Guide to the Geology of the Golconda Area, Pope and Hardin Counties

David L. Reinertsen
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Field Trip Guidebook 1994A   April 23, 1994

Department of Energy and Natural Resources
ILLINOIS STATE GEOLOGICAL SURVEY

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ILLINOIS STATE GEOLOGICAL SURVEY
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Cover photo Mississippian Cypress Sandstone bluff above old Lock and Dam No. 51 at Golconda (photo D.L. Reinertsen).

Geological Science Field Trips The Educational Extension Unit of the Illinois State Geological Survey 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 field trip is an all-day excursion through one or more Illinois counties. Frequent stops are made to explore interesting phenomena, explain the processes that shape our environment, discuss principles of earth science, and collect rocks and fossils. People of all ages and interests are welcome. The trips are especially helpful to teachers preparing earth science units. Grade school students are welcome, but each must be accompanied by a parent or guardian. High school science classes should be supervised by at least one adult for each ten students.

A brochure describing current year trips and a list of previous field trip guidebooks are available for planning class tours and private outings. These materials may be obtained by writing to the Educational Extension Unit, Illinois State Geological Survey, Natural Resources Building, 615 East Peabody Drive, Champaign, IL 61820-6964. Call (217) 333-4747.

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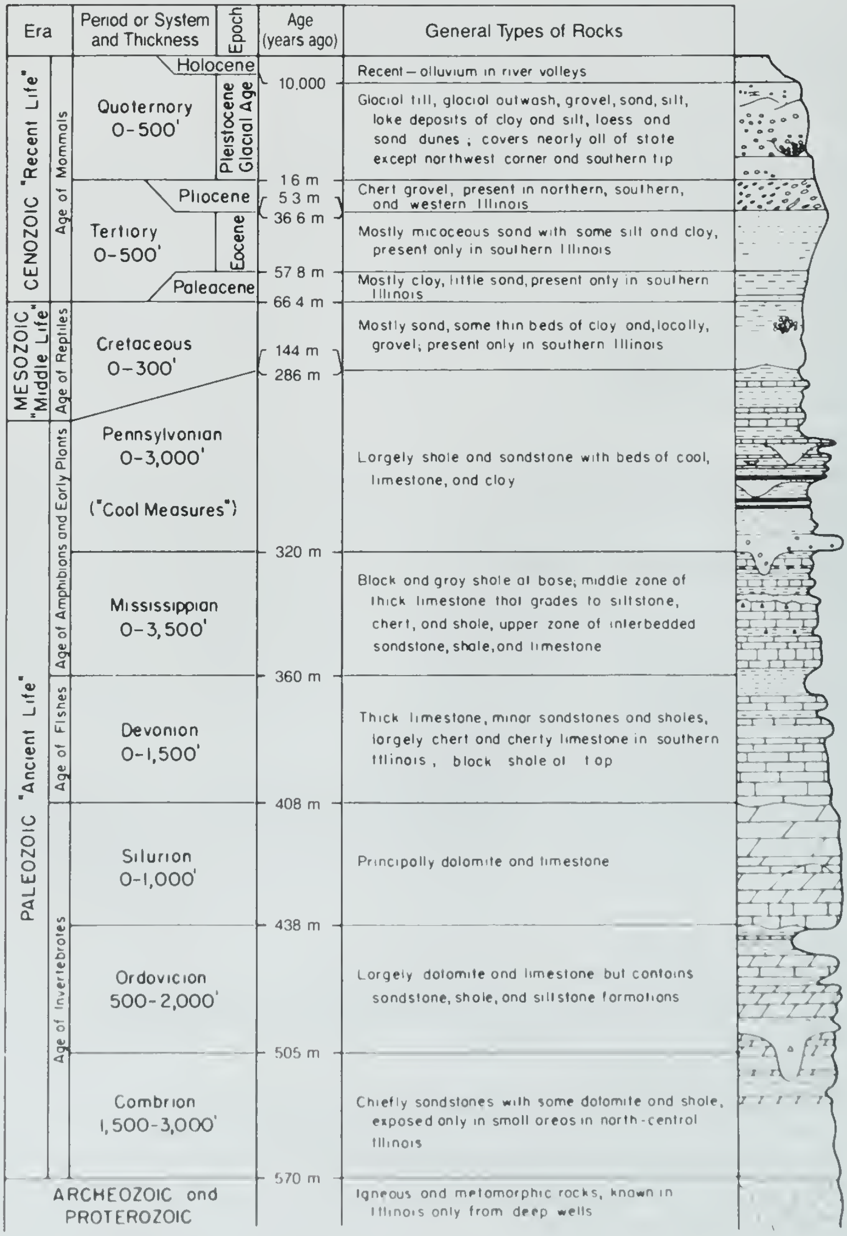

Era		Period or System and Thickness	Epoch	Age (years ago)	General Types of Rocks
CENOZOIC "Recent Life"	Age of Mammals	Quaternary 0-500'	Holocene	10,000	Recent—alluvium in river valleys
			Pleistocene Glacial Age	1.6 m	Glacial till, glacial outwash, gravel, sand, silt, lake deposits of clay and silt,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

Generalized geologic column showing the succession of rocks in Illinois.

GOLCONDA AREA

GENERAL SETTING AND HISTORY

The landscape, *geology*, and mineral resources surrounding the town of Golconda in extreme southeastern Illinois are the subjects of this field trip. The area's rugged surface, one of the most scenic landscapes in the state, was formed mainly by differential erosion of Upper Mississippian and Lower Pennsylvanian sedimentary *strata* (see rock succession column on facing page) consisting of regular alternations of sandstone, *limestone*, and shale. The high ridges denote areas underlain by resistant rocks, usually sandstones occurring in outcrops. The low areas, on the other hand, consist of valleys or depressions underlain by relatively softer limestones and shales. Numerous *faults* cut the strata and interrupt the regularity of the ridges and valleys. Some of the areas underlain by limestone exhibit *sinkhole topography*.

The town of Golconda lies approximately 315 miles south-southwest of Chicago, 175 miles south-southeast of Springfield, 130 miles southeast of East St. Louis, and 45 miles northeast of Cairo.

A stone monument on the lawn northeast of the Pope County Courthouse tells about the founding of Golconda:

> Sarah Lusk
>
> The brave pioneer woman who founded the town of Golconda, first called Sarahville, a century and a quarter ago.
>
> She established the first ferry across the Ohio River at this place which she operated with the aid of her young son and a faithful colored woman.
>
> Her rifle was always at hand to protect the passengers from the dangers that lurked on every side.
>
> Erected by the Civic Club of Golconda
> 1928

Structural and Depositional History

Precambrian Era The area encompassed by Pope and Hardin Counties, like the rest of Illinois, has undergone many changes through several billion years of geologic time. The oldest rocks beneath the field trip area belong to the ancient Precambrian (Archeozoic and Proterozoic) *basement complex*. We know very little about these rocks from direct observations because they are not exposed at the surface anywhere in Illinois. Only about 30 holes have been drilled deep enough in our state for geologists to collect samples from Precambrian rocks; depths range from 2,100 to 5,400 feet in northern Illinois and from 13,000 to more than 17,000 feet in southern Illinois. From these samples, however, we know that the ancient rocks consist mostly of granitic and possibly metamorphic, crystalline rocks that formed about 1.5 to 1.0 billion years ago when molten *igneous* materials slowly solidified within the earth. By about 0.6 billion years ago, deep weathering and erosion had exposed the ancient rocks at the surface, forming a landscape probably quite similar to part of the Missouri Ozarks. We have no rock record in Illinois for the long interval of weathering and erosion that lasted from the time Precambrian rocks were formed until Cambrian *sediments* were deposited across the older land surface; that interval, however, is longer than recorded geologic time from the Cambrian to the present.

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

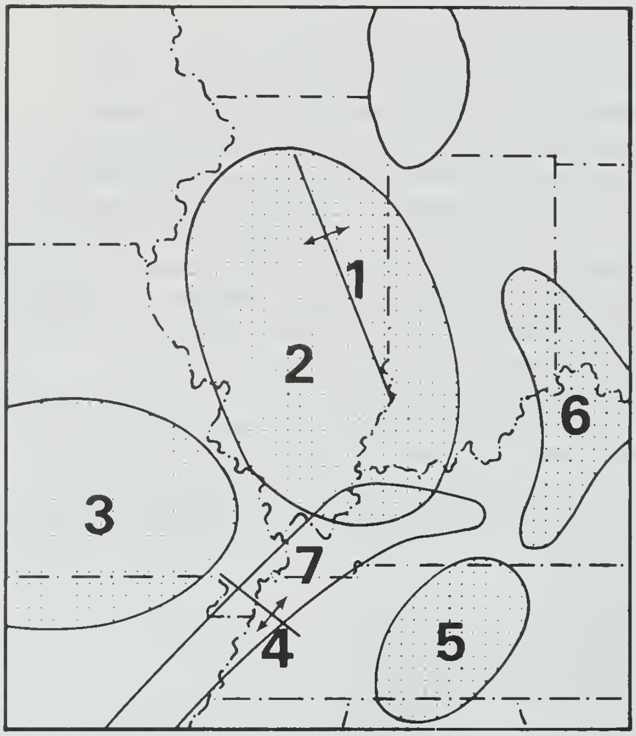


Figure 1 Location of some of the major structures in the Illinois region. (1) La Salle Anticlinal Belt, (2) Illinois Basin,(3) Ozark Dome, (4) Pascola Arch, (5) Nashville Dome, (6) Cincinnati Arch, and (7) Rough Creek Graben-Reelfoot Rift.

Geologists seldom see Precambrian rocks except as cuttings from drill holes, but they use various techniques to determine some of the characteristics of the basement complex. For example, surface mapping, measurements of Earth's gravitational and magnetic fields, and seismic records gathered for oil exploration and other research indicate that rift valleys, similar to those in east Africa, formed here in southernmost Illinois during the late Precambrian Era. This affected what later became the Kentucky-Illinois Fluorspar Mining District. In the midcontinent, these rift valleys are referred to as the Rough Creek *Graben* and the Reelfoot Rift (fig. 1). The midcontinental rift structures formed when plate *tectonic* movements (slow global deformation) began to rip apart an ancient Precambrian supercontinent that had formed earlier when various ancient landmasses came together. (Continental collision is going on today as the Indian subcontinent moves northward against Asia, lifting and folding the Himalayas.) The slow fragmentation of the Precambrian supercontinent eventually isolated a new landmass called *Laurasia*, which included much of the North American continent.

Near the end of the Precambrian *Era* and continuing until Late Cambrian time, about 570 million to 505 million years ago, tensional forces within the earth apparently caused block faulting and relatively rapid subsidence of the hilly landscape on a regional scale. This permitted the invasion of a shallow sea from the south and southwest.

Paleozoic Era During the Paleozoic Era, southern Illinois continued to sink slowly and to accumulate sediments deposited in shallow seas that repeatedly covered the area. At least 15,000 feet of sedimentary strata accumulated during the 325 million years of the Paleozoic Era. These sediments, after being compacted and hardened (*indurated*), along with the underlying Precambrian rocks, constitute the *bedrock* succession. Bedrock refers to the indurated rock units that underlie the soils or other relatively loose, crumbly, materials near the Earth's surface.

In Pope and western Hardin Counties, the field trip area may be underlain by about 13,000 feet of Paleozoic sedimentary strata, ranging from deeply buried rocks of Late Cambrian age (about 523 million years old) to surface exposures of Early Pennsylvanian age (about 315 million years old).

