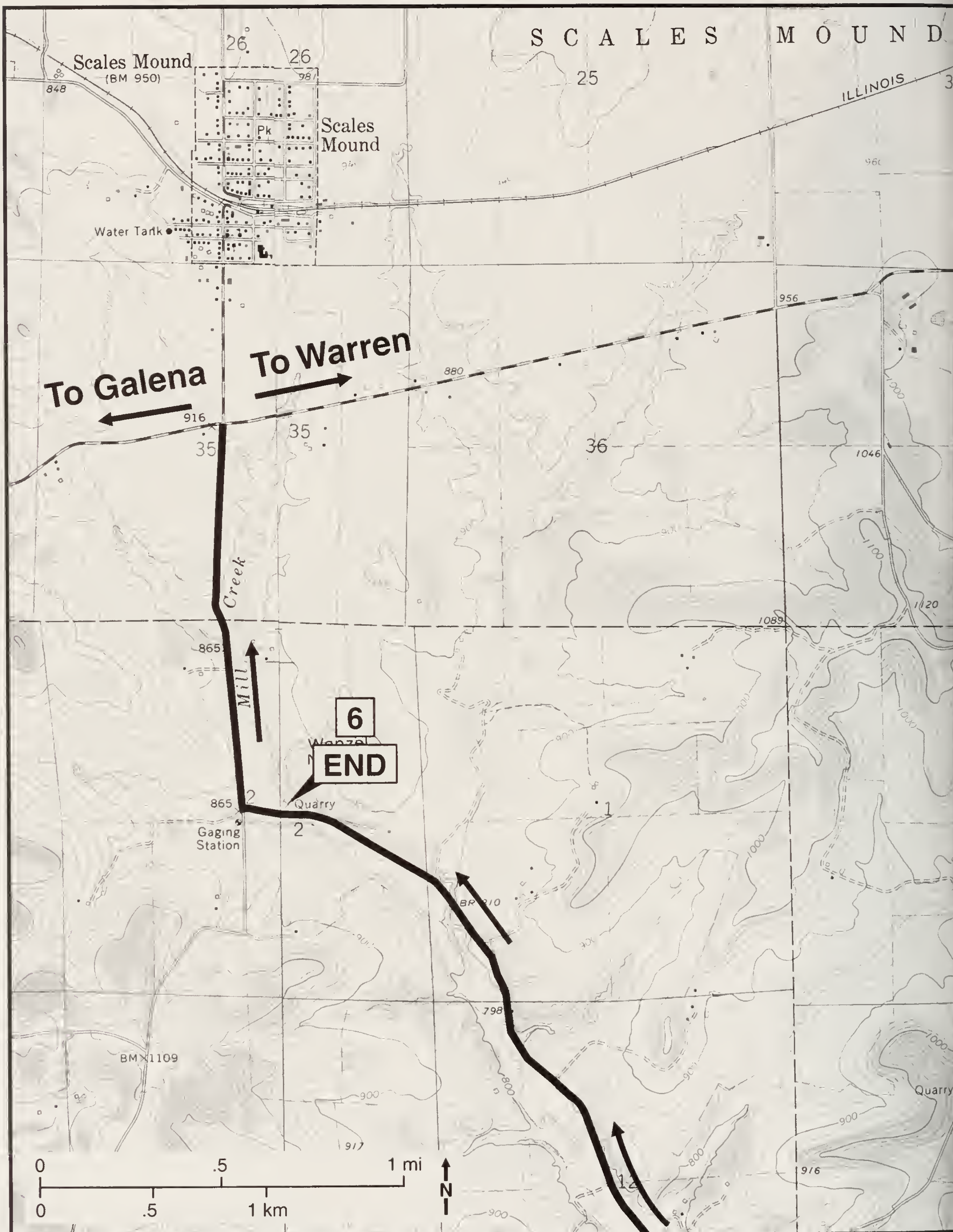

SCALES MOUND
Scales Mound
(BM 950)
Scales Mound
Pk
Water Tank
ILLINOIS
To Galena
To Warren
Mill Creek
6
END
Quarry
Gaging Station
BM 1109
Quarry
0 .5 1 mi
0 .5 1 km
N

Figure 16 West branch of the North Fork of the Apple River at Devils Hollow picnic area. Bluffs are composed of the Ordovician age Dunleith Formation (photo by W. T. Frankie).

STOP DESCRIPTIONS

START: The field trip will begin with a hike along the Primrose Nature Trail in Apple River Canyon State Park (SW, NE, SW, Sec. 4, T28N, R4E, 4th P.M., Elizabeth NE 7.5-minute Quadrangle, Jo Daviess County)(fig.16).

Apple River Canyon State Park

The following is modified from the Department of Natural Resources state park brochure.

Apple River Canyon State Park is in the hilly northwest part of Illinois in Jo Daviess County near the Wisconsin border (fig. 17). This scenic canyon area was formed by the eroding action of the winding waters of Apple River. Limestone bluffs, deep ravines, springs, streams, and wildlife characterize this area, which was once a part of a vast sea bottom that stretched from the Alleghenies to the Rockies.

The original 297-acre park was purchased by the State of Illinois in 1932. Today it totals 523 acres. Other properties within JoDaviess County managed by the Illinois Department of Natural

Resources include the Thompson and Salem Units, Witkowsky Wildlife Area, Tapley Woods, Hanover Bluff Nature Preserve, Wards Grove Nature Preserve, Artenson-Wells Nature Preserve, and Falling Down Prairie. For more information about these areas or the park, contact the Apple River Canyon State Park, 8763 E. Canyon Road, Apple River, Illinois 61001 (815-745-3302).

History In the nineteenth century, European settlers arrived; the Sauk and Fox tribes were driven out in the Black Hawk War; and Galena, thriving on the profits of lead mining, became a roaring boom town. Miners by the hundreds entered this country through a canyon that is now one of the principal attractions of the Apple River Canyon State Park.

The town of Millville was established where the park is now, but not a trace of it remains. Named after its two sawmills, Millville became a stop on the Galena-Chicago stage route and flourished until 1854 when the Illinois Central Railroad, building its line from Freeport to Galena, passed four miles north of the town. In 1892, a devastating flood washed out the dam, swept away many buildings, and drove the people from the town forever.

Natural Features Flowing endlessly for countless centuries, the Apple River has cut through the layers of limestone, dolomite, and shale until massive cliffs rose high above the water and canyons formed. Vast ages of water and erosion widened and deepened the crevices as rivers and streams cut their way through the stone. Close-up views of the colorful canyon reveal walls dotted with mosses, lichens, and tenacious bushes that have found crevices to hold their roots on the sheer walls.

The advance of glaciers, which ironed out hills and filled valleys in other parts of the state, left this area untouched. This circumstance accounts for the large number of fossil remains to be found near the surface in the northwestern part of Illinois. It also accounts for the easy availability to the veins of galena ore (lead) that had much to do with the early development of this section of Illinois.

The park contains such wildlife as deer, squirrels, rabbits, raccoons, badgers, eagles, hawks, and 47 varieties of birds. At least 14 different ferns, over 500 different herbaceous plants, and 165 varieties of flowers can be seen throughout the park. The upper part of the Apple River has been designated as a biologically significant stream because of the diversity of life within it. Some of the bluffs within the park are classified as mesic cliff communities. These bluffs are sheltered from temperature extremes; drip cool, clear limewater; and never see the sun. The species diversity within the park is due to the combination of location, topographic complexity, and geologic diversity of the area.

Fishing The Apple River contains a variety of fish, including smallmouth bass, sunfish, crappie, carp, and suckers. When economically feasible, the Illinois Department of Natural Resources stocks Apple River with keeper-size trout. The river is one of several in the state where the department releases this fish. Trout require clean, clear, cold water, and, in the spring, Apple River meets these requirements. However, normally the fish do not live through the hot summer months so the stream is stocked on a put-and-take basis.

Trails Five nature trails—Pine Ridge, Tower Rock, River Route, Sunset, and Primrose Trail—wind through the woods, bluffs, and along the scenic Apple River. Trails average 1.5 miles in length (fig.17).

For more information on state parks, write to the Illinois Department of Natural Resources, Office of Public Services, One National Resource Way, Springfield, Illinois 62702-1271, or call 217-782-7454.

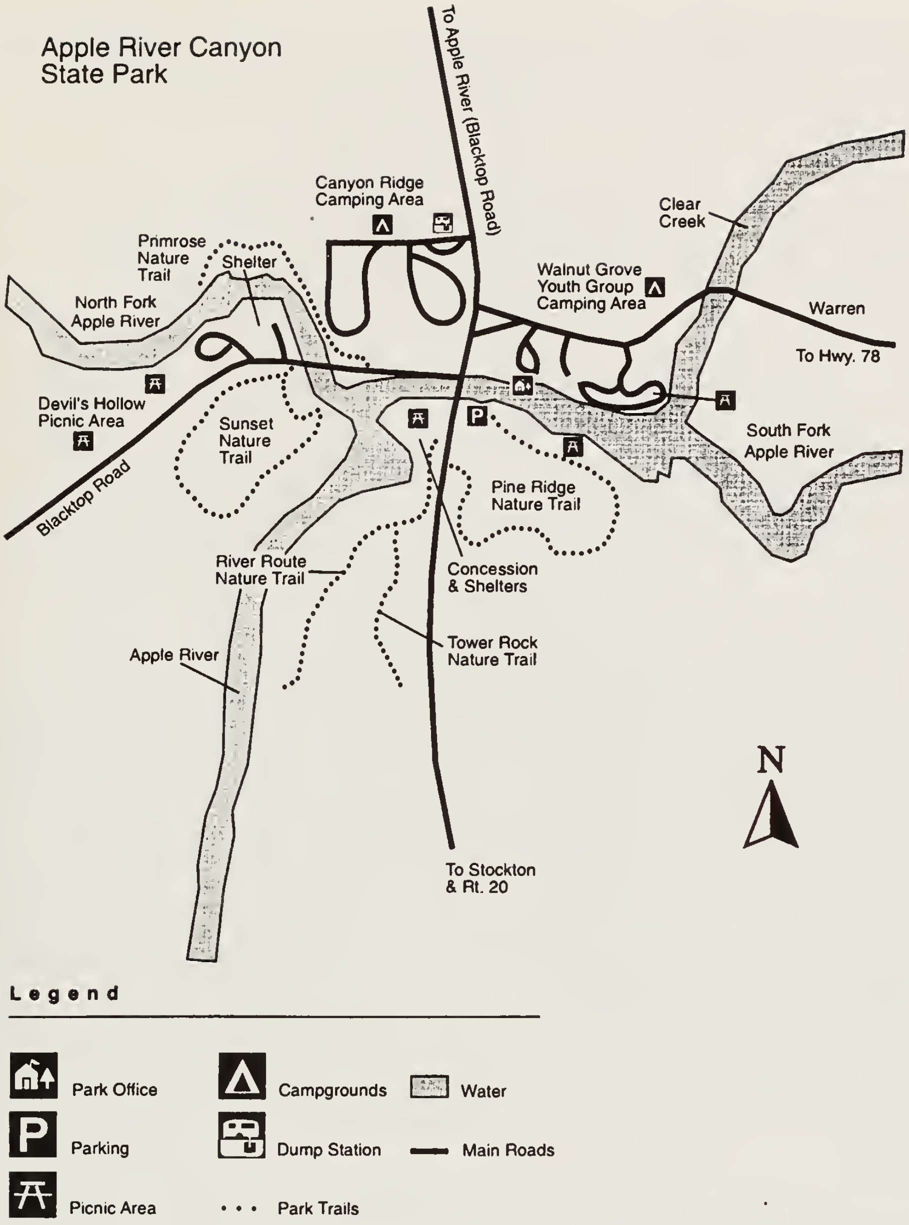


Figure 17 Apple River Canyon State Park (modified from the Illinois Department of Natural Resources state park brochure).

The telecommunication device for deaf and hearing-impaired natural resources information is 217-782-9175 for TDD only; the relay number is 800-526-0844. For more information on tourism in Illinois, call the Illinois Department of Commerce and Community Affairs' Bureau of Tourism at 1-800-2Connect.

History of the Apple River

The Apple River has a drainage area of 262 square miles. As you trace the Apple River to the southwest, the valley it occupies widens considerably below the confluence of Apple River and Mill Creek. As the valley widens, the Apple River meanders across this wider mature valley.

Trowbridge and Shaw (1916) studied this region in considerable detail and surmised that some peculiar characteristics of the valley of Apple River northeast of this locality strongly indicated that a major drainage change occurred as a result of the Illinois Glacial Episode.

Formation of the Apple River Canyon The following text and accompanying illustrations (fig. 18) explain the series of events that created the present-day drainage system and formed the Apple River Canyon. The following discussion of the diversion of the Apple River is modified from Trowbridge and Shaw (1916), Horberg (1950), and Reinertsen et al. (1972).

Figure 18 (A) Pre-Illinois Glacial Drainage. Two networks of streams, one flowing southeast and the other southwest, drained the area northwest of Stockton before the Illinois Glacial Episode. The two systems were separated by a drainage divide trending northwest-southeast that was underlain by resistant dolomite of the Galena Group. The divide crossed the area a short distance to the southwest of the Apple River Canyon State Park. Tributary streams joined master streams with "V"'s pointing downstream. Headward growth of two tributaries, one from the northeast (E) and one from the southwest (W), produced a slight low area, or sag, across the crest of the divide. Downstream, the distance between the valley walls widened and became less steep toward the southeast and the southwest along the major streams.

Figure 18 (B) Illinois Glacial Episode Drainage. During the Illinois Glacial Episode, the glacier advanced westward to the vicinity of Stockton, blocking the drainage that flowed to the southeast, and a lake formed upstream, to the northwest. Water flowing southeast from the headwaters and meltwater flowing northwest in the valley from the glacier formed a lake that rose high enough to discharge across the low sag in the divide that one of its tributaries had formed (E and W in part A). As the volume of water increased, its downcutting was accelerated by the hard, abrasive rock fragments carried in the torrents of water. Continued downcutting of the divide eventually drained the lake and produced a narrow outlet channel or canyon southwestward some 3.5 miles to Lilly Branch. This nearly straight, deep, narrow, steep-walled canyon is as much as 200 feet deep, 250 to 400 feet wide at the bottom, which is usually full of water, and 1,500 to 1,700 feet wide at the upper rim. The slope (gradient) of the canyon floor is about 20 feet per mile, or about twice that of other streams in the area. Only a few short, steep tributaries enter the river in this stretch, which is characteristic of a youthful stream. The main canyon, therefore, is younger than the valley upstream from it.

Figure 18 (C) Post-Illinois Glacial Episode Drainage Blockage of the southeast-flowing stream has persisted because the glacier smeared till across the area and buried its valley. South Fork drainage has been reversed and is quite small in relation to the size of its valley, which narrows downstream to the northwest. Tributaries in this stream segment now join the larger stream with their V's pointing upstream, the reverse of their direction during the pre-Illinois glacial episode. The valley of the North Fork is in keeping with the size of its stream, becoming wider downstream, and its tributaries join it with V's pointing downstream. The stream and its valley northwest of the canyon are crooked (meander), as is the valley below the canyon, which indicates that these portions of the stream are much older in their development than the canyon segment. The walls of the canyon remain steep (vertical in most places) because of the Galena dolomite's resistance to lateral erosion. The canyon bottom is generally water-filled, even during dry weather. Tributaries to the canyon are few, short, unbranched, and elevated above the floor to form waterfalls.

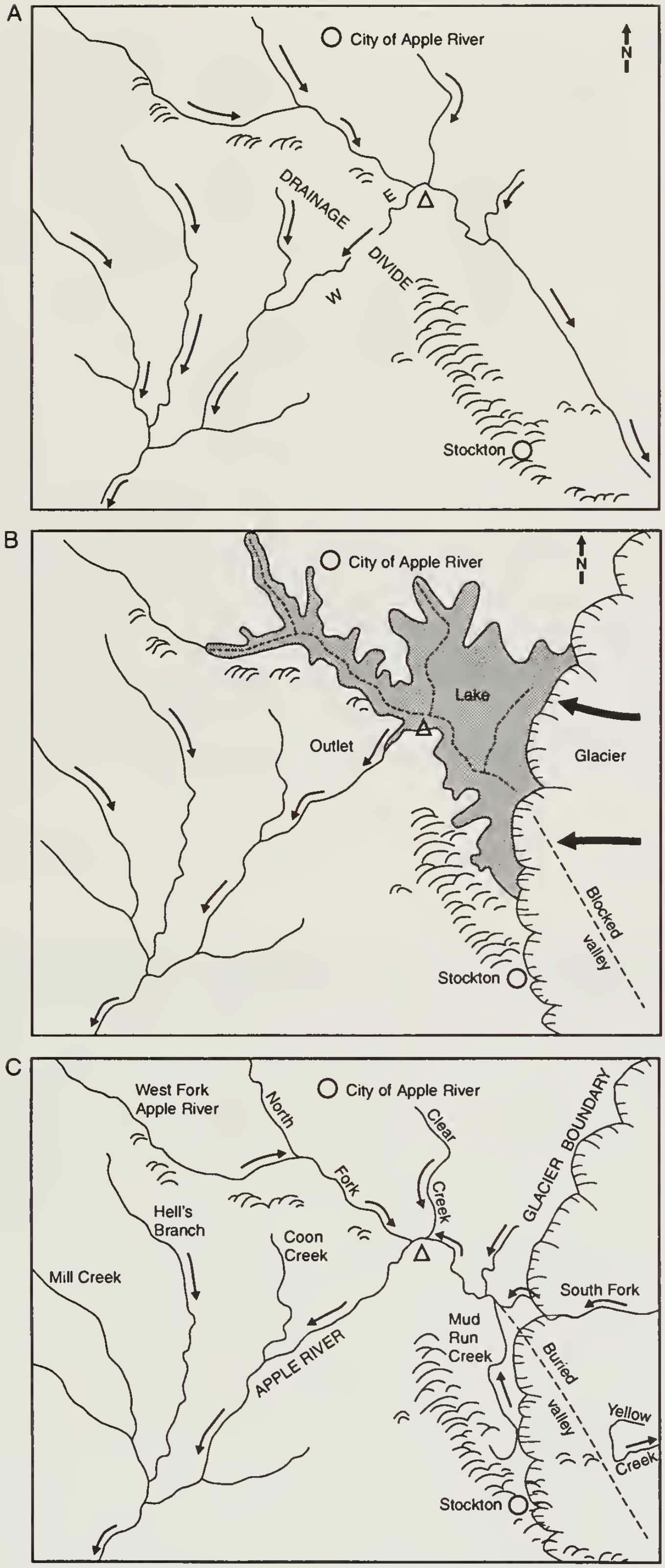


Figure 18. (A) Pre-Illinois glacial episode drainage (modified from Reinertsen et al.1972). **(B)** Illinois glacial episode drainage (modified from Reinertsen et al.1972). **(C)** Post-Illinois glacial episode drainage (modified from Reinertsen, Berggren, and Killey 1972).

Primrose Nature and Sunset Trails

Primrose Nature Trail From the Devil's Hollow Picnic Shelter, walk to the trail head for the Primrose Nature Trail by exiting the parking lot and walking east along Canyon Road. Cross the bridge and note the trail head sign board on the left. The trail head for Sunset Trail is directly across from the Devil's Hollow Picnic Shelter parking lot on the west side of the bridge (fig.16). The round trip distance for both trails is approximately 1.5 miles with an estimated minium hiking time of 1 hour. *Caution: The trails can be very muddy, and logs and roots pose tripping hazards.*

A portion of the following descriptions of the natural features along the trails has been modified from *Hiking Illinois* by S. L. Post (1997).

Trail Directions Using figure 19 as a guide, begin at the Primrose trail board, and immediately climb the 99 steps to the top of the bluff [1]. During the upward trek, check out the spring wildflowers protruding from the bluff. At the top, follow the trail to the left and pass through a grove of reforested White Pines. The Canyon Ridge Camping Area is on your right. Flowers called shooting stars occur along this trail among the White Pines. The campground is out of sight at 0.2 miles, and the trail passes an overlook of the Apple River on the left [2]. Directly across from the overlook is a small dolomite prairie restoration.

The overlook is a good spot to view the deep northwest-southeast–trending valley of the North Fork of the Apple River (fig. 20). At the overlook, swallows swooping for insects are very helpful in keeping mosquitoes and biting flies at bay. From the overlook, the trail curves right, going through a grove of big-tooth aspen. A bench is provided just before you head downhill. The trail passes through a zone of smooth weathered brown chert, a weathered residue of the eroded Dunleith Formation.

The trail crosses a bridge at 0.3 miles [3]. Notice the narrow V-shaped valley of this tributary to the Apple River. This shape is an indication of a young stream. The rapid downcutting of the Apple River Canyon left many of its tributaries at higher elevations, and a number of waterfalls can be seen along the Apple River Canyon, especially following a rainfall. After it crosses the bridge, the trail heads uphill, through an oak woods with lots of aspen. In spring look for hepatica, wild geranium, and wild ginger in this area. Within a few yards is another bridge crossing. When the formal trail ends at 0.4 miles, enter a picnic area [4] (fig. 21). Go left, meeting with a springtime profusion of wildflowers. Cross a small creek, and skirt the bluff on the far side.

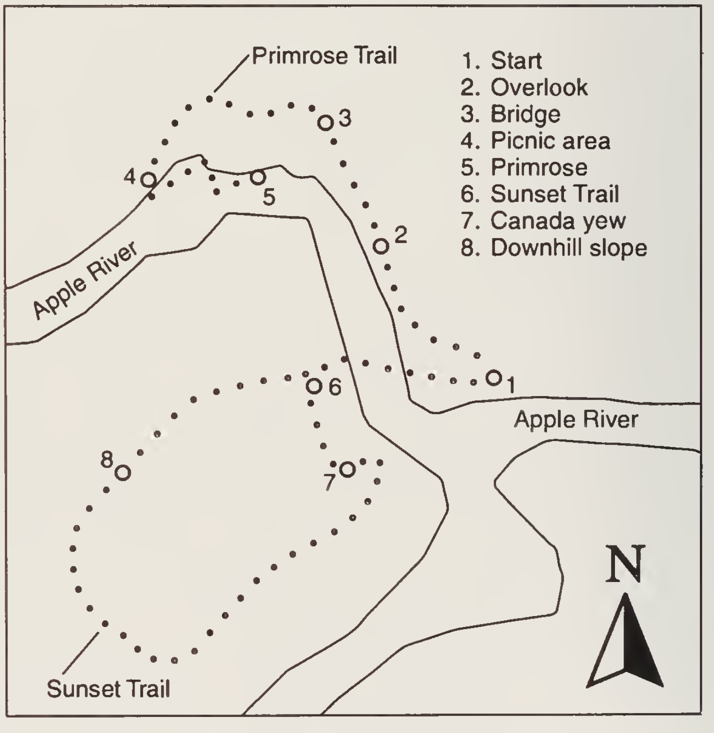


Figure 19 Primrose and Sunset trails with referenced locations (modified from Post 1997).

Figure 20 North Fork of Apple River at the Primrose Trail observation platform (photo by W. T. Frankie).

Figure 21 North Fork of Apple River along Primrose Trail at a picnic area. Dunleith Formation forms the canyon walls (photo by W. T. Frankie).

These bluffs are Ordovician age, Galena dolomite, and, where pockets of soil form, plants have been able to gain a foothold. Look for columbine, ferns, and bird's-eye primrose in the crevices. In 1909, Herman Pepoon, a botanist, described bird's-eye primrose as "tinting the bare rock a lavender purple with the multitudes of its blossoms." Bird's-eye primrose, a northern relic of cooler times, blooms in early May. Walk along these bluffs to discover these unique plants [5], but be careful not to fall in the river.

Then retrace your steps across the creek back to where the formal trail ended [4]. At times, when the water level is low, you may be able to cross Apple River at a ford to access Devil's Hollow picnic area. Before heading back along the main trail, look for chipmunks with full cheeks scurrying under large, moss-covered boulders. On the bluff look for Solomon's seal, Jack-in-the-pulpit, and prairie trillium. Retrace your steps back to the trail board (1 mile) [1].

Sunset Trail From the Primrose Trail, head west and walk along the edge of the park road (see figs. 17 and 19). Cross the bridge, taking time to enjoy the canyon from this other angle; on your left is the trail board for Sunset Trail (1.1 miles) [6].

Climb upward; after a few steps the trail splits. Go left and up again. In the spring, the trail is lined with wild ginger and anemones. The latter are called wind flowers because their slender stalks always blow in the wind. The trail follows a narrow ridge that overlooks the river and the park. Notice the trees with J-shaped trunks near their base. This trunk shape is an indication that the hillside is unstable and is slowly creeping toward the canyon below. At 1.2 miles [7], the low, sprawling evergreen on either side is Canada yew, a plant that occurs only in North America.

Just before reaching the switchback on the left is a carpet of ferns. Immediately past the ferns is the entrance to a small cave. Reach down and place your hand over the opening; the air coming out of this cave is 60 degrees Fahrenheit. At the switchback on the left is a short spur to an overlook; after viewing, go right and continue upward. You will encounter a pair of benches on the left near 1.25 miles.

From the first bench you encounter, an undeveloped trail leads west along the top of the bluffs. The trail proceeds to a narrow V-shaped valley with a series of small waterfalls in the upstream direction and one large waterfall dropping approximately 30 feet to the bottom of the Apple River Canyon, forming a large gravel talus fan at the base of the cliff. Retrace your steps back to the main trail.

From the benches continue along the main trail. You have been hiking among mixed hardwoods and big-tooth aspen. At 1.35 miles is another bench where the trail goes downward [8]. You have completed the loop, and the path soon ends at the trail board (1.5 miles) [6]. Return to the Devil's Hollow Picnic area parking lot.

STOP 1: Rutherford's Quarry and Dolomite Prairie (SW, SW, NE, Sec. 27, T29N, R4E, 4th P.M., Elizabeth NE 7.5-minute Quadrangle, Jo Daviess County). On the day of the field trip, we will park along the road.

Twin Bridges Road is named for the two bridges that cross over Clear Creek. Just south of the bridges, Clear Creek splits into east and west branches. A small quarry was operated north of the bridges and between the two branches of Clear Creek. The quarry is in the Wise Lake Formation of the Ordovician Galena Group (fig. 2). The Wise Lake Formation was deposited when the Ordovician seas were widespread. Very few clastics were being carried into the sea at this time. For this reason, the beds in the Wise Lake Formation are generally of high-quality dolomite in very thick and massive beds with few shale layers. Approximately 25 feet of the formation is present.

Located to the north and above the quarry is a native dolomite hill prairie remnant (fig. 22). This acreage has been set aside by the owner as part of the Illinois Acres for Wildlife program. This tract of land has been donated to help ensure the future of wildlife through habitat improvement and preservation. If you follow the old road on the right side of the old quarry, you will arrive at the hilltop prairie remnant.

Also present along the top of the bluff and on the slopes leading down to the east and west forks of Clear Creek are a number of large burr oak trees. Some of these oaks are estimated to be 200 years old. The following statement is from an article on the history of Jo Daviess Couty written in 1904.

> A large percentage of the timber of the county is oak, although other varieties exist to a considerable extent; but these are now being rapidly cut off for fuel and railroad ties, and, unless such destruction ceases, it will not be many years before Jo Daviess County will be almost void of timber.

At least someone was listening. Other species of trees include basswood, walnut, box elder, red cedar, and American elm.

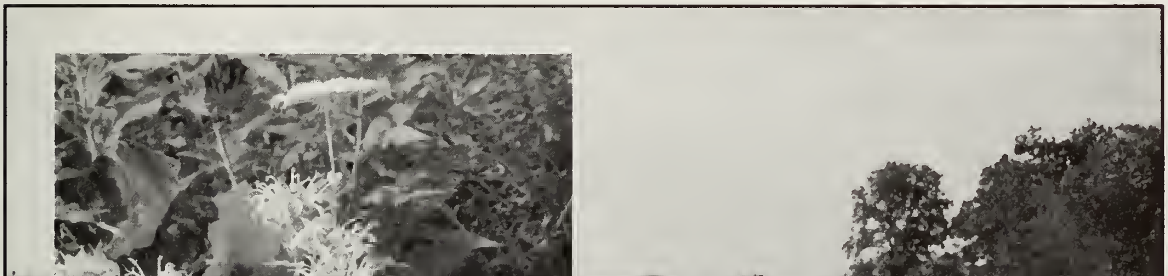


Figure 22 Dolomite hill prairie at Stop 1. A closeup of *Monarda fistulosa*, commonly called wild bergamot, a member of the mint family (photo by W. T. Frankie).

The dolomite hill prairie is a rare prairie community that almost exclusively occurs in Jo Daviess County along the Galena and Apple Rivers. These prairies, called "rock prairies" by some, occupy a south-to-west–facing slope where shallow soil 6 to12 inches in depth occurs over dolomite. Plants of the dolomite hill prairies include red cedar, pasque flower, little bluestem, and prairie violet (Post 1998). Some of the plants identified in this prairie also include, wild bergamot (mountain mint), goldenrod, Queen Anne's lace (wild carrot), and milkweed.