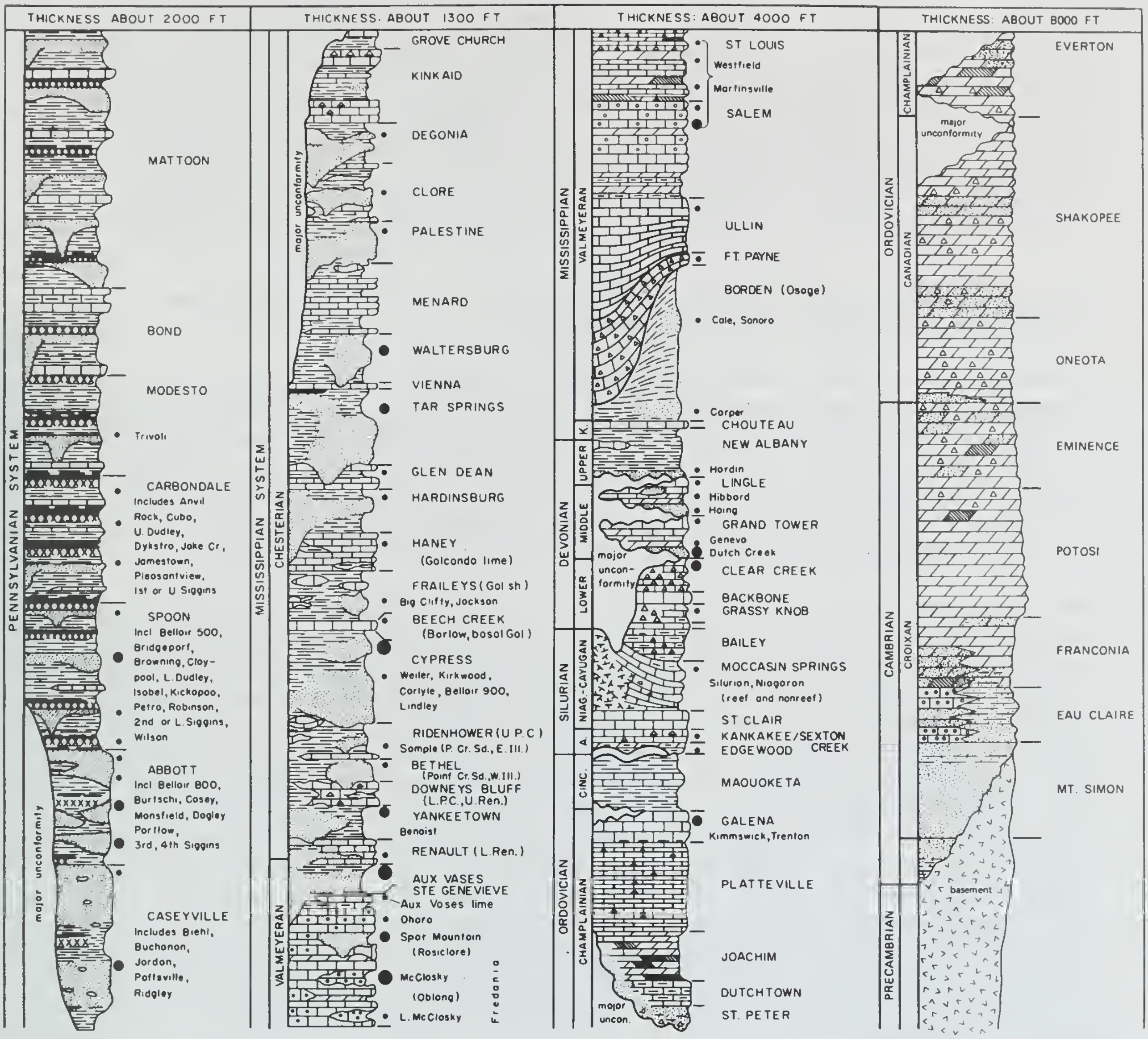


Figure 2 Generalized stratigraphic column of the southern part of the Illinois Basin. Black dots indicate oil and gas pay zones (variable vertical scale) (from Leighton et al. 1991).

From Middle Ordovician time about 460 million years ago until the end of the Permian *Period* (and the Paleozoic Era) about 245 million years ago, the area of Illinois, Indiana, and western Kentucky sank more slowly than it did earlier. Repeatedly, sediments poured into a broad trough or embayment covering the area and spilled into surrounding areas as well. Because of compressive and stretching forces that developed at various times, Earth's thin crust has frequently been flexed and warped in various places. These recurrent movements occurring over millions of years caused the seas to drain from the region and later to slowly return. Periodically, sea floors were uplifted and exposed to weathering and erosion by rain, wind, and streams. Because some of the strata were eroded, not all geologic units are represented in the rock record. Figure 2 shows the succession of rock strata that a drill bit would penetrate in this area if the rock record were complete and all the *formations* were present (the oldest strata are at the lower right and the youngest are at the upper left).

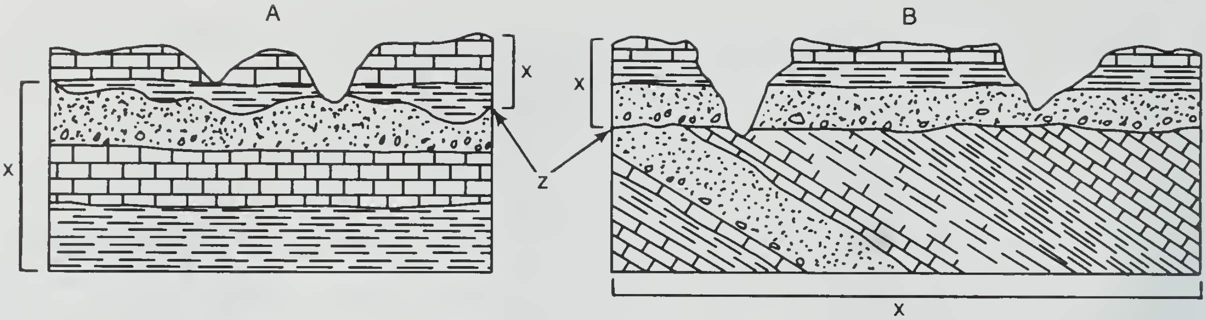


Figure 3 Schematic drawings of (A) a disconformity and (B) an angular unconformity (x represents the conformable rock sequence and z is the plane of unconformity).

Formations, conformable contacts, and unconformities Sedimentary units, such as limestone, sandstone, shale, or combinations of these and other rock types are called *formations*. A formation is a persistent body of rocks that has easily recognizable top and bottom boundaries, is thick enough to be readily traceable in the field, and is sufficiently widespread to be represented on a map. Most formations have formal names, such as Renault Limestone or Downeys Bluff Limestone, which are usually derived from geographic names and predominant rock types. In cases where no single type is characteristic, the word formation becomes a part of the name.

Many formations have conformable contacts where no significant interruptions took place in the deposition of the sediments that formed rock units (fig. 2). In such instances, even though the composition and appearance of the rocks change significantly at the contact between the two formations, fossils in the rocks and the relationships between the rocks at the contact indicate that deposition was essentially continuous. At other contacts, however, the lower formation was subjected to weathering and at least partly eroded before the overlying formation was deposited. In these cases, the fossils and other evidence in the formations indicate the presence of a significant gap between the time when the lower unit was deposited and the time when the overlying unit was laid down. This type of contact is called an *unconformity*. Where the *beds* above and below an unconformity are essentially parallel, the unconformity is called a *disconformity* (fig. 3a); where the lower beds were tilted and eroded before the overlying beds were deposited, the contact is called an angular unconformity (fig. 3b). Major unconformities are indicated on the columns of figure 2; each represents a long interval of time during which a considerable thickness of rock, present in nearby regions, was either eroded or never deposited in parts of this area. Several smaller unconformities are also present. They represent shorter time intervals and thus smaller gaps in the depositional record.

Mississippian Period Relatively low-lying lands adjacent to the Illinois embayment generally did not contribute large volumes of sediment to the seas covering the region during Mississippian time, 360 to 320 million years ago. Early Mississippian shale and silty limestone are exposed around the flanks of Hicks Dome just to the northeast of the field trip area. Most of the Mississippian sediments in this region consisted of either locally precipitated carbonates or muds and sands eroded from areas far to the northeast; the muds and sands were transported here by a large river *system* probably similar in size to the Mississippi River. (A section detailing Mississippian Deposition is at the back of the guidebook).

Local areas underlain by some of the thick middle Mississippian limestones exhibit sinkhole topography. The sinkholes have produced small areas of rolling landscape, characteristic of *karst* topography.

Near the close of the Mississippian Period, gentle arching of the bedrock in eastern Illinois initiated the broad upwarp of the La Salle Anticlinal Belt (figs. 1 and 4). This belt is a complex structure consisting of smaller structures such as domes, *anticlines* (strata arched upward), and

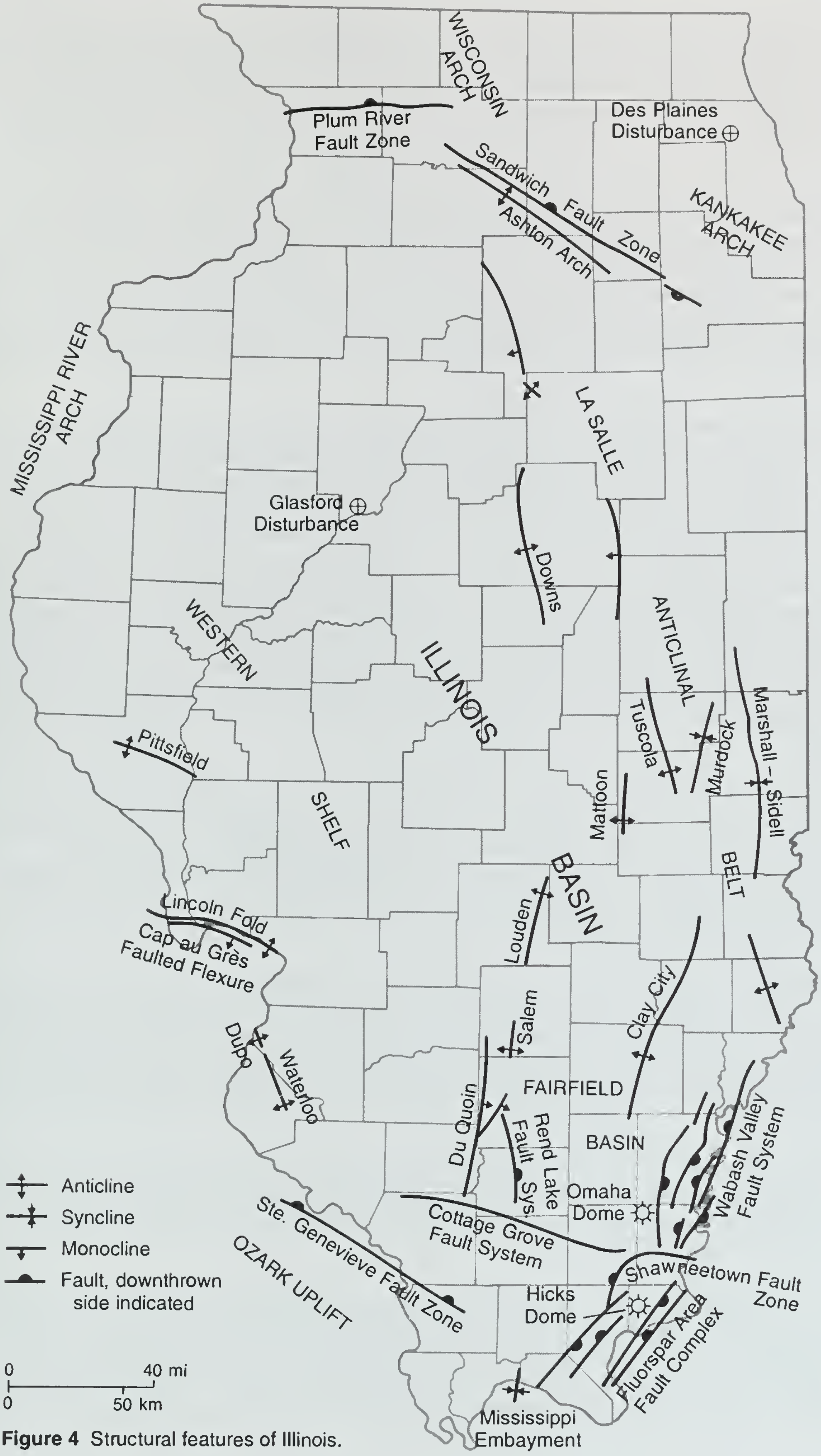


Figure 4 Structural features of Illinois.

synclines (strata arched downward) superimposed on the broad, general upwarp. This gradual arching continued through the Pennsylvanian Period. Because the youngest Pennsylvanian strata are absent from the area of the anticlinal belt, either as a result of nondeposition or erosion, we do not know just when movement along the belt ceased—perhaps by the end of the Pennsylvanian or a little later, during the Permian Period, the youngest rock system of the Paleozoic Era.

Pennsylvanian Period In the field trip area, Pennsylvanian-age bedrock strata consisting primarily of sandstone, siltstone, and shale, deposited as sediments in the trough's shallow seas and swamps between about 320 and 315 million years ago, are often capped by a relatively thin soil developed in windblown *loess* (pronounced "luss"). Resistant sandstones cap the prominent cliffs and ridges and are exposed in numerous streamcuts and roadcuts. Throughout a large part of Illinois, Pennsylvanian strata contain important coal resources. A description of these rocks and their occurrence may be found in *Depositional History of the Pennsylvanian Rocks* (at the back of the guidebook).

The thickness of Pennsylvanian strata is highly variable in the field trip area because these are the youngest bedrock strata present and the area has been highly faulted and eroded. This Pennsylvanian section, from the highest exposed strata down to the basal unconformity probably does not exceed 850 feet thick at any particular locality in the field trip area (Baxter et al. 1967), but only an aggregate thickness of about 600 feet of the section is exposed in outcrops. About 65 miles north-northeast in southeastern Wayne County, Pennsylvanian strata are more than 2,400 feet thick near the deepest part of the Illinois Basin. On the basis of evidence from outcrops and drill holes elsewhere in Illinois, geologists have concluded that the youngest rocks of latest Pennsylvanian and perhaps Permian age may have once covered some parts of what is now Illinois. Even younger rocks of Mesozoic and Cenozoic age also could have been present. On the basis of the degree of *metamorphism* (rank) of coal deposits and other indirect evidence, it is thought that latest Pennsylvanian and younger rocks as much as 1 mile thick, once covered some parts of the state.