In addition to the oak grove and the dolomite hill prairie is a wetland along the east fork of Clear Creek. The diversity of habitats at this stop are due, in part, to the geodiversity of the area.

STOP 2: Youngbluth Quarry (NE, NW, NW, Sec. 23, T28N, R4E, 4th P.M., Elizabeth NE 7.5-minute Quadrangle, Jo Daviess County)(fig. 23). Pull into the quarry and park on the bed of the quarry. Please wait for instructions from your field trip leaders before you attack the outcrop.

This quarry is operated by Conmat Inc., P.O. Box 750, Freeport, Illinois 60136. *Remember, you must ask for permission before entering this or any other privately owned land.*

Quarrying Procedure

The unwanted materials above the quarry stone (overburden) are removed by earth-moving equipment (fig. 24). The soil material may be stockpiled for reclamation use. An air drill bores 2- to 6-inch diameter blast holes to a set depth. The holes are closely spaced (between 10 and 20 feet apart) in rows (10 to 16 feet apart). The spacing is selected to achieve maximum rock breakage. With an air drill, compressed air is used to blow the drill cuttings out of the hole as the drill cuts downward. The holes can be vertical or inclined, depending on conditions. The blast holes are loaded with a detonator and an explosive. Ammonium nitrate and fuel oil (commonly called ANFO) is the least expensive explosive at about $0.30 per pound. Other explosives are sometimes used to obtain desired breakage. The detonators in each blast hole are wired through delays of (5, 7.5, or 10 milliseconds), so that the holes closest to the edge of a bench go off slightly before the next line of blast holes. This sequence of explosions causes the broken rock to kick out and form a muck pile of broken rock.

Figure 23 Youngbluth Quarry at Stop 2. An exposure of Dunleith Formation (lower 6 feet) is overlain by Wise Lake Formation (upper 70 feet). See figure 24 for a view of the quarrying procedure at site marked with an "A" (photo by W. T. Frankie).

The broken rock is hauled to the crusher by large endloaders. At the crusher, the rock is broken to smaller pieces. The crushed rock is then classified by size and stockpiled. The rock fragments range in size from riprap (big blocks) to coarse aggregate to fine aggregate. Illinois aggregate production in 2001 is given in table 1.

Table 1 Illinois aggregate production, 2001.[1,2]

Aggregate[2]	Tons
Stone	78,000,000
Sand and gravel	29,500,000

[1] Data are from the U.S. Geological Survey, Minerals Information, "Crushed Stone and Sand and Gravel in the First Quarter of 2002." U.S. tons and total aggregate were calculated by Construction Market Research.
[2] $547,000,000 revenue from aggregate.

Agstone (agricultural lime) is another product produced at this quarry. Repeated fertilizer applications make the soil more acidic, lowering the soil pH. Corn and beans grow best when the soil has a pH of about 6.5, and crushed dolomite and limestone neutralize acid (Tums is made from almost pure limestone). Agstone is applied to fields after harvest. The application rate is determined by a soil survey in which numerous documented soil samples are analyzed by a laboratory. The analyses are plotted on a location map, and the optimum application for the field is calculated.

Figure 24 Drilling operation on the upper bench at Youngbluth Quarry, preparing for a shot (photo by W. T. Frankie).

The strata exposed in this quarry belong to the Ordovician age, Wise Lake Formation of the Galena Group (see fig. 2). The floor of the quarry is in the Dunleith Formation. The sediments that form the dolomitic rocks were deposited in the marine waters of an extensive inland sea that covered all of the Upper Mississippi Valley. (See the Ancient Environmental History section in the introduction for a detailed discussion of the depositional environment during the Ordovician.)

Origin of the Dolomites

The dolomitic rocks of the Galena Group were originally deposited as limestones by the chemical precipitation of calcium carbonate from sea water and by the accumulation of the calcareous remains of marine plants and animals. There is considerable evidence that the limestones were changed to dolomites, or dolomitized, at some time after their deposition.

During dolomitization, magnesium ions replace calcium ions in the atomic structure of the mineral calcite ($CaCO_3$). Depending on the degree of dolomitization, a carbonate rock is classified as limestone (0 to 10% dolomite), dolomitic limestone (10 to 50% dolomite), calcitic dolomite (50 to 90% dolomite), or dolomite (90 to 100% dolomite). In pure dolomite, the calcium-magnesium ratio is about 1:1. Small amounts of ferrous iron usually replace some of the magnesium in dolomite, resulting in the characteristic light brown color of most weathered dolomite formations. Recrystallization also takes place during dolomitization, in many cases producing a sucrosic (sugary) texture that is also characteristic of many dolomites. Because of this recrystallization, primary sedimentary structures, such as internal bedding, are destroyed. In addition, the original shell material of the fossils has been largely destroyed or poorly preserved because of the recrystallization of the limestone into dolomite. However, a number of good fossil casts and molds can be found within the Galena Formation. (See the fossil plates in the back of the guidebook for identification.)

There are several geologic models for the origin of the dolomites. Some geologists think that dolomitization takes place soon after deposition, when the unconsolidated limy sediments are still in contact with the sea water. Magnesium in the sea water is exchanged for calcium in the sediments by a reaction with the sea water that bathes the upper part of the sediments. Other geologists think that, after the limy sediments have been consolidated to limestone, dolomitization takes place by a reaction with magnesium-rich formation water (connate water) that was trapped in the limy sediments or in associated sandstones and shales during deposition. Still another theory holds that dolomitization is accomplished by groundwater that becomes charged with magnesium from the zone of weathering at the land surface. The magnesium-rich groundwater percolates through the pores and cracks (joints) in the limestones, altering them to dolomite. There is evidence that dolomite is precipitated directly from sea water under certain specialized environmental conditions and that many dolomites are primary in origin rather than secondary alteration products of limestone. However, the special conditions required for primary precipitation of dolomite generally are not found in most regions of present limestone deposition in the seas. Space does not permit an evaluation of all the various theories that have been proposed to explain dolomitization. Suffice it to say that the problem is a complex one.

The estimated height of the quarry is about 80 feet (fig. 23). There are several distinct shale layers, one about 15 feet above the quarry floor; 3 feet above that layer is another shale layer overlain by approximately 40 feet of dolomite. A third shale layer is approximately 18 feet below the top of the quarry. Fresh exposures of the dolomite in the lower part of the quarry below the shale layer are gray, which weathers to a buff tan when exposed. Also note that the lower 30 feet of the quarry walls are very wet. There is a natural seepage from the upper dolomite beds along the shale layers within the quarry. This type of seepage is what creates most of the springs in this area.

Groundwater moving down through the dolomite comes in contact with lower shale layers. The flow of groundwater is then diverted laterally along the top surface of the shale layers and forms a seep or spring. The shale layers, because of their small grain size and the mineralogy of the clays, form an aquitard (a confining bed) that restricts water from flowing through. The lower dolomite exposed in the quarry, below the shale layer, is gray, rather than the typical tan color that is generally exhibited by the Ordovician dolomites. The shale layer has formed a protective barrier blocking the oxygenated water from coming in contact with the underlying dolomite. Hence, the upper dolomites have been rusted because of the chemical reaction between the iron in the dolomite and the oxygenated water flowing through. The lower gray dolomite will also weather to a tan if left exposed to the elements.

Some of the shale layers most likely represent volcanic ash deposits. Along the shale layers are plants that have taken root. The plants love these wet, nutrient-rich clay layers. Bentonite volcanic ash beds contain minerals that plants love to root in. Compare the vegetation along the shale layers in this relatively new exposure of rock to the established vegetation in the older exposed bluffs along the Apple River. These bluffs, both manmade and natural, provide unique habitats for a variety of common and rare plant and animal species.

Description of stratigraphic units exposed in Youngbluth Quarry (fig. 23):

Ordovician

Galena Group

Wise Lake Formation

70 feet — Medium brown to tan, dense dolomite, 1- to 2- foot beds, with some vugs; weathers medium yellow-brown. Possible ash beds 15 feet above the quarry floor and 18 feet below the top; some sulfide mineralization occurs along joints and bedding planes.

Dunleith Formation

>6 feet — Medium gray, dense, cherty, slightly argillaceous dolomite; beds generally less than 1 foot; the floor of the quarry is at the top of the unit.

STOP 3: Benton Mound (SW, NW, NE, Sec. 28, T28N, R4E, 4th P.M., Elizabeth NE 7.5-minute Quadrangle, Jo Daviess County). Overview of area, mounds, drainage divide, and formation of Apple River Canyon.

Different kinds of rocks give rise to a variety of topographic features. Flat areas are due, at least in part, to resistant, horizontal strata. The hard dolomite beds form the tops of the mounds, bluffs, cliffs, and steep valley walls. The soft Maquoketa Shale forms the wide, open, gentle slopes between the underlying and overlying Ordovician and Silurian dolomites (fig. 10).

Many of the hills or mounds in the Driftless Area are capped with the Silurian age, dolomitic Niagara Limestone. Under this lies the green and blue shale and limestone of the Ordovician age, Maquoketa Shale of the Cincinnati Group, but the great bedrock of the county is the Galena Dolomite (see fig. 2).

Mounds

Stop 3 is located on the north flank of the Benton Mound about 130 feet below the crest, which is 1,226 feet above mean sea level (msl). The mound is an erosional remnant that has been protected from erosion by a 100-foot-thick Silurian dolomitic cap. Several of the Silurian capped mounds are visible from this vantage point to the north and northwest (see route maps).

Six miles north-northwest at an elevation of 1,180 feet (msl) is a set of three small knobs that obscures the village of Apple River located about another mile to the northwest. Mt. Sumner, at 1,160 feet msl, is located 6.5 miles to the northwest and lies in front of Squirrel Grove and Hudson Mounds, which also are slightly higher than 1,160 feet. Charles Mound, with an elevation of 1,241 feet msl, is the highest land surface in Illinois and can be seen some 12 miles away slightly to the left (northwest of the other mounds). Because several mounds and ridges between here and Charles Mound are more than 1,100 feet, the latter does not stand out prominently on the horizon. The majority of these mounds represent remnants of the Dodgeville erosional surface (fig. 10).

Drainage Divide

To the north, you are looking down onto a very flat upland surface that developed in the top of the Galena dolomite and in a few places upon the lower section of the overlying Maquoketa Shale. This gently rolling upland is the top of the Lancaster erosional surface, developed on top of the Galena dolomite. The large flat area north of this stop trending northwest-southeast is part of the ancient drainage divide between the southeastward-flowing ancient Yellow River, a tributary to the ancient Pecatonica River, and the southwestward-flowing Apple River that drained into the Mississippi River. The divide was breached during the Illinois Glacial Episode, and some of the drainage on the east was pirated (diverted) to the west via the Apple River.

When the Illinois Episode Glacier stood just 2.5 miles east of here, it blocked the southeastward-flowing stream. This blockage created a large lake, which formed in the northwest-southwest–trending valley. Eventually the lake filled and spilled over the divide into the southwest-trending valley of the Apple River. This breaching of the drainage divide pirated (diverted) drainage east of the divide to the west via Apple River. The torrents of water flowing over this low area in the divide cut a canyon 200 feet deep, down through solid rock forming the straight northeast-southwest–trending Apple River Canyon. (See Stop 1 for a detailed description of the formation of the Apple River Canyon.)

Although not directly visible from here, Apple River Canyon is below the tree line and extends from a point about 2.25 miles west to a point 3.5 miles north (see route maps). Apple Canyon Lake dam is about 6 miles to the west-northwest on Hell's Branch.

STOP 4: Lunch (SW, NE, SW, Sec. 4, T28N, R4E, 4th P.M., Elizabeth NE 7.5-minute Quadrangle, Jo Daviess County). After lunch, reset the odometer at the entrance to the shelter parking lot to 0.0.

Stratigraphy of the Apple River Canyon State Park

The rocks exposed in the park belong to the dolomitic and shaley units of the Galena Group. Figure 25 identifies the outcrops exposed along North Canyon Park Road as it descends from the top of the Lancaster erosional surface (the flat area south of the park) to the base of the bluffs along Apple River.

The following descriptions are modified from Reinertsen et al. (1972). Starting at the top, about 10 feet of the Dubuque crops out beside the road near the top of the hill. The dolomite beds are 4 to 12 inches thick and are separated by shale beds up to 6 inches thick. The base of the Maquoketa Group is within a few feet of the top of this outcrop.

The Wise Lake Formation crops out in several places farther down the hill. The base of the formation is evidently at the top of the nodular chert band in the outcrop as the Wise Lake is essentially chert-free. The approximate elevation of the Wise Lake-Dunleith contact is 830 feet. The total thickness of the chert-free formations of the Galena Group (the Dubuque and Wise Lake) is about 110 feet.

The Dunleith Formation forms the cliffs at Apple River State Park (fig. 26). About 45 feet of Dunleith is exposed in the cliffs, less than half of the formation's thickness. Bands of chert nodules are conspicuous in the Dunleith. A bed of dolomite containing numerous *Receptaculites* species

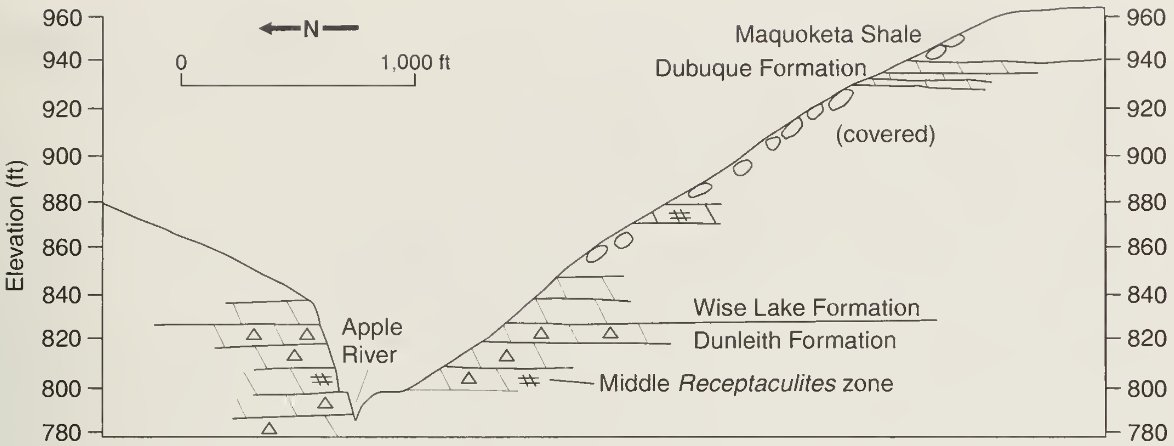


Figure 25 Topographic profile with a geologic cross section of stratigraphy exposed along North Canyon Park Road (modified from Reinertsen et al. 1972).