Regionally, the bedrock strata are tilted gently toward the north and northwest, although anomalous local dips are very common because of the great number of faults in the area. The area's major structural feature is Dixon Springs Graben, an elongate downfaulted block extending diagonally across the area from northeast to southwest (fig. 5). Southeast of the Dixon Springs Graben, the strata are cut by few faults in comparison to the complexly faulted strata within and to the northeast and northwest of the graben.

Peridotite *dikes* and explosion *breccias*, apparently related in origin, occur in the Illinois-Kentucky Fluorspar District; peridotite, a dark, coarse grained, igneous rock of iron-magnesian minerals, is formed deep within the earth. These features are believed to have formed during a period of intense crustal deformation when the strata were also broken by numerous faults. Radioactive dating of the igneous dikes has indicated a possible Permian age for their emplacement about 265 million years ago.

In the field trip area two occurrences of igneous rocks have been reported (fig. 5). The Golconda "Dike," of uncertain form, is located west of Golconda (SW NE Section 25, T13S, R6E); the Mix Dike, a *mica* peridotite, is located about two miles north-northeast of town near the Ohio River (NE NE NE Section 18, T13S, R7E).

Mesozoic and Cenozoic Eras After the Paleozoic Era, during the Mesozoic Era, the rise of the Pascola Arch (fig. 1) in southeastern Missouri and western Tennessee formed the Illinois Basin and separated it from other basins to the south. The Illinois Basin is a broad downwarp encompassing much of Illinois, southern Indiana, and western Kentucky (figs. 1 and 6). Development of the Pascola Arch in conjunction with the earlier sinking of deeper parts of the area gave the basin

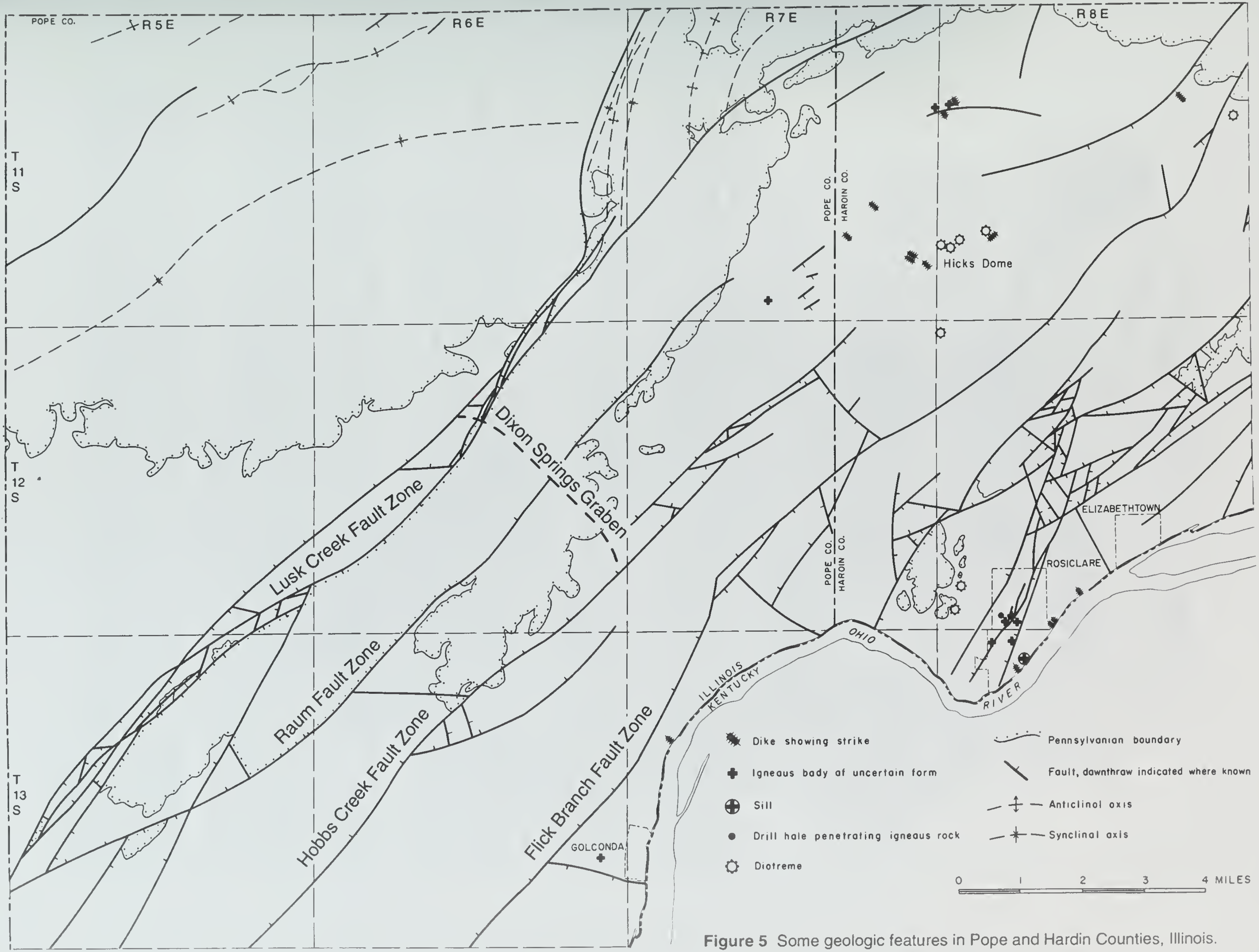


Figure 5 Some geologic features in Pope and Hardin Counties, Illinois.

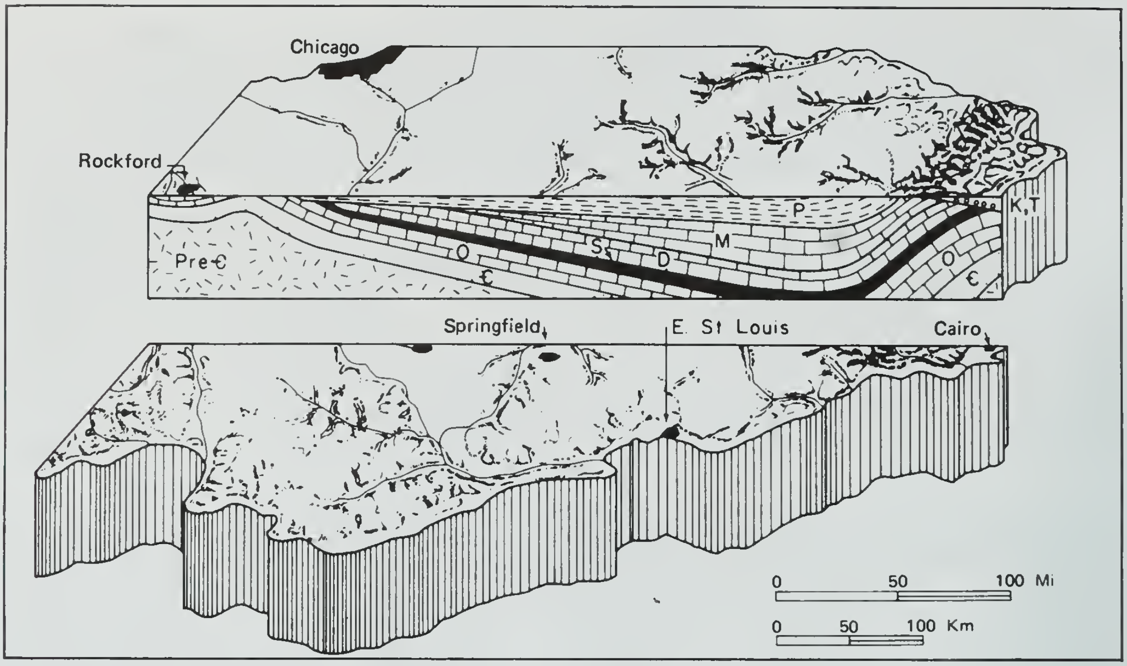


Figure 6 Stylized north-south cross section shows the structure of the Illinois Basin. To show detail, the thickness of the *sedimentary rocks* has been greatly exaggerated and younger, unconsolidated surface deposits have been eliminated. The oldest rocks are Precambrian (Pre-є) granites. They form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

its present asymmetrical, spoon shape. The geologic map of Illinois (fig. 7) shows the distribution of various rock systems as they occur at the bedrock surface; that is, as if all glacial, windblown, and surface materials were removed.

During the Mesozoic and part of the Cenozoic Eras, a span of some 243 million years, and before the start of glaciation 1 to 2 million years ago, the ancient Illinois land surface was exposed to long, intense weathering and erosion. All rocks, except those of Precambrian age, were subjected to erosion during this time when possibly as much as several thousand feet of post-Pennsylvanian bedrock strata were erased by erosion. This erosion produced a *series* of deep valley systems carved into the gently tilted bedrock formations.

Glacial History Beginning about 1.6 million years ago, during the Pleistocene *Epoch*, massive sheets of ice—continental *glaciers*—hundreds of feet thick flowed slowly southward from centers of snow and ice accumulation in the far north and covered parts of Illinois several times (fig. 8). The surface topography was considerably subdued by the repeated advance and melting back of the glaciers, which scoured and scraped the old erosion surface, and affected all exposed bedrock. When the last of the continental glaciers finally melted away from the region that is now northeastern Illinois, about 13,500 years ago, it left nonlithified deposits of *till* (sand, gravel, and silt) behind. Modern soils developed in these materials.

During the Illinoian glaciation, about 270,000 years before the present, North American continental glaciers reached their southernmost extent, advancing and leaving glacial materials (till) as far south as the southern shore of Lake of Egypt in northern Johnson County, about 27 miles west-northwest of Golconda. Meltwater floods from the waning glaciers contributed to the deposition of clay, silt, sand, and gravel by the larger streams in parts of their lower courses (a process known as alluviation).

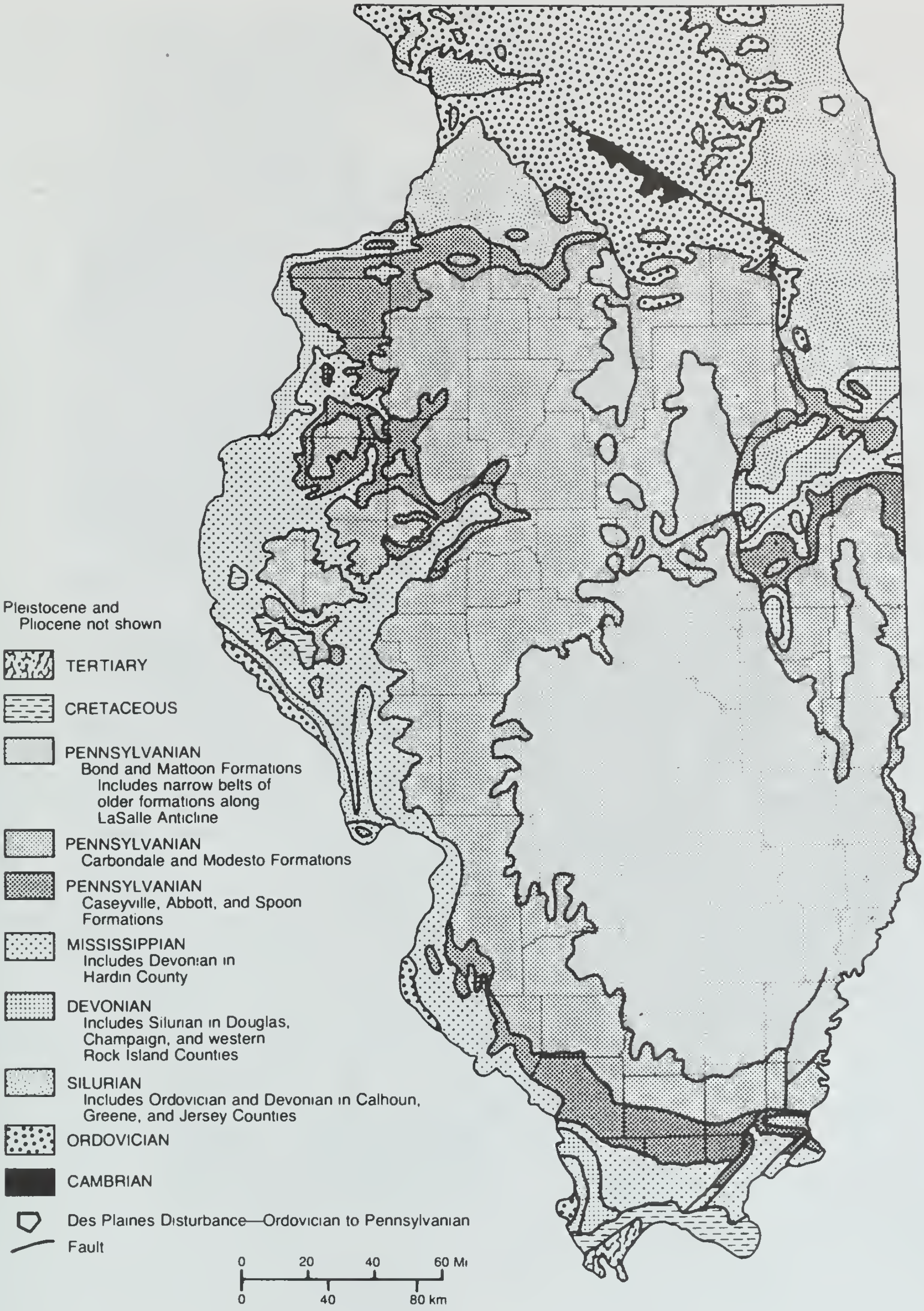


Figure 7 Bedrock geology beneath surficial deposits in IIllinois.