Figure 26 Apple River Canyon State Park. This gravel lag deposit was left on the grass-covered floodplain by a high-water flood stage on July 24, 2002. The bluffs are carved in the Dunleith Formation (photo by W. T. Frankie).

occurs several feet above the base of the cliff across the river and west of the main road intersection of West Canyon and North Canyon Park roads. This layer is the Middle *Receptaculites* Zone. This zone and two others have long been used by lead miners and geologists to identify the various dolomite layers of the Galena Group. The zones occur consistently at the same levels. The Lower *Receptaculites* Zone is near the base of the Dunleith, the Middle Zone is near its top (about 30 feet from the top here), and the Upper Zone is near the middle of the Wise Lake Formation.

STOP 5: Cox Quarry (NW, NE, NE, Sec. 25, T29N, R3E, 4th P.M., Elizabeth NE 7.5-minute Quadrangle, Jo Daviess County). Pull into the quarry and park on the bed of the quarry. Please wait for instructions from your field trip leaders before you attack the outcrop.

This quarry is operated by Conmat Inc., P.O. Box 750, Freeport, Illinois 60136. *Remember, you must ask for permission before entering this or any other privately owned land.*

Strata exposed in the Cox Quarry belong to the Wise Lake and Dubuque Formations (fig. 27). The total thickness exposed in the quarry varies from 48 to 60 feet. The 6-inch marker bed, which is used to separate the Wise Lake from the overlying Dubuque Formation, is located approximately 6 feet above the floor of the quarry. This 6-inch marker bed is overlain and underlain by a 0.5-inch shale layer that most likely represents a volcanic ash bed. The 6-inch marker bed can be traced from quarry to quarry throughout northwestern Illinois (fig. 28). Subsurface correlation of the marker bed is done with the use of gamma ray logs; the shale units above and below the marker beds respond with very high kicks (readings).

Figure 27 Cox Quarry at Stop 5, Ordovician age stratigraphic units exposed include the Wise Lake Formation and the overlying Dubuque formation (photo by W.T. Frankie).

Description of stratigraphic units exposed in Cox Quarry and shown in figure 23:

Quaternary

Loveland Silt-Peoria Loess

8 feet — Mottled light gray and light yellow, clayey silt with some manganese nodules and root casts; weathers medium tan.

<6 inches — Discontinuous bed of slightly polished, medium tan-brown to medium gray chert clasts, residuum on the Lancaster erosional surface.

Ordovician

Galena Group

Dubuque Formation

3 feet	Brown, fine-grained, weathered dolomite.
35 feet	Tan to brown dolomite in 1- to 3-foot beds, some shale partings; *Pseudolingula* with partial original shell material common on shale bedding planes.
15 feet	Brown to tan, fine-grained dolomite, beds 5 to 15 inches; recognizable packages of vuggy dolomite; dense dolomite with a hardground at discontinuity.
0.5 inches	Medium to dark gray shale; possible volcanic ash bed.
6 inches	Medium to light gray, dense dolomite; marker bed.
0.5 inches	Medium to dark gray shale; possible volcanic ash bed; some seeps at this horizon.

Wise Lake Formation

6 inches	Medium to light gray, dense dolomite; marker bed.
>9 feet	Medium gray, dense dolomite; 1- to 2-foot beds.

A number of exploration pits occur along Kentucky Creek east of the quarry. Some galena was found in the Wise Lake Formation when the quarry was first opened. The deposits of ore in this vicinity were mostly crevasse deposits. These ore bodies are generally found in long narrow solution channels that developed in the Galena dolomite along joint planes that intersect the rock. The lead and zinc ores of the crevasse deposits generally lie at higher levels in the formation than do the flat-and-pitch deposits in which the larger mines were operating. The crevasse deposits are rich but relatively small. A more detailed description of the geology of the zinc and lead deposits can be found in the Supplemental Reading section located in the back of the guidebook.

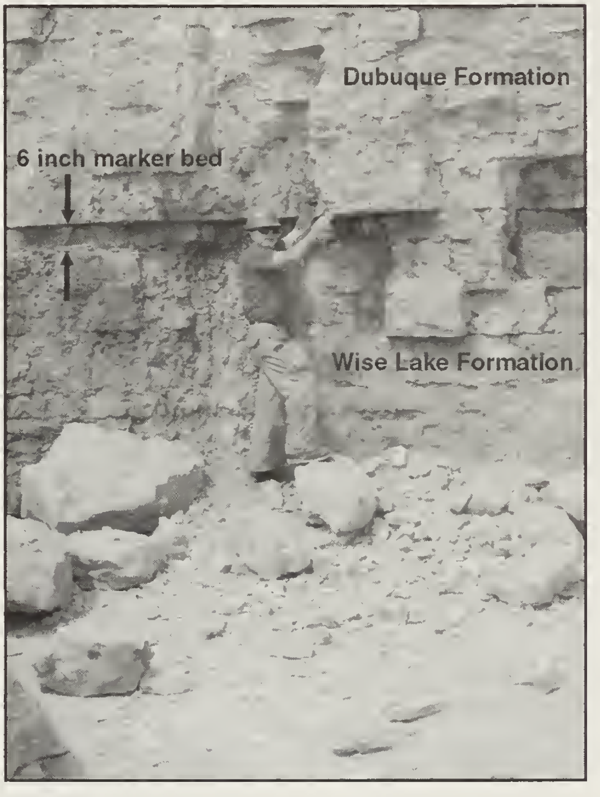


Figure 28 Geologist Skip Nelson measuring the 6-inch marker bed at the Wenzel Mound Quarry.

Lead and Zinc Mining in the Upper Mississippi Valley Region

The Upper Mississippi Valley Zinc–Lead District, an area of zinc and lead mineralization in extreme northwestern Illinois, southwestern Wisconsin, and adjacent parts of Iowa, is one of the oldest continuously operating mining districts in the United States. It is not known exactly when the existence of lead ore in this region first became known. Jean Nicolet may have been the first white man to note its presence when he journeyed up the Mississippi River in 1634, but this supposition is not confirmed by any record. There are reports that other French explorers had heard about Native American lead workings in the vicinity of Dubuque, Iowa, as early as 1658. However, Nicholas Perrot, a French commandant and trader who is known to have viewed their mines in 1682, is credited with the actual discovery of lead ore. Perrot settled on the east side of the Mississippi in 1690. La Salle and Father Louis Hennepin explored both the Illinois and Mississipi River valleys in the 1680s. On a map drawn by Hennepin in 1687, he located a lead mine in the Galena area. In addition, Joutel, who was in the Mississippi Valley in 1687 and who was later to record La Salle's expedition, wrote tales of Native American lead mines told by travelers to the "Upper Mississippi." The first to exploit these deposits was a Scotch adventurer, John Law. His Company of the West, founded in Paris in 1717 on the fraudulent claim that the Illinois lead mines were well-developed, collapsed with a thud, which was heard all over France and went down in history as the "Mississippi Bubble." These early galena discoveries eventually led to the development of vital economic resources hundreds of years later.

Commercial mining by the French and Native Americans continued on a small scale east of the Mississippi River for the next 100 years. In 1788, the Sac and Fox tribes gave Julien DuBuque permission to work mines on the west side of the river. DuBuque also opened a mine on the Illinois side near the site of Elizabeth. The lead mining industry continued to grow slowly until 1823, when it expanded greatly due to the rapid settlement of the area.

The principal lead ore mineral is galena, after which Galena, the county seat and largest city in Jo Daviess County, was named in 1827. Formerly La Point, Galena was the first city in this region to organize under a charter. The city grew rapidly as the mining industry expanded. Sphalerite, the ore of zinc, is also found with the galena, but, until about 1850, galena was the only ore mineral recovered. Mines in the Galena vicinity were the first in the United States to produce large quantities of lead ore, and, in 1845, the reported production was 27,000 tons. This tonnage was 90% of all the lead produced in the United States, then the world's leading lead producer (Cote et al.1971).

Early Mining

In the early days of mining, the lead ore was found primarily in rich pockets or in open vertical fissures, both referred to as "crevices." These crevices occur at or near the ground surface in the dolomite bedrock that underlies the region. As the mining industry expanded, these rich, easily exploited crevice lodes became harder to find. The crevices were largely exhausted by 1870, and, as a result, lead production sharply declined. The search for lead ore was then extended deeper into the bedrock. Some additional galena was found, but the deep ores consisted primarily of the mineral sphalerite. These deeper ores occur in fractures in the dolomite as horizontal and inclined veins referred to as "flats" and "pitches," respectively. Sphalerite was first reported in 1839, but was initially considered useless and was discarded by miners in search of lead ore. However, in 1852, a zinc ore reduction plant was opened near La Salle, and this mineral also became important to the economic development of the mining district. From 1852 to 1909, the total production of zinc ore was greater than that of lead ore in the same period (Trowbridge and Shaw 1916).

STOP 6: Wenzel Mound Quarry (SW, SW, NE, Sec. 2, T28N, R2E, 4th P.M., Scales Mound East 7.5-minute Quadrangle, Jo Daviess County). Pull into the quarry and park on the bed of the quarry. Please wait for instructions from your field trip leaders before you attack the outcrop.

This quarry is operated by Conmat Inc., P.O. Box 750, Freeport, Illinois 60136. *Remember, you must ask for permission before entering this or any other privately owned land.*

Description of stratigraphic units exposed in the quarry and shown in figure 29:

Quaternary

Loveland Silt-Peoria Loess

6 feet	Mottled light gray and light yellow, clayey silt with manganese nodules and root casts; weathers medium tan.
3 feet	Very dark gray clay and geosol in 8-foot-wide paleo-gully cut into bedrock.

Ordovician

Maquoketa Group

Scales Mound Formation

8 feet	Light gray, gray-green mudstone; weathers yellow-brown.
3–6 inches	Dark gray, phosphatic grainstone to phosphorite; abundant small fossils; 0.25-inch rusty zone at top.
3 inches	Medium tan, discontinuous fine-grained dolomite.
30 inches	Dark gray mudstone; weathers light gray to grayish tan.
1 foot	Medium dark gray shale.
<3 inches	Dark gray, phosphatic grainstone to phosphorite; abundant small fossils.

Galena Group

Dubuque Formation

2 feet	Tan to brown, fine-grained dolomite, with micro-karst and vugs; sulfide minerals line some vugs.
20 feet	Tan to brown dolomite in 1- to 3-foot beds; some shale partings.
15 feet	Light gray to tan, fine-grained dolomite; beds 5 to 15 inches; recognizable packages of vuggy dolomite overlain by dense dolomite with a hardground discontinuity at top of package.
0.5 inch	Medium to dark gray shale, possible volcanic ash bed; some seeps at this horizon.

Wise Lake Formation

6 inches	Medium to light gray, dense dolomite; marker bed.
>7 inches	Medium gray, dense dolomite, 1- to 2-foot beds, with some vugs; discontinuous sulfide mineralization about 30 inches above quarry floor; a number of large straight cephalopods are present on quarry floor.

The upper part of the quarry exposes a 12-foot-thick section of gray shale and phosphatic sediments in the lower part of the Maquoketa Group. The base of the shale overlies buff-colored dolomite of the middle Ordovician Dubuque Formation, the uppermost formation of the Galena Group. The shale exposed here belongs to the Scales Formation, one of several formations into which the Maquoketa Group has been divided. The type section for the Scales Formation is located in a

Figure 29 Wenzel Quarry at Stop 6. Ordovician age stratigraphic units exposed from base to the top include the Wise Lake Formation, Dubuque Formation, and the Scales Mound Formation (photo by W. T. Frankie).

railroad cut (SW, NE, SW, Sec. 26, T29N, R2E) within the community of Scales Mound, for which its name is taken.

Of particular interest here are the phosphatic sediments, which represent unusual conditions of deposition that occurred only during Maquoketa time in Illinois, and the contact between the Scales and Dubuque Formations, an ancient surface of erosion, which represents a major withdrawal of the sea from this region during Ordovician time.

This exposure within the quarry is one of the best exposures of the lower part of the Maquoketa shale in Illinois. As shale soon breaks down by weathering, most natural exposures are poor and grassed over. The Maquoketa Group consists mostly of light gray and greenish gray shale with thin even beds of light brownish gray siltstone. The lower 4 feet of the shale is dark brownish gray or dark gray (almost black), phosphatic, and carbonaceous shale. This dark-colored shale is very hard and slaty. At the bottom of the shale is a thin 2- to 6-inch layer of shaly, bluish gray phosphate rock composed of numerous small, pyritic, and phosphatic fossils, consisting mostly of pelecypods, gastropods, and other mollusks, mixed with phosphatic clay and shiny black grains, pellets, and nodules of phosphorite. The phosphate rock is also partially cemented by pyrite. Phosphorite is calcium-fluoro-phosphate, a variety of the mineral apatite that is commonly found in small quantities in marine sedimentary rocks. The fossils originally consisted of calcium carbonate, which was replaced by the pyrite and phosphorite. The phosphatic fossils are black, gray, and brownish gray. The pyrite weathers easily, and, as a result, the phosphate rock soon becomes rusty and loosely granular, making the phosphatic fossils easy to collect. A second bed of phosphate rock, about 8 inches thick and exactly like the lower one and containing the same fauna, occurs about 3.5 feet higher (Cote et al. 1971).

Depauperate Zone The lower bed of phosphate rock forms a crust-like layer on the top of the Dubuque Formation. This layer of phosphate rock is the famous "depauperate zone" that occurs widely at the base of the Maquoketa Shale throughout the Midwest. Most of the fossils of the depauperate fauna are very small, usually 0.25 inch or less in diameter. Because of the abundance of pyrite and carbonaceous material in the phosphatic sediments, many geologists formerly thought that the fossils had been dwarfed in a restricted marine environment of poorly circulating, oxygen-deficient waters. However, study has shown that the depauperate fauna consists mostly of normal size individuals of species that never grew any larger.

One possible explanation for the small-sized assemblage of fossils is that the depauperate zone represents a cycle of varying environmental conditions between good and bad living conditions, related to rapidly changing water depths and chemistry. The fossils are small because they represent colonies where life started to grow and then conditions changed and they all died, followed by repetitions of life starting and ending. Fossils of different degrees of preservation are found within this zone. It is thought that fossils that are well dissolved (eroded) represent early colonies that died when the living conditions became "a stinky bottom dwelling surface." The better preserved fossils represent later colonies that were subsequently buried by the overlying Maquoketa shale (Kolata, personal communication 2002).

What is unusual is that so many species of small animals were living together in the same environment. Forty-four species have been identified in the depauperate fauna, although not all are in any one place. Among these are species of *Ctenodonta, Vanuxemia* (pelecypods), *Trochonema, Cyclonema,* and *Hormotoma* (gastropods), which are illustrated on the fossil plate in the back of the guidebook.

Kolata and Graese (1983) provide a slightly more detailed list of the most abundant and widespread fossils found in the depauperate zone. This list includes *Palaeoneio(?) fecunda* and *Nuculites neglectus* (nuculoid bivalves), *Michelinoceras soc/ale* (cephalopod), *Plagioglypta iowensis* (scaphopod), *Liospira* (archaeogastropod), *Septemchiton* (polyplacophoran), *Onniella* sp. (orthid brachiopod), and *Leptobolus* (linguloid brachiopod).

Environment of Deposition The top of the Dubuque Formation is an erosion surface known as a disconformity. Some geologists prior to deposition of the Maquoketa Shale, the Middle Ordovician sea had withdrawn or became shallower, and this region was exposed to erosion. The phosphatic sediments were deposited on this erosional surface during the early part of the Late Ordovician re-invasion by the sea. The type of environment in which the Maquoketa phosphates were deposited is not exactly known, but it probably was not a restricted environment. In modern seas, phosphatic sediments are forming in unrestricted, open ocean environments at intermediate depths (200 to 1,000 feet) where bottom waters are freely circulating and well oxygenated. These areas are usually platforms bordering deep basins from which cold, phosphate-rich waters upwell toward the surface. Over these relatively shallow platforms, the upwelling basin waters are warmed, resulting in supersaturation of the seawater with dissolved phosphate. This supersaturation causes chemical precipitation of phosphorite, in the form of crusts or nodules, on the sea floor. The upwelling waters are also rich in other dissolved nutrients that support the growth of large populations of microscopic planktonic plants and animals in the surface waters. The plankton extract phosphate from the seawater during their life processes. When they die, their remains settle to the bottom, adding additional phosphate and organic carbon to the bottom sediments. Phosphate from the water also replaces calcium carbonate in the shells of benthonic (bottom dwelling) and planktonic animals that accumulate with the phosphatic sediments.

Almost no land-derived sediments (sand, silt, or clay) and no limestone are being deposited in present-day areas of phosphorite deposition. This nondeposition of other sediment types is a very important factor in the formation of concentrations of phosphorite. Phosphorite accumulates so slowly that the deposition of large quantities of other sediments would dilute the phosphorite and prevent its concentration. Phosphorite nodules would not form if they did not remain in contact with the sea water for a very long time. (On parts of the sea floor off the coast of southern California, phosphorite nodules similar to those at the base of the Maquoketa Shale are growing at the rate of only a few millimeters per thousand years.)

Perhaps an environment similar to the modern phosphate environments existed during Late Ordovician time when the phosphatic nodules and shales of the Maquoketa were deposited. The phosphate-rich waters associated with this deposit migrated from deep waters. The source was from the area of the Reelfoot Rift in the deepest part of the Illinois Basin during the Ordovician (fig. 1). The top phosphate-rich surface of the Galena dolomite can be traced southward toward Kentucky where it pinches out in western Kentucky (Kolata, personal communication 2002).

At the beginning of the Late Ordovician submergence, very little mud was carried into the sea from the land while the dark phosphatic shale was being deposited. Sedimentation was especially slow during the growth of the phosphorite nodules and deposition of the phosphate rock. The concentration of phosphate ended when large amounts of mud and silt were washed into the sea from the land and the overlying non-phosphatic light gray shales and siltstones were deposited. These sediments are almost barren of fossils because most bottom-dwelling animals could not tolerate the muddy conditions.

Mining in the Area

To the southeast of the Wenzel Mound Quarry is the abandoned Rockford Mining and Milling Company mine (NW, SW, Sec. 1, T28N, R2E) located southeast of the junction of the unnamed tributary and Mill Creek and on the east side of Mill Creek Road. The location of the mine is shown on a 1:62,500 topographic map of the Galena and Elizabeth Quadrangles (plates 1 and 4, Trowbridge and Shaw 1916). This old mine had two shafts about 200 feet apart on apparently separate eastward-striking fractures. Little is known about this ore body except that it is in the Stewartville Member of the Galena Dolomite, and it was mined between 1905 and 1915 (Heyl et al. 1959). The Stewartville Member forms the upper massive bedded part of the Wise Lake Formation of the Galena Group. This mine's name is also reported as the Scales Mound and Rockford Mine. A number of other small exploration pits are located along Mill Creek.

This mine is in the old lead mining area known as the Apple River–Warren District. The ore bodies in this district are generally in mineralized joints and openings, and, at one time, large quantities of lead were produced from the Stewartville Member of the Wise Lake Formation. A furnace at Warren produced about 300,000 tons of lead annually from 1872 to 1876 (Heyl et al. 1959).

The east highwall in the quarry contains a number of vertical joints that are filled with gouge. This clay-rich joint filling also contains some smooth, iron-stained chunks of chert. Although no lead was found within this joint during the preparation of this field trip, the joints in the highwall help illustrate the type of geological features that were explored during the Galena Rush.

Because of its early development and long history of mining, the total quantity of galena and zinc mined in the Driftless Area is uncertain. However, production records for Illinois and Wisconsin are available from 1940 to 1977, the last year of mining in the area. The 1940 to 1977 cumulative production of zinc and galena for Illinois was 323,525 tons of zinc, and 30,576 tons of galena and for Wisconsin was 567,437 tons of zinc and 46,640 tons of galena. Since the amount of zinc produced is more than 10 times the amount of galena, you may wonder why this area isn't called the Zinc District rather than the Lead District. The first mining in the area was for galena, and zinc was initially a curse to the early miners, having no value during the early mining period.

REFERENCES

Bradbury, J.C., 1960, A structural analysis of the northwestern Illinois Zinc-Lead District: Transactions of the Illinois State Academy of Science, v. 53, nos. 1 and 2, p. 20–24.

Buschbach, T.C., and D.R. Kolata, 1991, Regional setting of the Illinois Basin, *in* M.W. Leighton, D.R. Kolata, D.F. Oltz, and J.J. Eidel, eds., Interior Cratonic Basins: American Association of Petroleum Geologists, Memoir 51, p. 29–55.

Clark, P.U., M.R. Greek, and M.J. Schneider, 1988, Surface morphology of the southern margin of the Laurentide Ice Sheet from Illinois to Montana (Abstr.), *in* Program and Abstracts of the Tenth Biennial Meeting, American Quaternary Association: Amherst, University of Massachusetts, p. 60.

Cote, W.E., D.L. Reinertsen, G.M. Wilson, and M.M. Killey, 1971, Galena area geological science field trip, Jo Daviess County: Illinois State Geological Survey, Geological Science Field Trip Guide Leaflet 1971C, 20 p. plus attachments.

Damberger, H.H., 1971, Coalification pattern of the Illinois Basin: Economic Geology, v. 66, no. 3, p. 488–494.

Hansel, A.K., and W.H. Johnson, 1996, Wedron and Mason Groups: Lithostratigraphic reclassification of deposits of the Wisconsin Episode, Lake Michigan Lobe Area: Illinois State Geological Survey, Bulletin 104, 116 p.

Heyl, A.V., Jr., A.F. Agnew, E.J. Lyons, and C.H. Behre, Jr., 1959, The geology of the Upper Mississippi Valley Zinc-Lead District: U.S. Geological Survey, Professional Paper 309, 310 p. plus plates.

Horberg, C.L., 1950, Bedrock topography of Illinois: Illinois State Geological Survey, Bulletin 73, 111 p.

Illinois State Geological Survey, Geological Science Field Trip Guide Leaflet 1972D & 1973C, 24 p. plus attachments.

Killey, M.M., 1998, Illinois' Ice Age legacy: Illinois State Geological Survey, GeoScience Education Series 14, 66 p.

Kolata, D.R., and T.C. Buschbach, 1976, Plum River Fault Zone of northwestern Illinois: Illinois State Geological Survey, Circular 491, 20 p.

Kolata, D.R., and A.M. Graese, 1983, Lithostratigraphy and depositional environments of the Maquoketa Group (Ordovician) in northern Illinois: Illinois State Geological Survey, Circular 528, 49 p.

Leighton, M.M., G.E. Ekblaw, and C.L. Horberg, 1948, Physiographic divisions of Illinois: Illinois State Geological Survey, Report of Investigations 129, 19 p.

Nelson, J.W., 1995, Structural features in Illinois: Illinois State Geological Survey, Bulletin 100, 144 p.

Piskin, K., and R.E. Bergstrom, 1975, Glacial drift in Illinois; Thickness and character: Illinois State Geological Survey, Circular 490, 34 p.

Post, S.L., 1997, Hiking Illinois; America's best day hikes series: Champaign, Illinois, Human Kinetics, 212 p.

Post, S.L., 1998, The Driftless Area; An inventory of the regions resources; A product of the Critical Trends Assessment Program: Springfield, Illinois, Illinois Department of Natural Resources, Office of Reality and Environmental Planning, 22 p.

Reinertsen, D.L., D.J. Berggren, and M.M. Killey, 1972, Stockton area, Jo Daviess County:

Schwegman, J.E., 1973, Comprehensive plan for the Illinois Nature Preserve System. Part 2 - Natural Divisions of Illinois: Springfield, Illinois, Illinois Nature Preserves Commission, 32 p.

Trowbridge, A.C., and E.W. Shaw, 1916, Geology and geography of the Galena and Elizabeth Quadrangles: Illinois State Geological Survey, Bulletin 26, 233 p.

Willman, H.B., and J.C. Frye, 1970, Pleistocene stratigraphy of Illinois: Illinois State Geological Survey, Bulletin 94, 204 p.

RELATED READINGS

Bradbury, J.C., R.M. Grogan, and R.J. Cronk, 1956, Geologic structure map of the northwestern Illinois Zinc-Lead District: Illinois State Geological Survey, Circular 214, 7 p.

Bretz, J.H., and S.E. Harris Jr., 1961, Caves of Illinois: Illinois State Geological Survey, Report of Investigations 215, 87 p.

Cox, G.H., 1910, Elizabeth Sheet of the Lead and Zinc District of northern Illinois *in* Year-book for 1909: Illinois State Geological Survey, Bulletin 16, p. 24–41.

Cox, G.H., 1914, Zinc and lead deposits of northwestern Illinois: Illinois State Geological Survey, Bulletin 21, 120 p.

Grant, U.S., and M.J. Perdue, 1908, Millbrig Sheet of the Lead and Zinc District of northern Illinois: Illinois State Geological Survey, Bulletin 8, pp.335–343.

Hackett, J.E., and R.E. Bergstrom, 1956, Groundwater in northwestern Illinois: Illinois State Geological Survey, Circular 207, 24 p.

Herzog, B.L., B.J. Stiff, C.A. Chenoweth, K.L. Warner, J.B. Sieverling, and C. Avery, 1994, Buried bedrock surface of Illinois: Illinois State Geological Survey, Illinois Map 5; 1:500,000; 33.25 inches × 60.75 inches.

Heyl, A.V., Jr., W.A. Broughton, and W.S. West, 1970 (1978 revised), Geology of the Upper Mississippi Valley Base-Metal District: Madison Wisconsin, Wisconsin Geological and Natural History Survey, Information Circular 16, 45 p.

Horberg, C.L., 1946, Preglacial erosion surfaces in Illinois: Illinois State Geological Survey, Report of Investigations 118, 13 p.

Ipe, C.V., 2000, Illinois Mineral Industry 1993–1996 and a report on water resources of Illinois: Illinois State Geological Survey, Illinois Minerals 119, 41 p.

Johnson, T.M., and K. Cartwright, 1980, Monitoring of leachate migration in the unsaturated zone in the vicinity of sanitary landfills: Illinois State Geological Survey, Circular 514, 82 p.

Larson, T.H., A.M. Graese, and P.G. Orozco, 1993, Hydrogeology of the Silurian dolomite aquifer in parts of northwestern Illinois: Illinois State Geological Survey, Environmental Geology 145, 29 p.

Leighton, M.M., D.R. Kolata, D.F. Oltz, and J.J. Eidel, eds.,1990, Interior Cratonic Basins: American Association of Petroleum Geologists, Memoir 51.

Lineback, J.A., et al., 1979, Quaternary deposits of Illinois: Illinois State Geological Survey, Map; 1:500,000; 40 × 60 inches; color.

Ludvigson, G.A., and B.J. Bunker, eds., 1988, New perspectives on the paleozoic history of the Upper Mississippi Valley: An examination of the Plum River Fault Zone: Iowa Department of Natural Resources, Geological Survey Bureau Guidebook No. 8, 245 p.

McFall, D., and J. Karnes, eds., 1995, A directory of Illinois Nature Preserves; Volume 2, Northwestern, central and southern Illinois, Illinois Department of Natural Resources, Division of Natural Heritage, 321 p.

Mohlenbrock, R.H., 1974, Apple River Canyon State Park: Outdoor Illinois Magazine, v. 13, no. 1, p.15–30.

Odom, E.L., and G.M. Wilson, 1963, Savanna area geological science field trip: Illinois State Geological Survey, Geological Science Field Trip Guide Leaflet 1963D, 22 p.

Post, S.L., 1999, In a place called Illinois: Mississippi Palisades State Park: The Illinois Steward, v. 8, no. 1, p. 2–3.

Raasch, G.O., 1948, Apple River Canyon area geological science field trip: Illinois State Geological Survey, Geological Science Field Trip Guide Leaflet 1948C, 7 p.

Raasch, G.O., 1952, Galena area geological science field trip: Illinois State Geological Survey, Geological Science Field Trip Guide Leaflet 1952C, 10 p. plus attachments

Raymond,Martin, L., 2001, Bibliography and index of Illinois geology, 1966–1996: Illinois State Geological Survey, Bulletin 105, 446 p.

Reinertsen, D.L., 1992, Guide to the geology of the Galena area, Jo Daviess County, Illinois, and Lafayette County, Wisconsin: Illinois State Geological Survey, Geological Science Field Trip Guidebook 1992B, 38 p. plus attachments.

Reinertsen, D.L., and W.T. Frankie, 1994, Guide to the geology of the Elizabeth area, Jo Daviess County: Illinois State Geological Survey, Geological Science Field Trip Guide Leaflet 1994C, 34 p. plus attachments.