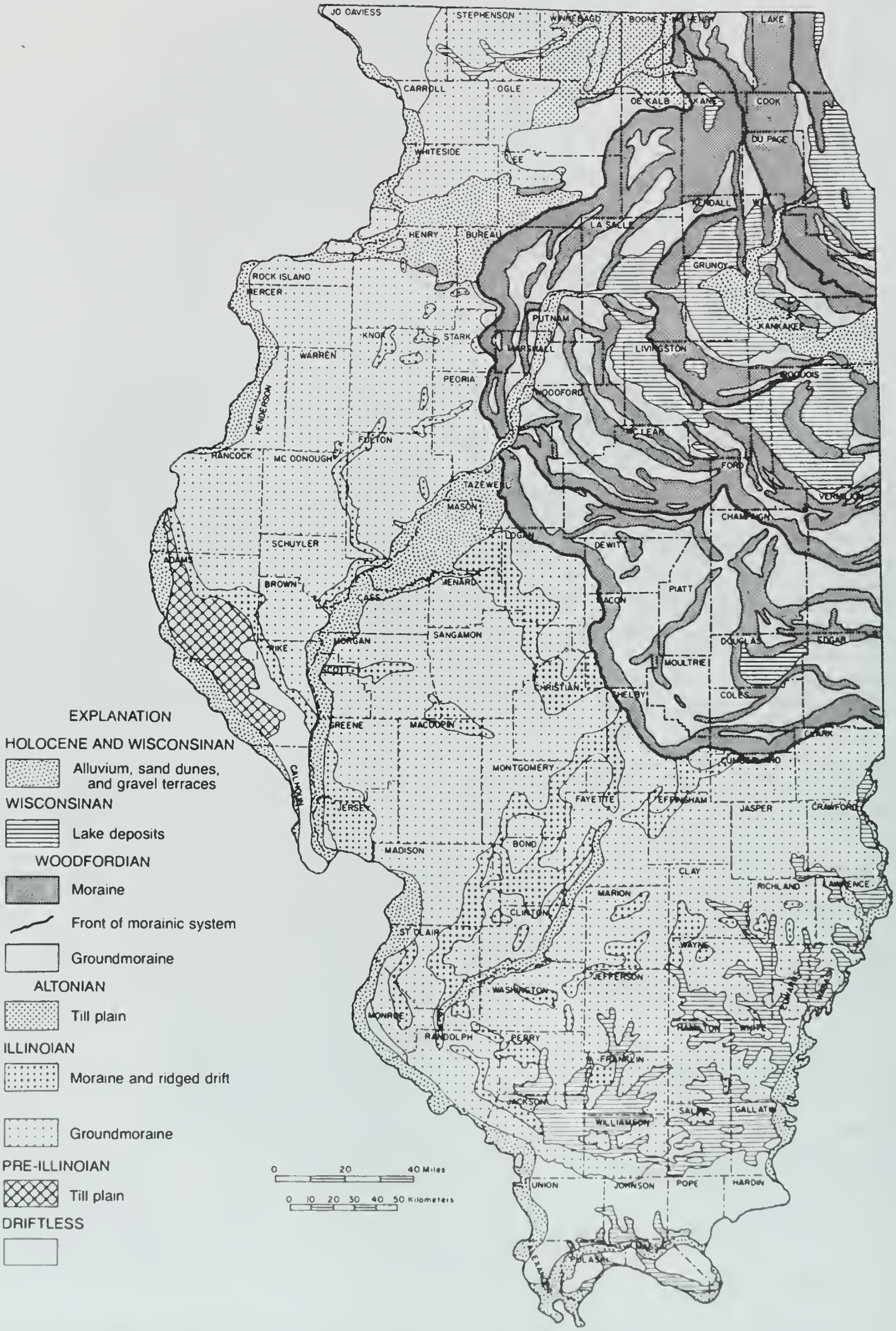


Figure 8 Generalized map of glacial deposits in Illinois (after Willman and Frye 1970).

A cover of loess mantles the bedrock surface here. These fine grained dust deposits of Illinoian and Wisconsinan age, which are 7 to 10 feet thick in the field trip area, are generally thicker closer to the Ohio River, where thick alluvial deposits were one of the major sources of the fine material.

Physiography

A *physiographic province* is a region in which the *relief* and landforms differ markedly from those in adjacent regions. The Golconda area lies in the eastern part of the Shawnee Hills Section in Illinois. Physiographically, this westernmost part of the Interior Low Plateaus Province (fig. 9), is popularly referred to as the "Illinois Ozarks." The rugged terrain has resulted mainly from differential erosion of alternating sequences of resistant beds (sandstones) and less resistant strata (shales, limestones). Normally, erosion of these alternating layers of varied composition would produce a series of parallel ridges and valleys. Intense faulting and bending of the bedrock strata has resulted, however, in a complex pattern of stream dissection of an upland underlain by Mississippian and Pennsylvanian strata. The upland is maturely dissected, that is, there are only scattered remnants of a once widespread upland level. The mostly sloping terrain is produced by a profusion of younger streams (Leighton et al. 1948). The smaller streams have relatively short, steep longitudinal bottom profiles (gradients) and narrow, steep walls that appear V-shaped in cross section. The larger streams generally have somewhat wider *alluviated valleys.*

Drainage

Today's drainage system is relatively complete. The larger streams have broad valleys and low *gradients* in their lower courses; the uplands generally have fairly good natural drainage. The southern part of the field trip area is drained by Bay Creek. Lusk Creek, which flows into the Ohio River, drains the central part. The northern part is drained by the Big Grand Pierre Creek. A number of smaller streams are tributaries to the larger creeks and the Ohio River.

Relief

The highest land surface the field-trip route will cross and the highest in the area is 781 feet above mean sea level (msl) elevation at mileage 27.7+ (SW SE SW Section 26, T12S,R6E). The lowest elevation is 310 feet msl, the normal pool elevation of the Ohio River in this area upstream from the Smithland Lock and Dam. The surface relief of the field trip route, calculated as the difference between the highest and lowest elevations, is approximately 471 feet. The greatest *local relief* is near cliffs where it may be 310 to 320 feet, such as War Bluff (SE Section 24, T12S, R6E) and near Ropers Landing at the east end of the ancient Ohio River valley (SE SW SW Section 12, T14S, R6E).

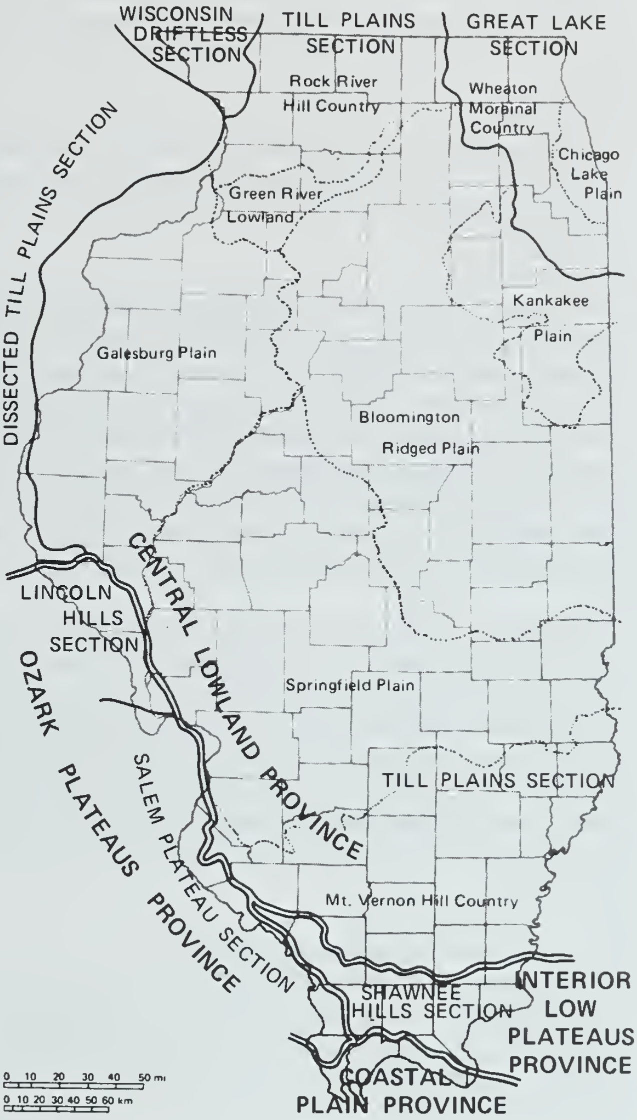


Figure 9 Physiographic divisions of Illinois.

MINERAL RESOURCES

Mineral Production

According to the U.S. Bureau of Mines (USBM) Commodity Summaries (1993), Pope County did not report any mineral production for 1991, the last year for which complete records are available. Among Illinois' 102 counties in 1991, Hardin County ranked 21st in total value of minerals extracted: (in order of value) stone, fluorspar, zinc, gemstones, sandstone, barite, silver, and germanium. The stone that is produced here is used as agricultural lime, roadstone, riprap, and in the manufacture of cement.

During 1991, more than $2.90 billion worth of minerals were extracted, processed, and manufactured in Illinois, 0.3% lower than the 1990 value. The total value reported to the USBM is not necessarily the actual value because many producers do not report their production figures.

During 1991, the value of extracted commodities in Illinois was $2,617.2 million, a decrease of 0.3% from 1990. Mineral fuels (coal, crude oil, and natural gas) made up 79.8% of the total value. Industrial and construction materials such as clay, fluorspar, sand and gravel, stone, and tripoli accounted for 19.9%. The remaining 0.3% came from metals such as lead, zinc, and silver, and from other minerals, such as peat and gemstones (Samson 1991). Illinois ranked 17th among the 50 states in total production of nonfuel minerals and continued to lead all other states in production of industrial sand, tripoli, and fluorspar.

Groundwater

Few of us 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 depend on groundwater for their water supply.

The source of groundwater in Illinois is precipitation that infiltrates into 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. 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.

The best permeable and widely distributed sand and gravel aquifers occur along the deeper part of the Cache River-Bay Creek Valley in the southern part of the field trip area. Fair to good sand and gravel deposits of variable permeability occur along the flanks of this *bedrock valley* and also in a discontinuous band of varying width along the Ohio River in Pope and Hardin Counties. The uplands are essentially bare of sand and gravel deposits that would yield water supplies. However, in the northern part of the area, thick Pennsylvanian sandstones at or near the surface may yield domestic water supplies. Most wells in the southern part of the area have been finished in the fractured and creviced middle Mississippian limestones that occur below the Chesterian surface rocks.

Future of Mineral Industries in Illinois

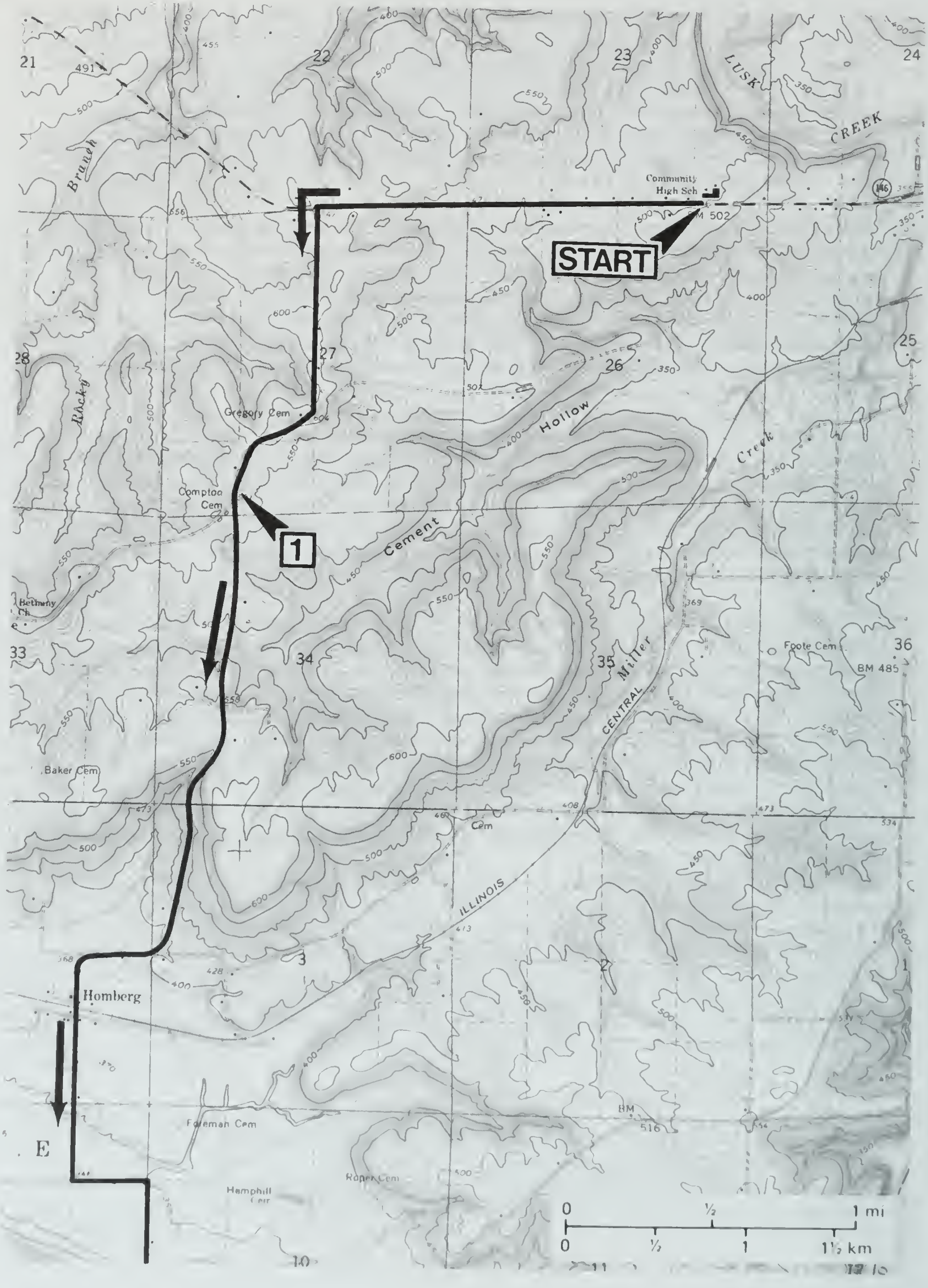
For many years, the mineral resources of the Midcontinent region have been instrumental in the development of our nation's economy. The mineral resource extraction and processing industries continue to play a prime role in our economy and in our lives, and will continue to do so into the future. The following paragraphs tell of recent initiatives involving the ISGS and mapping, especially in southern Illinois.

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 the scientific community, industry, and the general public. 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 began a program to geologically map the 1,071 7.5-minute quadrangles of Illinois.

Geologic mapping of southern Illinois at the 1:24,000 scale (1 inch on the map equals nearly 0.4 mile on the ground) began with the Cave in Rock area (Baxter et al. 1963). This detailed mapping program led to a new understanding of the mineral potential for this area. In 1981, the ISGS resumed detailed mapping in southern Illinois with funding from the Nuclear Regulatory Commission (NRC). In 1984, mapping was continued with matching federal funds from the Cooperative Geologic Mapping Program (COGEOMAP) of the U.S. Geological Survey (USGS). (More details are in the *Cooperative Geologic Mapping Program in Southern Illinois* at the back of the guidebook.)

The U.S. Congress passed the National Geologic Mapping Act of 1992, which authorizes a national program to map the geology of the United States in detail. Under the Act, the USGS will work with the 50 state geological surveys to coordinate and plan the program. The Act calls for expenditures of up to $25 million annually that will be matched by the states. In Illinois, similar authorizing legislation was introduced in the General Assembly. If passed and fully funded at the state and federal levels, this program would result in completing the detailed geologic mapping of Illinois in about 20 years.

In 1975, the USGS began work on the quadrangle for Rolla, Missouri, under the Conterminous U.S. Mineral Assessment Program (CUSMAP). In 1987, the USGS continued this program for the adjacent Paducah 1° x 2° Quadrangle (scale of 1:250,000 or 0.25 in. = 1 mile). Because of the large area covered, this program involves the cooperative efforts of the USGS, ISGS, Kentucky Geological Survey, the Missouri Division of Geology and Land Survey, and the Indiana Geological Survey. (More details are in *Mineral Assessment Program for Southern Illinois* at the back of the guidebook.) In January 1992, a symposium on the Paducah CUSMAP and the Illinois Basin Consortium was held in St. Louis to present the results of the cooperative research programs. The results of these studies were presented in a USGS open-file collection of abstracts. (The preface from this volume, *Mineral Resources of the Illinois Basin in the Context of Basin Evolution*, is at the back of the guidebook.)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Gregory Cem
Hollow
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Compton
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1
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Bethany
Ch
33
34
35
36
Miller
CENTRAL
Foote Cem
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Baker Cem
473
408
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ILLINOIS
413
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Roper Cem
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11
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GUIDE TO THE ROUTE

Assemble in the parking area on the west side of Pope County Community High School on the north side of State Route (SR) 146 (S½ SW SE SE Section 23, T13S, R6E, 3rd Principal Meridian (P.M.), Pope County; Brownfield 7.5-Minute Quadrangle [37088C5]*). Start calculating your mileage at the west entrance of the parking lot.

You must travel in the caravan. ***Do not drive ahead of the caravan!*** Please drive with your 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 emergency vehicle with flashing lights and flags, then obey the signals of the ISGS staff member directing traffic. When we stop, park as close as possible to the car in front of you and turn off your lights.

Some stops on the field trip are on private property. The owners have graciously given us permission to visit their property 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, please do not litter or climb on fences. Leave all gates as you found them. These simple rules of courtesy also apply to public property. If you use this booklet for a field trip with your students, youth group, or family, you must get permission from property owners or their agents before entering private property (because of trespass laws and liability constraints).

Miles to next point	Miles from start	
0.0	0.0	Intersection with SR 146 at west parking lot exit. TURN RIGHT (west). Use extreme caution when pulling out on the highway because visibility is limited from the your left (east).
1.15	1.15	Prepare to TURN LEFT on the Homberg Road. Use extreme caution making the turn because the road ahead has a slight rise to it and the highway curves into it from the right (northwest). Poor visibility and traffic can be fast!
0.1+	1.25+	TURN LEFT (south) uphill on the Homberg Road toward a large white water tower.
0.35	1.6+	Pass the water tower.
0.15+	1.75+	VIEW TO LEFT (east): Golconda water tower and buildings, a little more than 2½ miles away. CONTINUE AHEAD (south and then southwest) on the blacktop.
0.6	2.35+	PARK along and as far off the roadway as you safely can. DO NOT block the road to the right. CAUTION: fast traffic up the hill in front of us. Assemble on the east side road shoulder.

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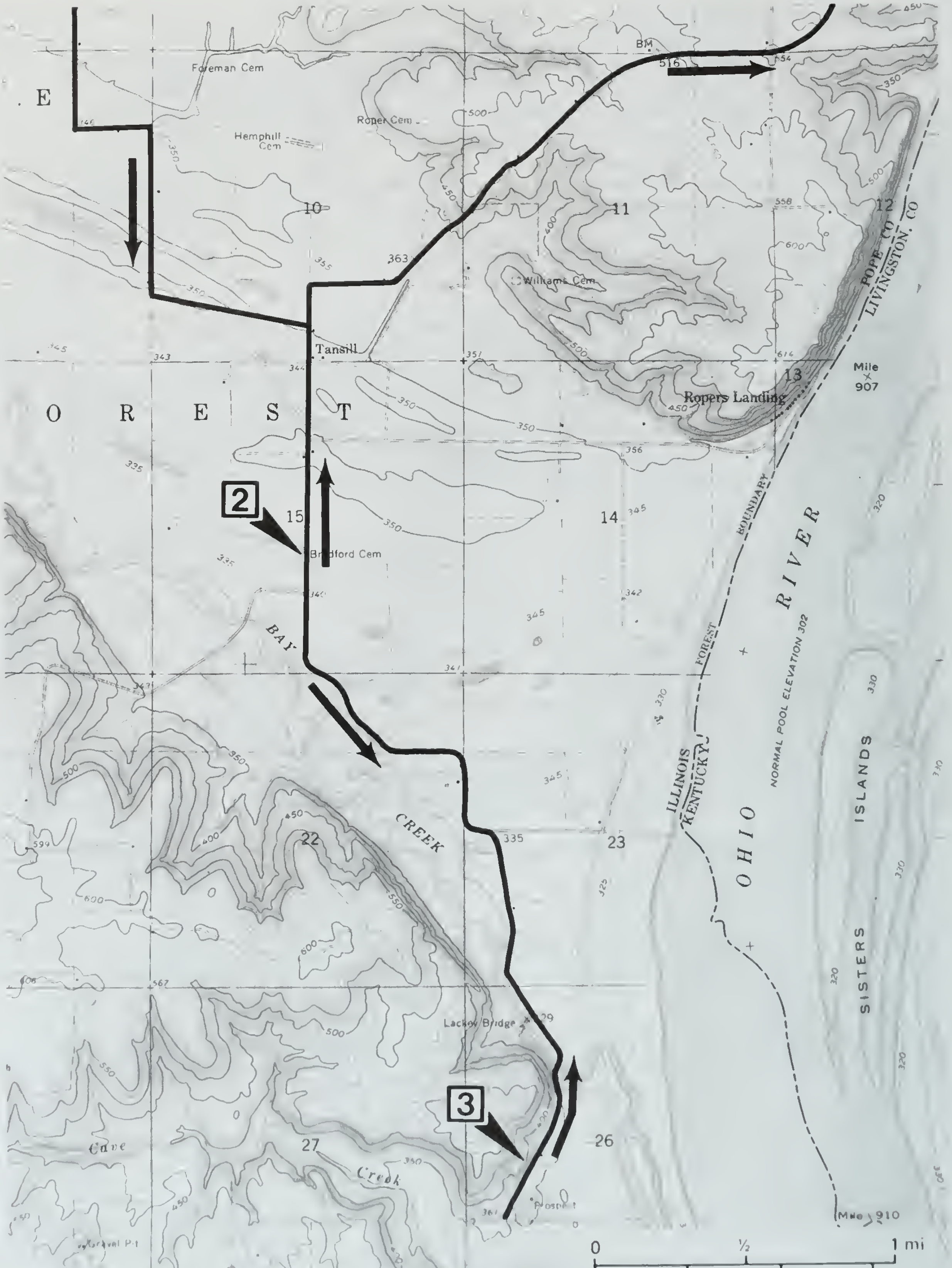
*The number in brackets [37088C5] after the topographic map name is the code assigned to that map as part of the National Mapping Program. The state is divided into 1° blocks of latitude and longitude. The first two numbers refer to the latitude of the southeast corner of the block; the next three numbers designate the longitude. The blocks are divided into 64 7.5-minute quadrangles; the letter refers to the east-west row from the bottom, and the last digit refers to the north-south column from the right.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Roper Cem
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Williams Cem
POPE CO
LIVINGSTON CO
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343
344
351
O R E S T
Mile
907
13
Ropers Landing
2
15
Bradford Cem
14
BOUNDARY
FOREST
RIVER
BAY
CREEK
22
23
335
ILLINOIS
KENTUCKY
OHIO
NORMAL POOL ELEVATION 302
ISLANDS
SISTERS
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Creek
Prospect
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STOP 1 View of *cuesta* north of Golconda and discussion of its origin (near SE corner NE SE SW SW Section 27, T13S, R6E, 3rd P.M., Pope County; Brownfield 7.5-Minute Quadrangle [37088C5]).

After the Illinois Basin formed millions of years ago during the Mesozoic Era, extensive erosion occurred across the region. The more resistant strata, such as sandstone, were left standing as ridges. The softer, less resistant strata, such as limestone and shale, occupy the lower areas between the ridges. The ridges in the Shawnee Hills are capped and protected by sandstone.

Where folding and faulting have occurred, bedrock strata may be inclined to form a cuesta, an asymmetrical ridge in which one side slopes much more steeply than the other. The south face is sharp and cliff-like, while the top surface slopes gently to the north toward the deep part of the Illinois Basin.

The cuesta face is an erosional escarpment developed in the Golconda limestone and shale. This cuesta is capped by the resistant Mississippian Hardinsburg Sandstone (fig. 2), which parallels the gently dipping backslope of the cuesta toward the north.

If you look carefully, you will be able to see other cuestas during the field trip. There are many excellent examples of this type of landform throughout southern Illinois.