Rios, B., D. Barnstable, J.H Goodwin, and N.P. Schneider, 1999, Life on the edge: The Illinois Steward, v. 8, no.2, 8 p.

Schockel, B.H., 1916, History of development of Jo Daviess County: Illinois State Geological Survey, Bulletin 26, 233 p.

Willman, H.B., 1973, Rock stratigraphy of the Silurian system in northeastern and northwestern Illinois: Illinois State Geological Survey, Circular 479, 55 p.

Willman, H.B., E. Atherton, T.C. Buschbach, C.W. Collinson, J.C. Frye, M.E. Hopkins, J.A. Lineback, and J.A. Simon, 1975, Handbook of Illinois stratigraphy: Illinois State Geological Survey, Bulletin 95, 261 p.

Willman, H.B., and J.C. Frye, 1969, High-level glacial outwash in the Driftless Area of northwestern Illinois: Illinois State Geological Survey, Circular 440, 21 p.

Willman, H.B., and D.R. Kolata, 1978, The Platteville and Galena Groups in northeastern Illinois: Illinois State Geological Survey, Circular 502, 75 p.

Willman, H.B., and R.R. Reynolds, 1947, Geological structure of the Zinc-Lead District of northwestern Illinois: Illinois State Geological Survey, Report of Investigations 124, 15 p.

Willman, H.B., R.R. Reynolds, and P. Herbert, Jr., 1946, Geological aspects of prospecting and areas for prospecting in the Zinc-Lead District of northwestern Illinois: Illinois State Geological Survey, Report of Investigations 116, 48 p.

Willman, H.B., J.A. Simon, B.M. Lynch, and V.A. Langenheim, 1968, Bibliography and index of Illinois geology through 1965: Illinois State Geological Survey, Bulletin 92, 373 p.

Willman, H.B., et al., 1967, Geologic map of Illinois: Illinois State Geological Survey, Map; 1:500,000; 40 × 56 inches; color.

Wilson, G.M., 1957, Elizabeth area earth science field trip, Jo Daviess County: Illinois State Geological Survey, Geological Science Field Trip Guide Leaflet 1957D, 7 p. plus attachments.

Worthen, A.H., 1866, Geology: Illinois Geological Survey, v. 1, 504 p.

Glossary

The following definitions are adapted in total or in part from several sources. The principal source is R.L. Bates and J.A Jackson, eds., 1987, *Glossary of Geology*, 3rd ed.: Alexandria, Virginia, American Geological Institute, 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.

aggraded Built up by deposition.

aggrading stream A stream that is actively depositing sediment in its channel or floodplain because it is 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 sorted or semisorted sediment deposited during comparatively recent time by a stream or other body of running water.

angular unconformity The name of the contact when the beds below the unconformity are tilted and eroded prior to deposition of overlying beds.

anticline A convex-upward rock fold in which strata have been bent into an arch; the strata on either 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.

anticlinorium A complex structure having smaller structures, such as domes, anticlines, and synclines superimposed on its broad upwarp.

aquifer A geologic formation that is water-bearing and that transmits water from one point to another.

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

argillaceous Said of rock or sediment that contains, or is composed of, clay-sized particles or clay minerals.

base level Lower limit of erosion of the land's surface by running water. Controlled locally and temporarily by the water level of stream mouths emptying into lakes, or more generally and semipermanently by the level of the ocean (mean sea level).

basement complex The suite of mostly crystalline igneous and/or metamorphic rocks that generally underlies the sedimentary rock 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; the term also denotes an area of relatively deep water adjacent to shallow-water shelf areas.

bed A naturally occurring layer of earth material of relatively greater horizontal than vertical extent that is characterized by physical properties different from those of 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 stream channel.

bedrock The solid rock (sedimentary, igneous, or metamorphic) that underlies the unconsolidated (non-indurated) surface materials (for example, soil, sand, gravel, glacial till).

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.

biota All living organisms of an area; plants and animals considered together.

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. Most streams that receive more sediment load than they can carry become braided.

calcarenite Describes a limestone composed of more or less worn fragments of shells or pieces of older limestone. The particles are generally sand-sized.

calcareous Said of a rock containing some calcium carbonate ($CaCO_3$), but composed mostly of something else (synonym: limey).

calcining The heating of calcite or limestone to its temperature of dissociation so that it loses its carbon dioxide; also applied to the heating of gypsum to drive off its water of crystallization to make plaster of Paris.

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 the Mohs scale; it effervesces (fizzes) readily in cold dilute hydrochloric acid. It is the principal constituent of limestone.

capric The top layer of 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 Said of rocks composed of particles of other rocks or minerals, including broken organic hard parts as well as rock substances of any sort, transported and deposited by wind, water, ice, or gravity.

claypan (soil) A heavy, dense subsurface soil layer that owes its hardness and relative imperviousness to higher clay content than that of the overlying material.

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

columnar section A graphic representation, in the form of one or more vertical columns, of the vertical succession and stratigraphic relations of rock units in a region.

conformable Said of strata deposited one upon another without interruption in accumulation of sediment; beds parallel.

cuesta A ridge with a gentle slope on one side and a steep slope on the other.

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

detritus Loose rock and mineral material produced by mechanical disintegration and removed from its place of origin by wind, water, gravity, or ice; also, fine particles of organic matter, such as plant debris.

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 time interval of nondeposition.

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

dome A general term for any smoothly rounded landform or rock mass that roughtly resembles the dome of a building.

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.

earthquake Ground displacement associated with the sudden release of slowly accumulated stress in the lithosphere.

end moraine A ridge or series of ridges formed by accumulations of drift built up along the outer 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.

en echelon Said of geologic features that are in an overlying or staggered arrangement, for example, faults.

epoch An interval of geologic time; a division of a period (for example, Pleistocene Epoch).

era The unit of geologic time that is next in magnitude beneath an eon; it consists of two or more periods (for example, Paleozoic Era).

erratic A rock fragment carried by glacial ice and deposited far from its point of origin.

escarpment A long, more or less continuous cliff or steep slope facing in one general direction; it generally marks the outcrop of a resistant layer of rocks or the exposed plane of a fault that has moved recently.

esker An elongated ridge of sand and gravel that was deposited by a subglacial or englacial stream flowing between ice walls or in an ice tunnel and left behind by a melting glacier.

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

flaggy Said of rock that tends 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 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.

flux A substance used to remove impurities from steel. Flux combines with the impurities in the steel to form a compound that has a lower melting point and density than steel. This compound tends to float to the top and can be easily poured off and separated from the molten steel.

formation The basic rock unit, one 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), generally derived from the geographic localities where the unit was first recognized and described.

fossil Any remains or traces of a once-living plant or animal preserved in rocks (arbitrarily excludes recent remains); any evidence of ancient life. Also used to refer to any object that existed in the geologic past and for which evidence remains (for example, a fossil waterfall)

fragipan A dense subsurface layer of soil whose hardness and relatively slow permeability to water are chiefly due to extreme compactness rather than to high clay content (as in claypan) or cementation (as in hardpan).

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 cemented sandstone.

geest An alluvial material that is not of recent origin lying on the surface.

geology The study of the planet Earth that is concerned with its origin, composition, and form, its evolution and history, and the processes that acted (and act) upon the Earth to control its historic and present forms.

geophysics Study of the Earth with quantitative physical methods. Application of the principles of physics to the study of the earth, especially its interior.

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 formed on land by the compaction and recrystallization of snow.

gley horizon A soil developed under conditions of poor drainage that reduced iron and other elemental contents and results in gray to black, dense materials.

gob pile A heap of mine refuse left on the surface.

graben An elongate, relatively depressed crustal unit or block that is bounded by faults on its long sides.

gradient A part of a surface feature of the Earth that slopes upward or downward; the angle of slope, as of a stream channel or of a land surface, generally expressed by a ratio of height versus distance, a percentage or an angular measure from the horizontal.

gypsum A widely distributed mineral consisting of hydrous calcium sulfate ($CaSO_4 \cdot 2H_2O$). Gypsum is soft (hardness of 2 on the Mohs scale); white or colorless when pure but commonly has tints of gray, red, yellow, blue or brown. Gypsum is used as a retarder in portland cement and in making plaster of Paris.

hiatus A gap in the sedimentary record.

horst An elongate, relatively uplifted crustal unit or block that is bounded by faults on its long sides.

igneous Said of a rock or mineral that solidified from molten or partly molten material (that is, from magma).

indurated Said of 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 (*see also* fault).

karst Collective term for the land forms and subterranean features found in areas with relatively thin soils underlain by limestone or other soluble rocks; characterized by many sinkholes separated by steep ridges or irregular hills. Tunnels and caves formed by dissolution of the bedrock by groundwater honeycomb the subsurface. Named for the region around Karst in the Dinaric Alps of Croatia where such features were first recognized and described.

lacustrine Produced by or belonging to a lake.

Laurasia A 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 supercontinent from which both were derived is Pangea. Laurasia 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; geologic features on opposite sides of these zones are very similar.

lava Molten, fluid rock that is extruded onto the surface of the Earth through a volcano or fissure. Also the solid rock formed when the lava has cooled.

limestone A sedimentary rock consisting primarily of calcium carbonate (the mineral, calcite). Limestone is generally formed by accumulation, mostly in place or with only short transport, of the shells of marine animals, but it may also form by direct chemical precipitation from solution in hot springs or caves and, in some instances, in the ocean.

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

lithology The description of rocks on the basis of their color, structure, 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 accumulation of silt-sized material deposited by the wind.

magma Naturally occurring molten rock material generated within Earth and capable of intrusion into surrounding rocks or extrusion onto the Earth's surface. When extruded on the surface it is called lava. The material from which igneous rocks form through cooling, crystallization, 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 swales and gentle ridges along a river's floodplain that mark the positions of abandoned parts of a meandering river's channel. They are generally filled in with sediments and vegetation and are most easily seen in aerial photographs.

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 (for example, gneisses, schists, marbles, and quartzites)

mineral A naturally formed chemical element or compound having a definite chemical composition, an ordered internal arrangement of its atoms, and characteristic crystal form and physical properties.

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 land forms that are independent of control by the surface on which the drift lies (*see also* end moraine).

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

natural gamma log One of several kinds of measurements of rock characteristics taken by lowering instruments into cased or uncased, air- or water-filled boreholes. Elevated natural gamma radiation levels in a rock generally indicate the presence of clay minerals.

nickpoint A place with an abrupt inflection in a stream profile, generally formed by the presence of a rock layer resistant to erosion; also, a sharp angle cut by currents at base of a cliff.

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

nonlithified Said of unconsolidated materials.

normal fault A fault in which the hanging wall appears to have moved downward relative to the footwall.

outwash Stratified glacially derived sediment (clay, silt, sand, and gravel) deposited by meltwater streams in channels, deltas, outwash plains, glacial lakes, and on floodplains.

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

overburden The upper part of a sedimentary deposit, compressing and consolidating the material below.

oxbow lake A crescent-shaped lake in an abandoned bend of a river channel. A precursor of a meander scar.

paha A low, elongated, rounded glacial ridge or hill consisting mainly of drift, rock, or windblown sand, silt, or clay but capped with a thick cover of loess.

palisades A picturesque extended rock cliff or line of bold cliffs, rising precipitously from the margin of a stream or lake.

Pangea The supercontinent that existed from 300 to 200 million years ago. It combined most of the continental crust of the Earth, from which the present continents were derived by fragmentation and movement away from each other by means of plate tectonics. During an intermediate stage of the fragmentation, between the existence of Pangea and that of the present widely separated continents, Pangea was split into two large fragments, Laurasia on the north and Gondwana in the southern hemisphere.

ped Any naturally formed unit of soil structure (for example, granule, block, crumb, or aggregate).

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

Pentamarus An articulate brachiopod.

period An interval of geologic time; a division of an era (for example, Cambrian, Jurassic, and Tertiary).

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.

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

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

radioactivity logs Any of several types of geophysical measurements taken in boreholes using either the natural radioactivity in the rocks, or the effects of radiation on the rocks to determine the lithology or other characteristics of the rocks in the walls of the borehole (for example, natural gamma radiation log; neutron density log).

relief (a) A term used loosely for the actual physical shape, configuration, or general uneveness 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 regional extent. Formed in places where the forces of plate tectonics are beginning to split a continent (for example, East African Rift Valley).

rift (a) A narrow cleft, fissure, or other opening in rock made by cracking or splitting; (b) a long, narrow continental trough that is bounded by normal faults—a graben of regional extent.

sediment Solid fragmental matter, either inorganic or organic, that originates from weathering of rocks and is transported and deposited by air, water, or ice or that is accumulated by other natural agents, such as chemical precipitation from solution or secretion from organisms. When deposited, sediment generally forms layers of loose, unconsolidated material (for example, sand, gravel, silt, mud, till, loess, and alluvium).

sedimentary rock A rock resulting from the consolidation of loose sediment that has accumulated in layers (for example, sandstone, siltstone, mudstone, and limestone).

shoaling Said of an ocean or lake bottom that becomes progressively shallower as a shoreline is approached. The shoaling of the ocean bottom causes waves to rise in height and break as they approach the shore.

silt A rock fragment or detrital particle smaller than a very fine sand grain and larger than coarse clay, having a diameter in the range of 4 to 62 microns; the upper size limit is approximately the smallest size that can be distinguished with the unaided eye.

sinkhole Any closed depression in the land surface formed as a result of the collapse of the underlying soil or bedrock into a cavity. Sinkholes are common in areas where bedrock is near the surface and susceptible to dissolution by infiltrating surface water. Sinkhole is synonymous with "doline," a term used extensively in Europe. The essential component of a hydrologically active sinkhole is a drain that allows any water that flows into the sinkhole to flow out the bottom into an underground conduit.

slip-off slope Long, low, gentle slope on the inside of a stream meander. The slope on which the sand that forms point bars is deposited.

stage, substage Geologic time-rock units; the strata formed during an age or subage, respectively. Generally applied to glacial episodes (for example, Woodfordian Substage of the Wisconsinan Stage.

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.

stratigraphy The study, definition, and description of major and minor natural divisions of rocks, particularly the study of their form, arrangement, geographic distribution, chronologic succession, naming or classification, correlation, and mutual relationships of rock strata.

stratum A tabular or sheet-like mass, or a single, distinct layer of material of any thickness, separable from other layers above and below by a discrete change in character of the material, a sharp physical break, or both. The term is generally applied to sedimentary rocks but could be applied to any tabular body of rock (*see also* bed).

subage A small interval of geologic time; a division of an age.

syncline A convex-downward fold in which the strata have been bent to form a trough; the strata on either side of the core of the trough are inclined in opposite directions toward the axis of the fold; the core area of the fold contains the youngest rocks (*see also* anticline).

system A fundamental geologic timeBrock unit of worldwide significance; the strata of a system are those deposited during a period of geologic time (for example, rocks formed during the Pennsylvanian Period are included in the Pennsylvanian System).

tectonic Pertaining to the global forces that cause folding and faulting of the Earth's crust; also used to classify or describe features or structures formed by the action of those forces.

tectonics The branch of geology dealing with the broad architecture of the upper (outer) part of Earth; that is, the major structural or deformational features, their origins, historical evolution, and relations to each other. It is similar to structural geology, but generally deals with larger features such as whole mountain ranges or continents.

temperature-resistance log A borehole log, run only in water-filled boreholes, that measures the water 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 Nonlithified, 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 an 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 Said of strata that do not succeed the underlying rocks in immediate order of age or in parallel position. A general term applied to any strata deposited directly upon older rocks after an interruption in sedimentation, with or without any deformation and/or erosion of the older rocks.

unconformity A substantial break or gap in the geologic record where a rock unit is overlain by another that is not next in stratigraphic successsion.

underfit stream A misfit stream that appears to be too small to have eroded the valley in which it flows. It is a common result of drainage changes effected by stream capture, by glaciers, or by climate variations.

valley train The accumulation of outwash deposited by rivers in their valleys downstream from a glacier.

water table The point in a well or opening in the Earth where groundwater begins. It generally marks the top of the zone where the pores in the surrounding rocks are fully saturated with water.

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

ZINC AND LEAD DEPOSITS OF NORTHWESTERN ILLINOIS

Principal Mineralized Area

The principal mineralized area in which the zinc and lead deposits in northwestern Illinois have been found occurs in Jo Daviess County in a belt 5 to 10 miles wide and 15 miles long (fig. A1). The belt extends approximately northeast through Galena, from the Mississippi River to the Wisconsin state line. Lead ore has also been mined near Elizabeth, Apple River, Warren, and at other places in Jo Daviess County. These occurrences increase the known mineralized district to include most of the county. Small amounts of lead ore are also reported to have been mined outside of this area near Freeport in Stephenson County and near Mount Carroll in Carroll County.

Stratigraphic Position of Ore Deposits

The zinc and lead ore deposits occur in the middle Ordovician carbonate formations of the Galena and Platteville Groups (Champlainian Series) of the Ordovician System (fig. A2). The major deposits of zinc ore (sphalerite, ZnS) are found in the lower part of the Galena Group, which includes the "Drab," "Gray," and "Blue" zones of the Dunleith Formation; the "oil rock" or Guttenberg Formation; and the "clay bed" or Spechts Ferry Formation. Some deposits are found in the "glass rock" or Quimby's Mill Formation, which is in the top of the Platteville Group. These deposits are mainly of the flat-and-pitch type.

The major deposits of lead ore (galena, PbS) containing little associated sphalerite are found principally in the upper part of the Galena Group. This includes the top half of the Dunleith ("Drab") and the overlying Wise Lake Formation ("Buff"). These deposits are of the crevice type. Locally, the lead ore may grade into the mixed lead-zinc ore, especially in the lower part of the Wise Lake Formation.

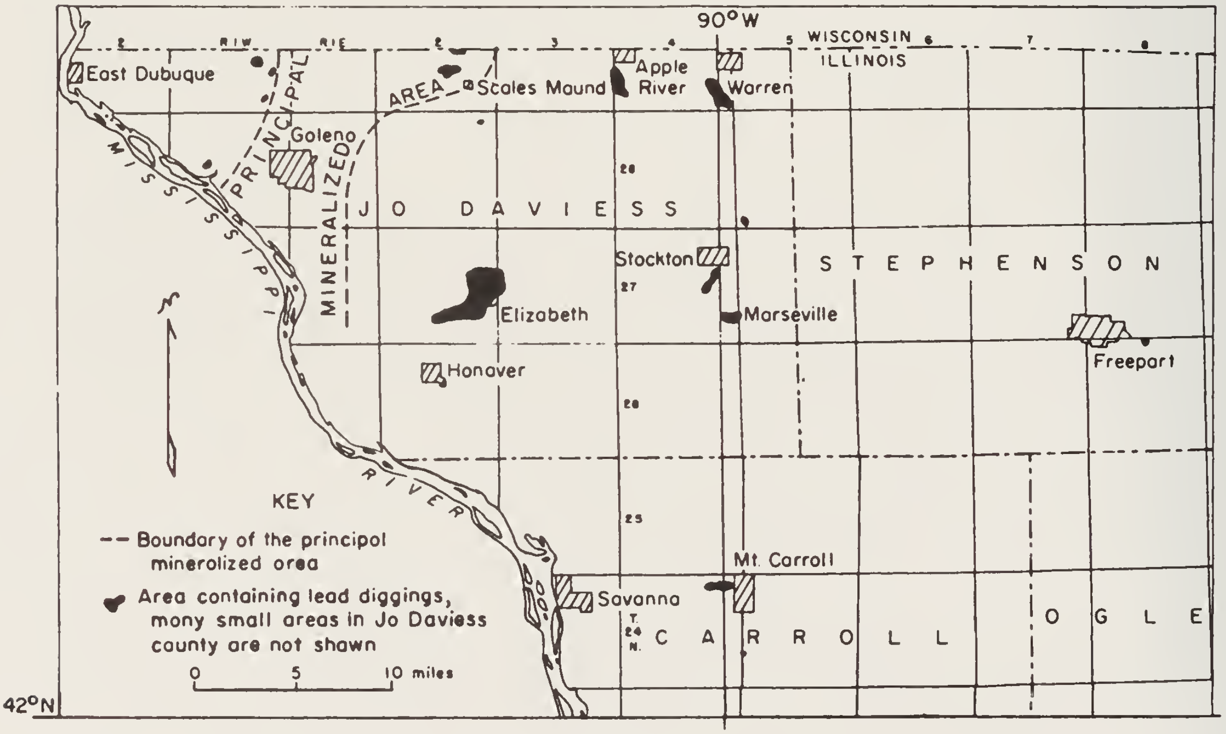


Figure A1 Zinc and lead district in northwestern Illinois.

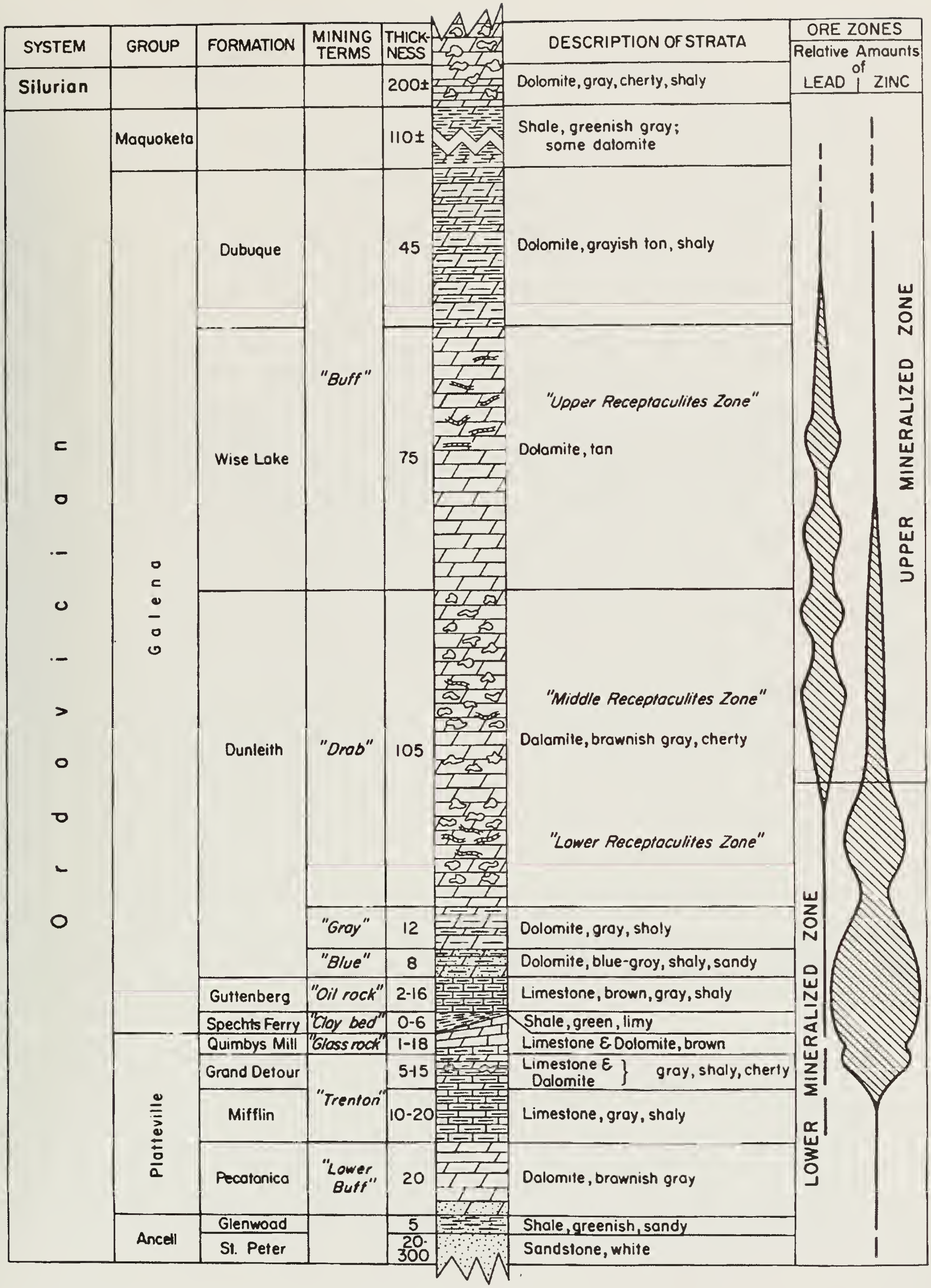


Figure A2 Generalized sequence of strata in the Galena area.

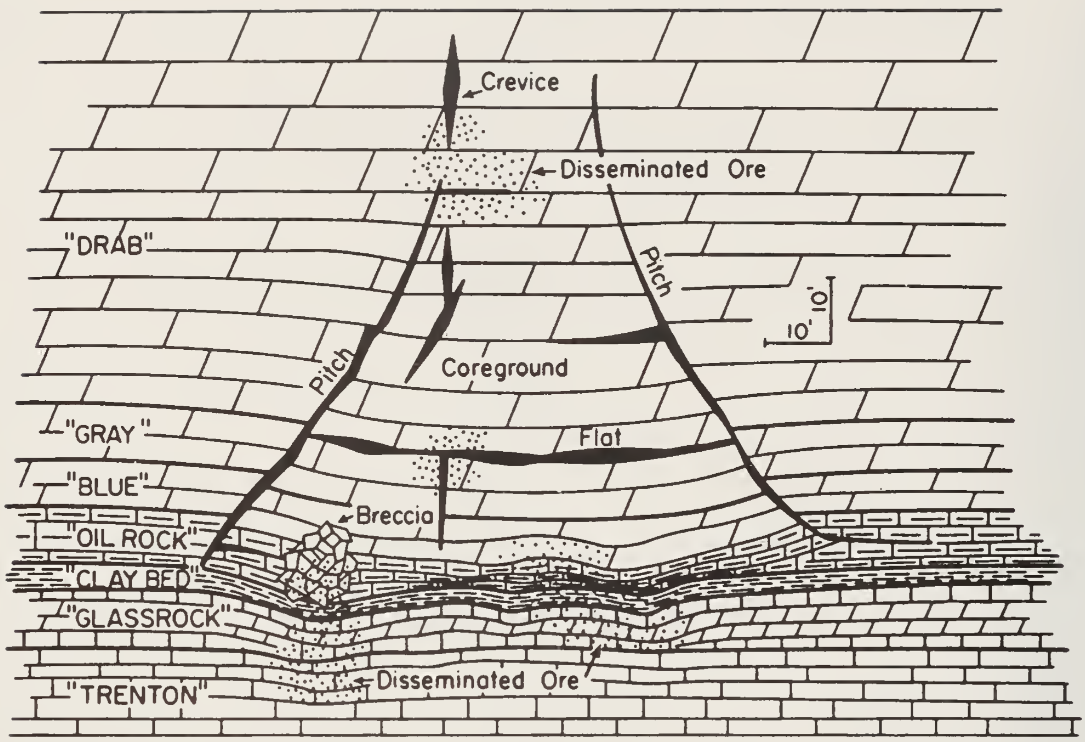


Figure A3 Flat-and-pitch ore bodies.

Flat-and-Pitch Deposits

The flat-and-pitch deposits in the lower ore-bearing zone consist of flats, which are nearly horizontal, sheet-like bodies of ore between or parallel to the bedding planes of the strata, and pitches, which are similar to flats except that they cut across the bedding planes (fig. A3). Pitches usually slope more than 45 degrees, and many become more steep upward and grade into vertical crevices; some flatten downward. The mineralized rock between pitches bounding an ore body is called the coreground.

Flat-and-pitch deposits are associated with small synclinal structures, which trend northwest, northeast, or east-west. Between pitches bounding an ore body, the oil rock and glass rock are thinner than usual, apparently because of dissolution, and the overlying strata have sagged to form the synclinal structure. This sagging opened up the fractures, which became mineralized. The mineralized sags are usually 50 to 200 feet wide, but they may be as wide as 300 feet and extend longitudinally for thousands of feet in a straight line or in an arcuate manner. Usually, the minable thickness is about 40 feet, but sometimes it is thicker. There are many variations in the shape or character of these deposits. The ore generally occurs as fissure-filled deposits, but in the oil rock and glass rock there are also disseminated-type deposits. Rarely, the ore will assay as high as 20% zinc, but 10% zinc is considered rich ore, and 3% to 4% ore is considered minable. In some deposits, minable ground is confined entirely to the pitches, but parts of the coreground are also minable. Minerals, other than galena, associated with zinc ore include pyrite (FeS_2), marcasite (FeS_2), and calcite ($CaCO_3$). Above the water table, where oxidation has occurred, secondary minerals occur, including cerussite (lead carbonate, $PbCO_3$), anglesite (lead sulfate, $PbSO_4$), smithsonite (zinc carbonate, $ZnCO_3$), and limonite (iron oxide, $2Fe_2O_3 \cdot 3H_2O$).