0.0	2.35+	Leave Stop 1. CONTINUE AHEAD through the Homberg/Hodgeville Y-intersection. BEAR LEFT on the blacktop and downhill toward Homberg.
0.5+	2.85+	Cross the Cement Hollow bridge.
0.4	3.25+	VIEW TO LEFT: Mississippian Hardinsburg Sandstone (fig. 2). Slightly farther on, numerous sandstone slump blocks are seen on the slope above the road.
0.45+	3.7+	Begin a sharper descent into a broad valley now occupied by Bay Creek.
0.2	3.9+	BEAR RIGHT (west) at Y-intersection.
0.25	4.2	BEAR LEFT at r-intersection.
0.1+	4.3+	CAUTION: enter the hamlet of Homberg.
0.05+	4.35+	Cross the abandoned Illinois Central (IC) RR crossing.
0.05-	4.4+	Offset intersection. CONTINUE AHEAD and stay on the main gravel to the south and east. We will be crossing or driving along some elongate ridges in this broad valley. These ridges are composed of sand and are similar to the sand bars that are common along modern streams. Some of these ridges occur on a relatively flat terrace. The valley probably was filled with sediments at least to the level of the terrace. The topographic map indicates that some 20 to 30 feet of material has been removed in some areas. These *floodplain* features formed during the latter days that the valley was occupied by the ancestral Ohio River. Look behind or to the left to get occasional glimpses of the north valley wall, which is a cliff in many places. Tall trees may obscure it and the thick vegetation in the valley bottoms also masks it.

1.2	5.6+	VIEW TO RIGHT: low area outlined by trees. The low areas tend to be more moist. The plants that grow profusely here form mats of organic debris when they die. The water-filled organic materials do not drain readily and thus hold enough moisture to support a large plant community under rather swampy conditions.
0.65+	6.25+	STOP: 1-way at T-intersection. TURN RIGHT (south). Notice that most of the houses and buildings tend to be located on the higher sandy ridges where it is more dry.
0.6+	6.9+	VIEW TO LEFT: derelict log cabin.
0.1+	7.0+	PARK along the shoulder as far off the blacktop as you safely can. DO NOT block the entrance drive to Bradford Cemetery. CAUTION: fast traffic. Assemble at the cemetery entrance drive.

STOP 2 View of the broad bottom and discussion of the Cache Valley in extreme southern Illinois (SE corner NE NE SW Section 15, T14S, R6E, 3rd P.M., Pope County; Brownfield 7.5-Minute Quadrangle [37088C5]).

The Cache Valley is an abandoned segment of the trunk portion of a major drainage system and is one of the best exposed and most widely recognized landforms in Illinois. It stretches east to west for nearly 45 miles from the Ohio River to the Mississippi River, across all or parts of Pope, Massac, Johnson, Union, Pulaski, and Alexander Counties. Physiographically, it forms the northernmost edge of that part of the Coastal Plain Province (fig. 9) known as the Mississippi Embayment. Here the embayment abuts against the Shawnee Hills section of the Interior Low Plateaus Province. The valley extends westward from Ropers Bluff, the prominent nose to your left (east-northeast) nearly 1.5 miles away. Ropers Bluff is about 5 miles south of Golconda. The relatively flat floor of the Cache Valley ranges from about 1.5 to nearly 4 miles wide.

The valley walls occasionally follow fault zones. Where resistant Paleozoic strata are exposed, the north valley walls are much steeper, 150 to 250 feet high and better defined than the south side, where all but the eastern one-quarter was eroded in softer, relatively unconsolidated Cretaceous and Tertiary sediments (fig. 7). The eastern part of the valley is now occupied by Bay Creek, and the western part by the Cache River, both underfit streams too small to have eroded such an enormous valley. The origin of the Cache Valley and its history have remained matters for research and discussion for more than 50 years. Research projects underway along the valley may soon provide definitive answers to some of the problems.

The earliest *fluvial* system to occupy the position of the Cache Valley is unknown, but it is reasonable to suspect that its beginning dates back to the Paleozoic/Mesozoic erosional unconformity. The major rivers draining southern Illinois and adjacent regions were established before the beginning of the Pleistocene Epoch, but flowed along somewhat different courses than now (fig. 10). Because the ancient Mississippi and Ohio Rivers drained all of the area covered by ice from the Appalachian to the Rocky Mountains, glaciers had a profound influence on the history of these streams. There are few, if any, deposits in the Cache Valley and vicinity to provide evidence of the effect of pre-Illinoian glacial and interglacial *stages* on the area. However, it seems likely that during the early Pleistocene eustatic lowering of sea level and *epeirogenic* uplift the ancestral Ohio River channel was deeply entrenched into bedrock beneath the Cache Valley. The bottom of this deep valley follows the Ohio, then down the Cache Valley at an elevation of about 120 feet msl. Drill hole records show that the present Ohio Valley is not entrenched much below the present river channel of about 220 feet msl. However, a deep valley appears to extend from the

Figure 10 Location of the Cache Valley in southern Illinois.

mouth of the Tennessee River northeastward within the present Ohio River valley to the upstream end of the Cache Valley.

Throughout most of the Pleistocene, the southward course of the Mississippi River from St. Louis to Cape Girardeau, Missouri was roughly the same as today. At Cape Girardeau the river turned west and then south flowing through southeast Missouri and northeast Arkansas. At a time of extremely high water during the Wisconsinan Stage, the river flowed over a low divide into the Ohio Valley and cut a new narrow gorge through the hills at Thebes, abandoning the old channel to the west and south.

The ancestral Ohio River was a small stream that originated in western Ohio and flowed westward to north of Shawneetown where it joined the Wabash River. From Shawneetown southward, the Ohio followed its present course to the Ropers Bluff area where it turned westward. Farther south the Cumberland and Tennessee Rivers flowed westward through a portion of the present Ohio River Valley. During a time of extremely high water in the Wisconsinan Stage, and at about the same time that the Mississippi River's course was changed at Thebes, the Ohio River cut across a low, narrow divide to capture the lower valleys of the Cumberland and Tennessee Rivers and establish its present course. The present Ohio River, like the Mississippi at Thebes, occupies a narrow gorge where it crosses from its old valley to the broad and equally old valley of the Tennessee.

The shallow sediments underlying the Cache Valley are mostly late Wisconsinan and Holocene in age, bracketing the time of the diversion of the Ohio, Cumberland, and Tennessee Rivers from the Cache Valley into the present Ohio Valley.

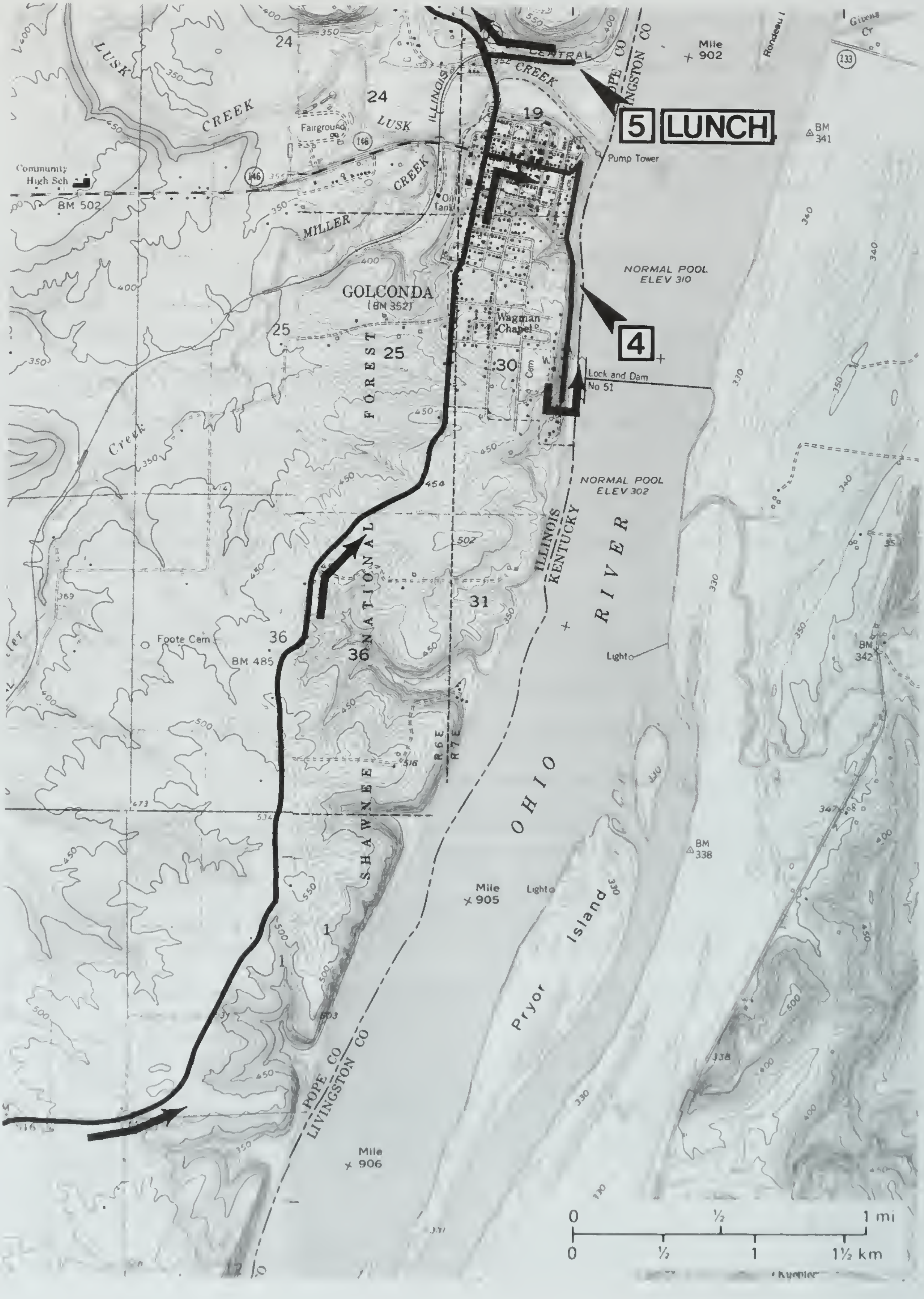
0.0	7.0+	Leave Stop 2 and CONTINUE AHEAD (south).
0.1+	7.15	T-intersection from right. CONTINUE AHEAD (south) and then curve LEFT (east).
0.3	7.45	VIEW TO RIGHT: areas that frequently flood along Bay Creek.
1.6+	9.05+	Enter bridge across Bay Creek. VIEW TO RIGHT of Mississippian age strata exposed in cut bank on south side of Bay Creek. Upper Valmeyeran Renault Limestone at the base, overlain by lower Chesterian Bethel Sandstone at the top. Will probably be difficult to see when the foliage is out. This bluff is the south boundary of the Cache Valley. As you move across the bridge, the VIEW TO LEFT over your shoulder is of the prominent headland at Ropers Bluff, the north Cache Valley wall where the river turned westward. You will get a chance to look at this more closely when we come back across the bridge.
0.4	9.45+	PARK along the road shoulder as far off the roadway as you safely can. CAUTION: fast traffic! DO NOT stand in the road!

STOP 3 View of and fossil collecting from Mississippian (middle Chesterian) Menard Limestone blocks on the RIGHT (west) side of the road (SE NE NW SW Section 26, T14S, R6E, 3rd P.M., Pope County; Brownfield 7.5-Minute Quadrangle [37088C5]). (See fossil plate in back of the guidebook).

The Menard Limestone exposed here appears to be slump blocks that have moved down slope perhaps partly as the result of road construction oversteepening the slope just below. The blocks crept down the unstable slope to their present position. J. Weller (1939) indicated the presence of a northeast-southwest trending fault slightly up the hill from here. A small area underlain by Menard Limestone is present just to the southeast. On the other side of the fault, which is not visible and at a somewhat higher elevation, is the Renault Limestone. Here it underlies the Menard Limestone, indicating vertical uplift of perhaps 500 feet.

The limestone may be as thick as 100 feet and interbedded with shale. It is a gray to brown stone that is very fine to medium grained with scattered zones of coarse grained bioclasts. Fossils are mainly found in the coarser zones and consist of pelecypods, brachiopods, bryozoans, and echinoderms. Many of the forms are fragmented, but good whole specimens are present.

0.0	9.45+	Leave Stop 3 and CONTINUE AHEAD (south).
0.2	9.65+	CAUTION: TURN AROUND at farm lane from the LEFT. Retrace route northward.
0.5+	10.2+	VIEW TO LEFT: Mississippian Renault and Bethel formations in the high bluff.
0.05-	10.2+	SLOW: Cross Bay Creek bridge. VIEW AHEAD and SLIGHTLY TO THE RIGHT is the north wall of the Cache Valley at Ropers Bluff about 2.2 miles away.
1.45	11.65+	VIEW TO RIGHT: Ropers Bluff.
1.3	12.95+	T-road from left is Homberg Road. CONTINUE AHEAD (north and northeast).
0.5+	13.5	You are starting to ascend the north wall of Cache Valley.
0.25+	13.75+	VIEW TO LEFT: Mississippian Cypress Sandstone is exposed in the roadcut.
4.1-	17.85	CAUTION: enter Golconda on Adams Street.
0.75	18.6	STOP: 4-way at SR 146. TURN RIGHT (east) on Main Street.
0.05	18.65	CAUTION: enter business district.
0.15+	18.8+	VIEW TO RIGHT: large boulder near the northeast corner of the courthouse lawn has a bronze plaque telling about the settling of Golconda. CONTINUE AHEAD (east) to the top of the seawall (levee).
0.8+	19.6+	To the right is the Illinois Department of Conservation, Old Dam No. 51 office. CONTINUE AHEAD (south).
0.05+	19.7	This is a turnaround. RETRACE your route north along the Ohio River.
0.05+	19.75+	The small structure to the right, which looks like a guardhouse, housed the controls for pumping water into Dam 51 lock below. This is the approximate west end of the old dam. This was a wicket dam. During low water you can still see riffles across the river at the approximate location of the dam.
0.3+	20.1	PARK as close to the cable guardrail as you can. Keep the gaps closed.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(BM 352)
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LUSK
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146
Oil tank
Pump Tower
Wagman Chapel
Cem
Lock and Dam No 51
CENTRAL
CREEK
ILLINOIS
POPE CO
LIVINGSTON CO
ILLINOIS
KENTUCKY
Mile 902
Rondeau
Givens Cr
133
BM 341
NORMAL POOL ELEV 310
NORMAL POOL ELEV 302
OHIO
RIVER
Light
BM 342
Foote Cem
BM 485
SHAWNEE NATIONAL FOREST
R6E R7E
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36
1
12
Mile 905
Light
Pryor Island
BM 338
Mile 906
0 ½ 1 mi
0 ½ 1 1½ km

STOP 4 Ohio River Lock and Dam No. 51, Ohio River floodplain, and outcrop of Mississippian Cypress Sandstone and underlying Paint Creek Shale (SW SE NE NW Section 30, T13S,R7E, Pope County; Golconda 7.5-Minute Quadrangle [37088C4]).

From the Illinois side of the Ohio River at Golconda near the site of the old Lock and Dam No. 51, there is a good view of the wide floodplain located on the Kentucky side of the river. The steep bluff of Mississippian Cypress Sandstone is on the Illinois side of the river on the left (west).

At this stop the Cypress Sandstone and the upper part of the underlying Paint Creek Shale are well exposed. The Cypress, as it is at this stop, is a massive sandstone and very similar to the Bethel Sandstone that occurs below the Paint Creek Formation. Although the upper part of the Cypress is evenly *bedded*, in some places it tends to be relatively thin bedded. It is composed of fine grained sand, and on weathered surfaces it is light yellowish brown or tan, and on freshly broken surfaces it may be almost white. An interesting feature also at this stop shows the rapid thickening of the Cypress Sandstone. The underlying Paint Creek Formation grades laterally from irregularly bedded sandstone to predominantly shale.

Approximately eight sandstone beds and eight limestone–shale beds compose the Chesterian Series, the upper division of the Mississippian System. Fossil remains in the limestones and shales indicate that they are predominantly marine (sea) deposits. On the other hand, woody materials in the sandstone indicate that they are non-marine, perhaps river floodplain or *delta* deposits. The alternating limestone–shale and sandstone beds suggest rapidly changing conditions in the Illinois Basin during Chesterian time (330 to 320 million years ago).

Today similar deposits are developing in the Mississippi River delta region. As the Mississippi River reaches the delta, it divides into a series of branching distributaries, the channels of which contain thick sand deposits bordered by sand deposits of lesser thickness. The bottom surfaces of these deposits are U-shaped while the upper surface is usually flat (fig. 11). Note that the bottom of the Cypress Sandstone is U-shaped and that it cuts into the underlying Paint Creek Shales. This relationship possibly indicates that this was a channel of one of the many distributaries of the ancient delta on which the Cypress Sandstone was deposited. Channel development in the Cypress has been observed in many places in the area. Plant fossils are relatively numerous at many places in this sandstone.

A modern analog for the occurrence of plant fossils in the Cypress Sandstone is easily seen at this stop. Look at the Ohio River and notice the number of trees and logs floating downstream to the Mississippi Delta where they may become part of that deltaic deposit. Given a few million years some of this vegetation eventually will become fossilized.

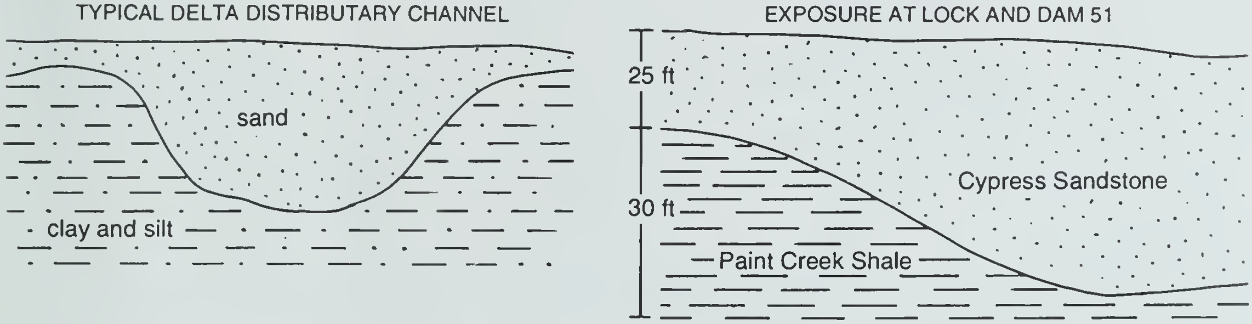
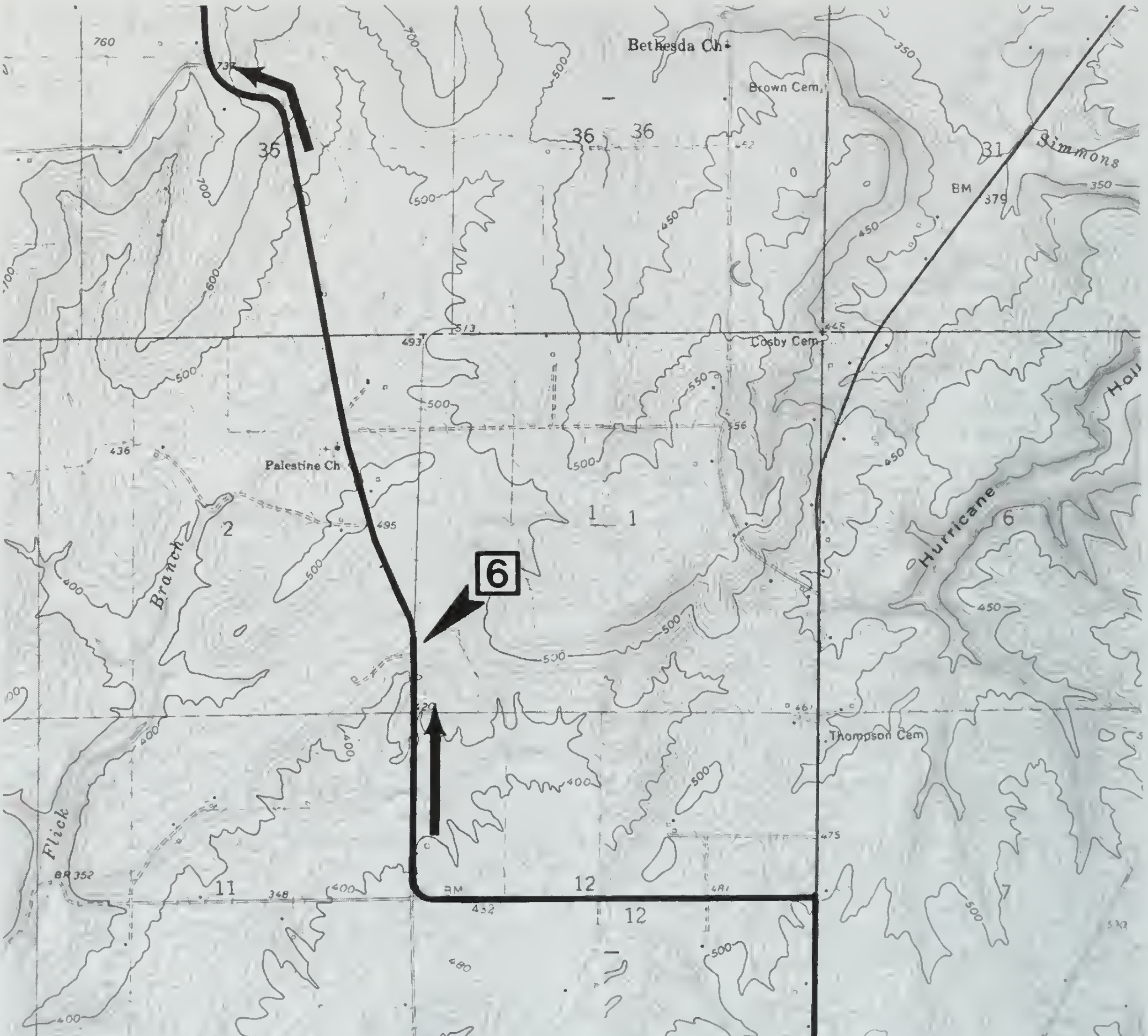


Figure 11 Typical Mississippi delta distributary channel profile compared to the Cypress Sandstone exposed at the abandoned Lock and Dam No. 51 near Golconda, Illinois.


Bethesda Ch
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Thompson Cem
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Giddeonson Hollow
POPE CO
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0.0	20.1	Leave STOP 4 and CONTINUE AHEAD (north and west) retracing the route back to the 4-way Stop at SR 146.
0.4+	20.5+	CAUTION: enter east side of Golconda business district.
0.25+	20.8+	STOP: 4-way. TURN RIGHT (north) on SR 146 East.
0.1+	20.95	North floodgate on the levee.
0.1	21.05	Cross Lusk Creek bridge and prepare to TURN RIGHT.
0.1+	21.15+	TURN RIGHT (east) on the access road (formerly ICRR trackage) to the Golconda Marina.
0.25+	21.4+	Please follow parking directions. Mileage count will resume from the SW corner of the parking area.

STOP 5 LUNCH – enjoy the peaceful view of the river and the towboats from the Golconda Marina.

0.0	21.4+	Leave Stop 5 from the SW corner of the parking area. Resume mileage count from here. TURN LEFT (west) toward SR 146.
0.25+	21.7+	STOP: 1-way at T-intersection. TURN RIGHT (north) on SR 146.
2.05	23.75	Prepare to TURN LEFT.
0.15	23.9	TURN LEFT on the Eddyville Road.
1.05	24.95	Curve RIGHT on the blacktop at the crossroad.
0.6+	25.55+	VIEW TO RIGHT: Mississippian Menard Limestone exposed in the field.
0.05+	25.65+	PARK along road shoulder as far off the road as you safely can. CAUTION: limited visibility and fast traffic!

STOP 6 Mississippian Palestine Sandstone exposed in the roadcut (NW$_{ext.}$ SW SW Section 1, T13S, R6E, 3rd P.M., Pope County; Waltersburg 7.5-Minute Quadrangle [37088D5]).

Evidence of one of the many faults in this area can be seen in the roadcut at this spot. The actual fault, the Flick Branch Fault Zone, is not visible, but strata sharply inclined because of slippage of one side against the other is well exposed.