Crevice Deposits

The crevice deposits of the upper mineralized zone occur as fissure fillings along joints that are oriented mainly in an east-west direction (fig. A4). The crevices are actually vertical fissures, or cavities, that were opened up along the joints by solution of the dolomite. Along a typical crevice, the minable ore occurs as pods or lenses, which range from a few feet to a few hundred feet long, scattered along the strike of the joints. The ore bodies are generally only a few inches to a few feet wide, but where there are two or more closely spaced crevices, they extend over widths of 30 feet or more. The ore is usually pure galena, but locally it may grade to mixtures of galena and sphalerite.

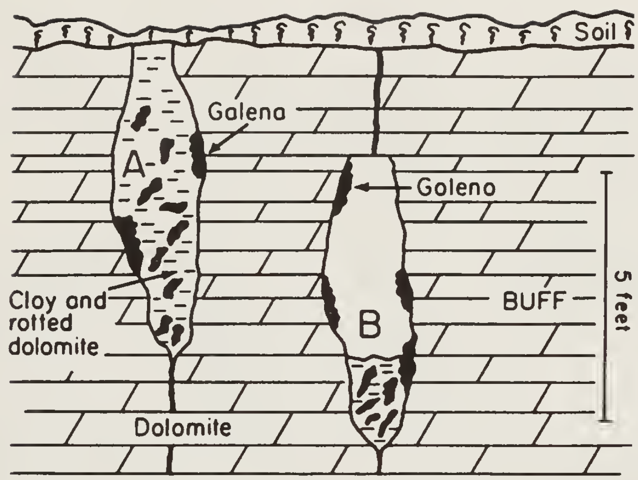


Figure A4 Crevice ore bodies. Crevice A reaches the ground surface and is filled with clay; B is only partially clay-filled.

Shallow crevice deposits were the principal source of lead ore in the United States between 1820 and 1865. These deposits were easily discovered in partial exposures along stream valleys. They were also discovered by the presence of residual accumulations of ore where erosion had intersected mineralized joints. In some cases, the topographic expression of crevices as shallow depressions led to the discovery of ore bodies. When these easily exploited deposits were depleted, lead ore production declined sharply. During the later years of production, zinc ore was the chief mineral commodity of the area, and it was obtained almost exclusively from the larger, deeper flat-and-pitch deposits. The last operating mine in northwestern Illinois, which was located south of Galena, was closed in 1973.

Origin of Ore Deposits

The origin of the ore bodies is still in question. An early theory that was widely accepted is the "cold water theory." In this theory, lead and zinc minerals were assumed to be present in trace quantities disseminated throughout the Galena Dolomite or higher rock units. The lead and zinc were originally supposed to have been deposited with the carbonate rocks when they were precipitated from the ancient Ordovician sea more than 400 million years ago. Percolating groundwater then dissolved the lead and zinc minerals from these rocks and carried them downward to be reprecipitated in openings in the strata where the ore is now found.

The theory now generally favored by geologists is emplacement by warm solutions emanating from deeply buried strata. The warm, mineralized solutions ascended until they encountered the cavernous, jointed Champlainian (middle Ordovician) rocks that had the proper temperature-pressure conditions to allow the precipitation of the lead and zinc sulfides. The neutralizing effect of carbonate-rich groundwater on the acid-sulfide–bearing solutions could also have been partly responsible. These ideas may explain why the ore bodies are restricted to such a narrow vertical interval of Ordovician strata. However, the absence of deep downward extensions of ore and major faults that could have provided access to the rising solutions has not been resolved.

The open fissures in which the crevice ores were deposited and the synclinal structures associated with the flat-and-pitch ore bodies are solutional in origin and were formed before ore emplacement. Whether solution was by meteoric groundwater or by warm solutions from depth has not been definitely determined. If the latter is true, the openings might have been formed contemporaneously with ore deposition.

Prospecting for Ore Deposits

The long, fairly narrow ore bodies in the Upper Mississippi Valley Zinc and Lead District, especially the deeper ore bodies, are difficult to find. To extend the life of the mining district, new reserves must be found. Geophysical and geochemical methods have been used in the exploration for ore deposits, but with limited success. Drilling is the most commonly used means of prospecting for lead and zinc ores and is currently the most effective method of searching for the deep ore bodies. Drilling is used to explore the trends of known ore deposits and to search for new ore bodies in previously untested areas.

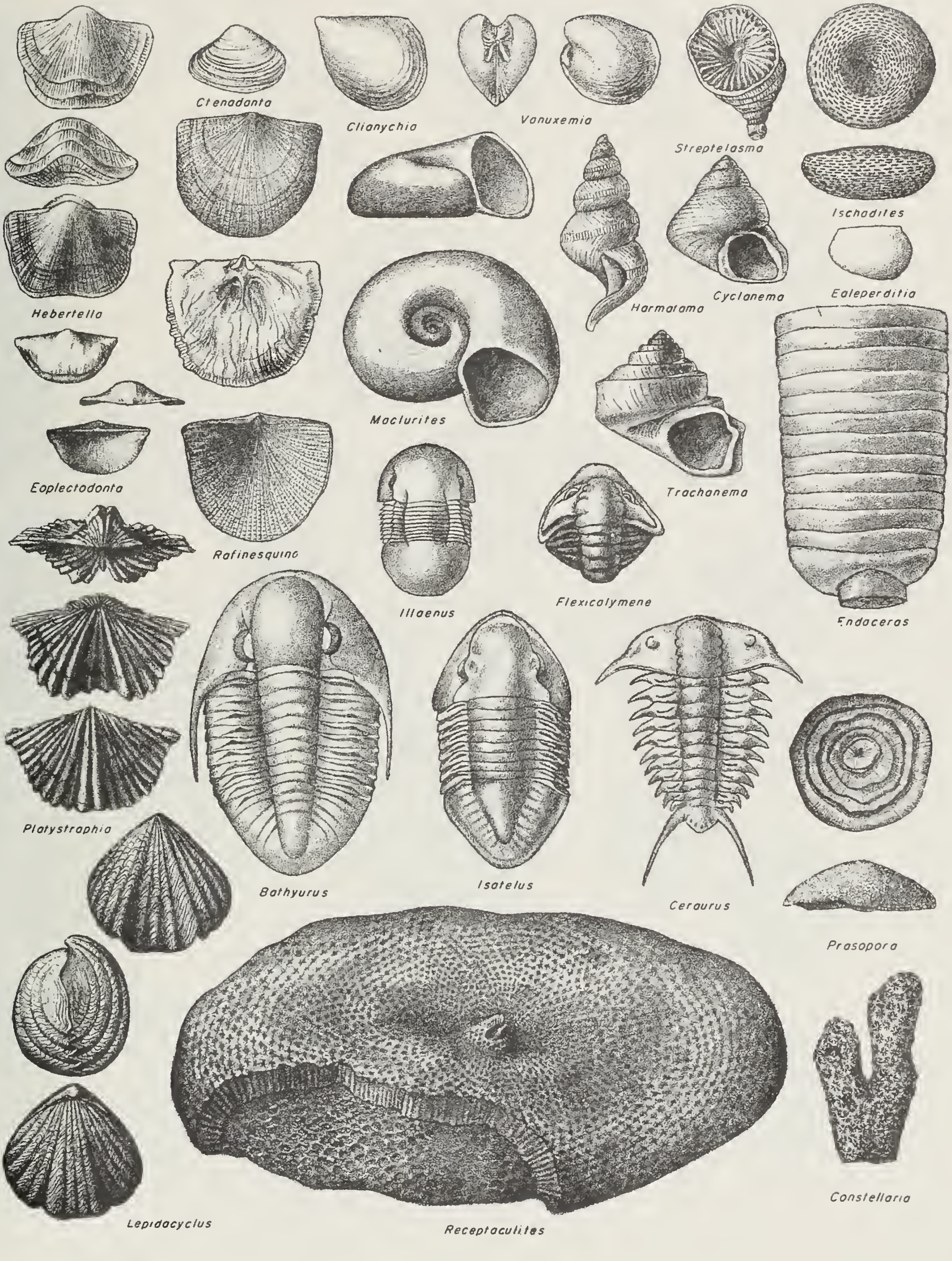
Most prospecting for lead and zinc ores in northwestern Illinois has consisted largely of drilling in areas of old shallow lead diggings, along the trends of known deeper ore bodies, and in the vicinities of occasional water wells that happen to penetrate ore. Wildcat holes drilled in unproven ground outside areas of known ore deposits have been relatively few. Many interrelated geologic factors must be evaluated by the geologist before deciding where to drill such exploratory holes.

There are two principal methods of drilling deep holes: churn drilling and rotary drilling with a diamond bit.

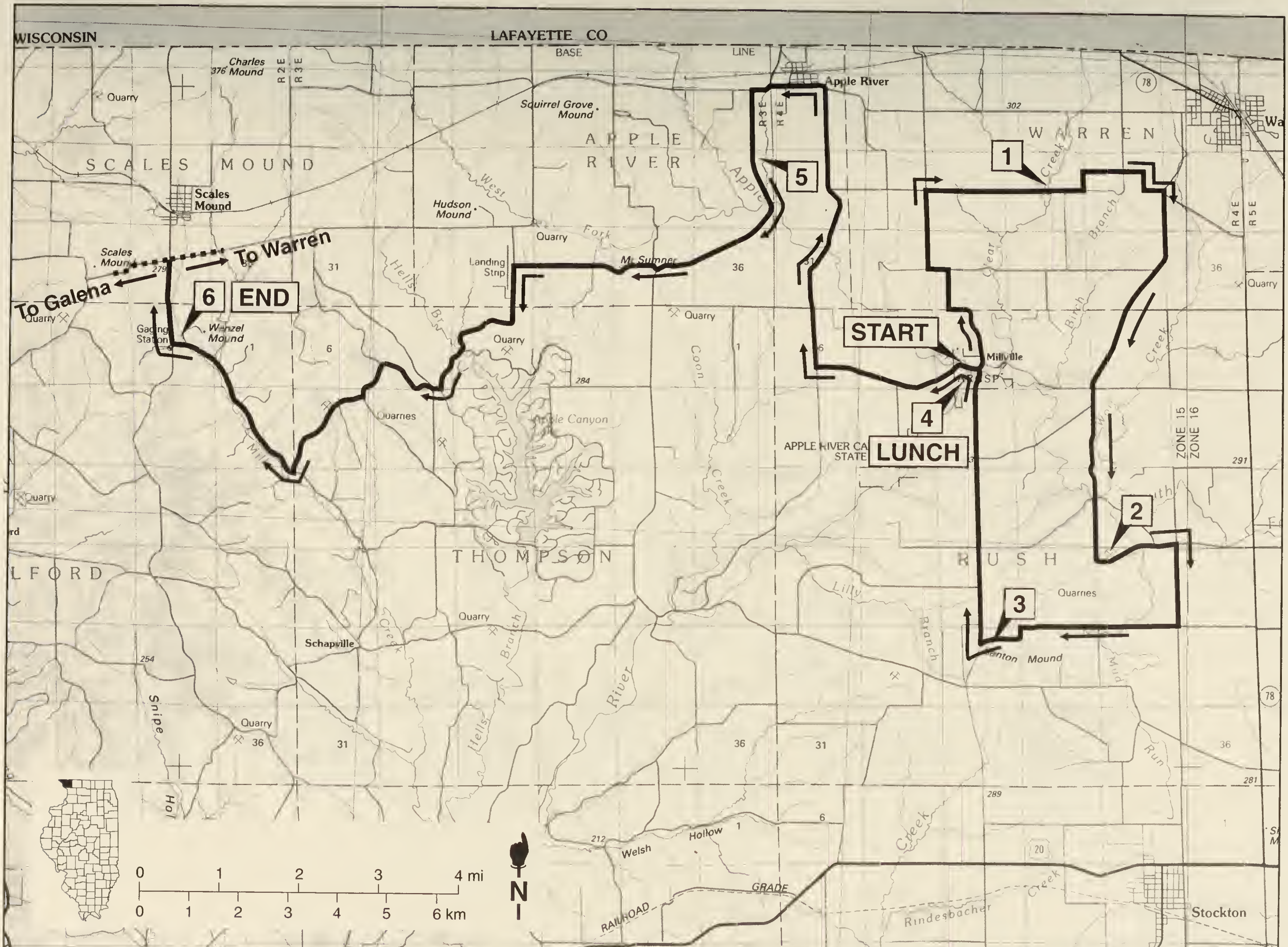
Churn drilling Churn drilling, also known as cable-tool drilling, is much less expensive than diamond drilling and has been widely used in the area for deep prospecting. Vertical holes 6 inches in diameter are drilled by a heavy steel, rock-cutting bit, suspended from a steel cable that is attached to the controlling machinery at the surface. The heavy bit is alternately lifted and dropped, and the rock is penetrated by the repeated blows of the bit. The broken rock is periodically bailed from the hole, and samples of the rock chips are saved for examining or assaying.

Diamond drilling Diamond drilling provides better rock samples than those obtained by churn drilling. The cores obtained are continuous samples, or a column, of the rock interval penetrated by the bit. In soft or fractured rock, often in critical zones of mineralization where samples are most desired, an incomplete sample may be recovered in some intervals because of poor core recovery. A definite advantage of diamond drilling is the ability to drill inclined holes. Drilling is accomplished by means of a small-diameter diamond bit attached to a column of pipe called the drill stem. The bit cuts through the rock when the drill stem is rotated by the power machinery at the surface. Water or a water-oil mixture is pumped down the inside of the drill stem under pressure to cool and lubricate the diamond bit. The water also flushes out crushed rock from the bottom of the hole and carries it up the drill hole to the surface. The rock core enters the hollow drill stem, where it is surrounded by the coolant as the bit cuts downward, and the core remains there until it is retrieved when the drill stem is pulled out of the hole. The diameter of the drill stem and bit are usually decreased periodically as the hole deepens, depending on the depth to be drilled.

ORDOVICIAN FOSSILS



REPRESENTATIVE SILURIAN FOSSILS FROM NORTHWESTERN ILLINOIS



WISCONSIN
LAFAYETTE CO
BASE
LINE
Charles Mound
Scales Mound
Apple River
Squirrel Grove Mound
Hudson Mound
SCALES MOUND
APPLE RIVER
WARREN
THOMPSON
RUSH
To Galena
To Warren
START
LUNCH
END
1
2
3
4
5
6
Millville
Mt Sumner
Landing Strip
Gaging Station
Wenzel Mound
Schapville
Apple Canyon
APPLE RIVER CA
STATE
Quarry
Quarries
Welsh Hollow
RAILROAD GRADE
Rindesbacher Creek
Stockton
ZONE 15
ZONE 16
R 2 E
R 3 E
R 4 E
R 5 E
0 1 2 3 4 mi
0 1 2 3 4 5 6 km
N