Southeastern Illinois is cut by a complex series of faults, most of which trend in a northeast-southwest direction. The Golconda area is intensely faulted (fig. 12 illustrates types of faults here). The major faults can be located on topographic maps by the linear features of some of the creeks and sandstone bluffs. The majority of the faults in the fluorspar district are shown on various geologic quadrangle maps. In addition to the known faults in this area, many more are probably present but are undetected because they are covered by erosional debris or vegetation. Throughout this

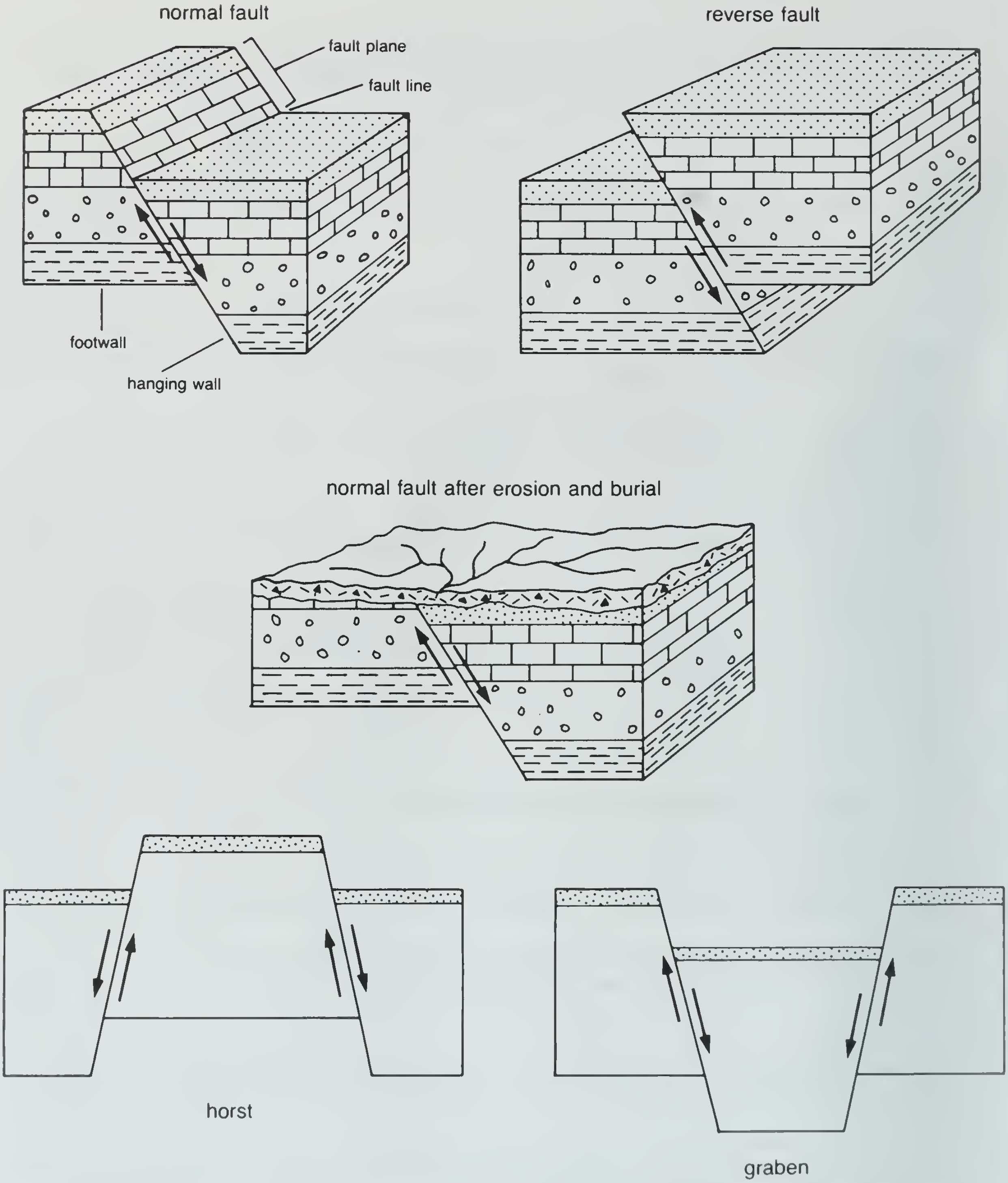


Figure 12 Illustrations of fault types that may be present in the field trip area. Arrows indicate relative directions of movement on each side of the fault.

area, steeply inclined strata — such as seen here — are good evidence of a fault close by. The actual fault plane can seldom be observed, but inclined strata adjacent to faults, especially in sandstones, are usually present. Here, the Palestine Sandstone has been downthrown on the northwest side of the fault zone. The upper part of the Palestine Sandstone, therefore, is only a few feet above the upper part of the Menard Limestone seen a short distance southeast of here.

Discussion about the geologic engineering work.

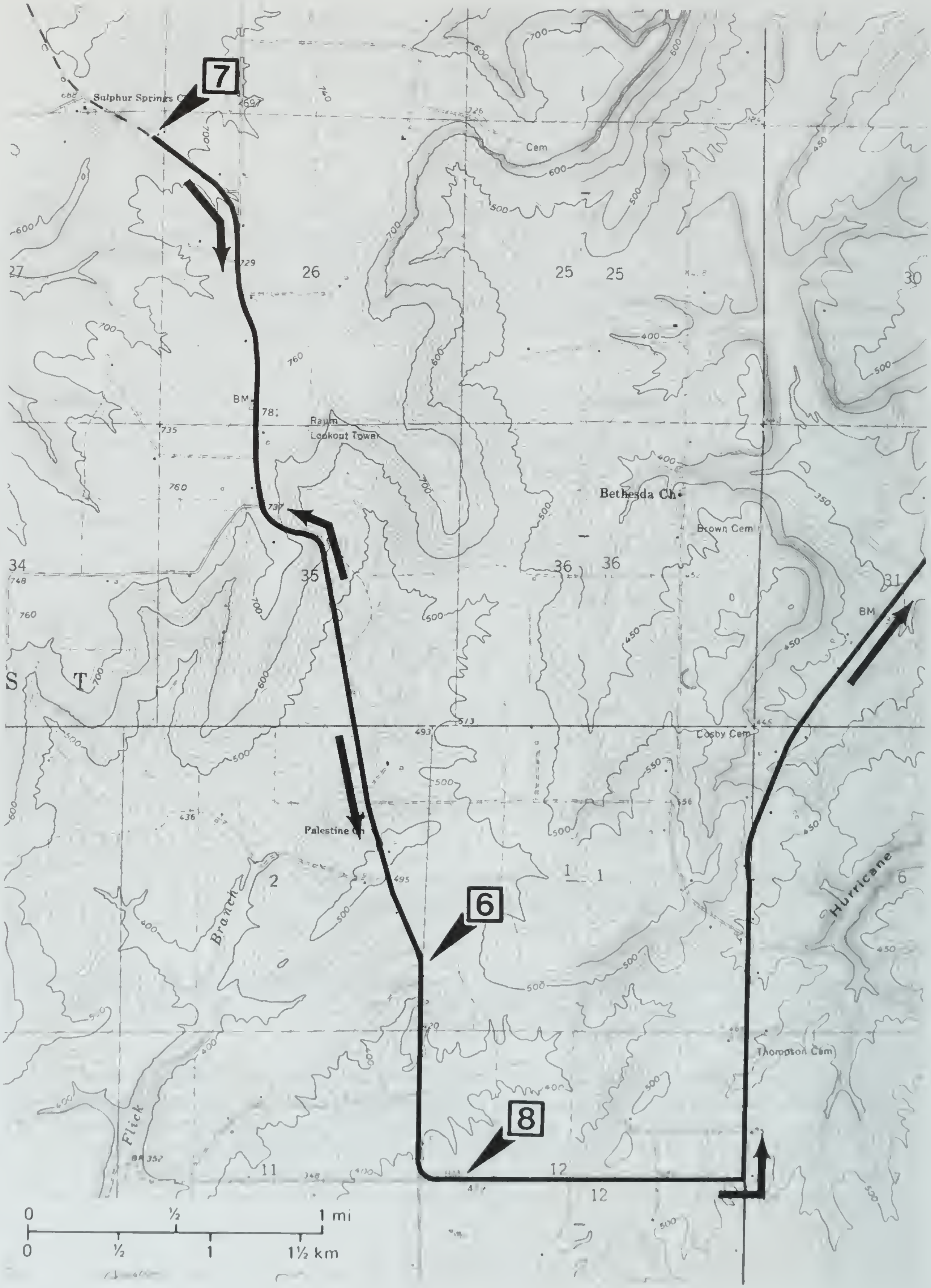
In the early 1960s, the ISGS conducted a geologic evaluation for a proposed dam and construction of Shawnee Lake in the Lusk Creek Valley. The ISGS was requested to geologically evaluate two potential dam sites, both in Section 14, T13S, R6E. The Survey's report noted two and possibly three faults crossing Section 14. In addition, the Golconda Limestone and Shale occur along the sides of Lusk Creek valley. This limestone is known to be cavernous and sinkholes occur at the surface where the limestone crops out. The topographic map shows several sinkholes in Section 11.

Because of the numerous faults and the possibility of leakage through sinkholes in the area, both sites in Section 14 were considered unfavorable. ISGS engineers suggested another site upstream in Section 32, T12N, R6E; however, this site would reduce the area of the lake considerably. Note: to date this lake has not been constructed.

0.0	25.65+	Leave Stop 6 and CONTINUE AHEAD (northwest).
0.7+	26.4	Cross Flick Branch bridge.
0.75+	27.15+	Sandstone of the Pennsylvanian Caseyville Formation ("Wayside" Member) exposed in the roadcut on the inside of the curve to the left (west).
0.5+	27.7+	ON THE LEFT (west) side of the road is the location of a triangulation station used for surveying this area. The elevation is 781 feet msl, the highest point on the field trip route.
0.6+	28.35	STRAIGHT AHEAD is the road to Raum, BEAR LEFT (northwest) and stay on the Eddyville Road.
0.4+	28.75+	TURN RIGHT (northeast) and enter Jan Stone Company. *You must have permission to enter this property.*

STOP 7 Observe building stone quarry and fault in the Pennsylvanian Caseyville sandstones (entrance on NE side of Eddyville Road in NE NE NE NE Section 27, T12S, R6E, 3rd P.M., Pope County; Waltersburg 7.5-Minute Quadrangle [37088D5]).

A quarry has been in operation at this locality for approximately 40 years and has been operated for the last ten years by Jan Stone Enterprises Inc. The sandstone beds are mechanically pried apart using a hydraulic machine that was specifically built for this purpose. The sandstone is then sized by hand and sold by the ton according to the thickness of the flagstone needed. An estimate of the number of square feet that one ton of flagstone will cover for a given thickness of sandstone is as follows: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Raum Lookout Tower
Bethesda Ch
Brown Cem
Cosby Cem
Palestine Ch
Thompson Cem
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31
2
1
1
6
11
12
12
S
T
0
½
1 mi
0
½
1
1½ km

Thickness in inches	Number of square feet
4	70
3	100
2	140
1	200

Note: The lodge at Giant City State Park was constructed using stone from this quarry. When the current operators took over this quarry they sold 300 tons for additional construction at the lodge and for the retaining walls at Giant City State Park. The quarrying of 300 tons was completed by three shifts operating for a period of 3 months. Flagstone from this quarry has been shipped to places as far away as St. Louis, Missouri, and Champaign, Illinois.

The Raum Fault Zone is at the western edge of this property near Beatty Branch. The rocks on the west side of the creek have been downthrown in relation to those on the east side so that the upper member of the Caseyville (Pounds Sandstone) is inclined steeply in the opposite direction from the slightly older rocks on the east side. This change in dip direction is a strong indicator of a fault. An exposure of the steeply dipping beds that are nearly vertical are located on the west side of the creek along the north side of the road.

0.0	28.75	Leave Stop 7 and retrace route toward SR 146.
1.05	29.8+	Crossing the highest elevation on the Golconda field trip route.
2.65+	32.5	BEAR LEFT (east) at a crossroads.
0.15+	32.65+	PARK on the shoulder as far off the road as you safely can. DO NOT stand in the road. CAUTION: Fast traffic!

STOP 8 View the remains of a concrete benchmark post and discuss land surveys (near north edge of NW NW NW SW Section 12, T13S, R6E, 3rd P.M., Pope County; Waltersburg 7.5-Minute Quadrangle [37088D5]).

A broken concrete post is located on the south side of the road at the top of the roadcut. A witness sign for the marker is on top of a metal post that stands adjacent to the benchmark post. We collected three pieces of the benchmark that appears to have been broken by a brush-hog used to maintain the right-of-way.

The marker was placed in 1957. The elevation is 432 feet msl. The number stamped below that is TT10MT.

At this stop we will discuss the land survey system in Illinois. An examination of the 15- and 7.5-minute quadrangles in the field trip area shows that section lines do not show a perfect rectangular grid pattern over the whole area. You will note that some sections are different sizes and somewhat misshapen because of slightly slanted section and quarter section lines.

In 1804, initial surveying from the 2nd P.M. (fig. 13) continued westward from Vincennes, Indiana. This survey became the basis for surveying about 10% of what is now eastern Illinois. It was decided in 1805 to designate the 3rd P.M. as beginning at the mouth of the Ohio River and extending northward to facilitate surveying new land cessions. During March 1806, surveying commenced northward on both sides of the 3rd P.M. After an initial baseline survey point was established, later it was arbitrarily moved northward 36 miles where it roughly coincides with the baseline of the 2nd P.M.

The township and range system permits the accurate identification of most parcels of land in Illinois to facilitate the sale and transfer of public and private lands. In the early 1800s, each normal township was divided (to the best of the surveyor's ability) into 36 sections, each of which was 1 mile square and contained 640 acres (see route maps).

Township and range lines do not form a perfect rectangular grid over the state (fig. 14) because of the use of different baselines and principal meridians, and because minor offsets were necessary to compensate for the Earth's curvature. The surveying corrections producing the minor offsets were usually made at regular intervals of about 30 miles.

Here, although Section 12 is 1 mile from north to south, it is about 5,750 feet rather than 5,280 from east to west. You will note on the route map that the boundary between T12S and T13S

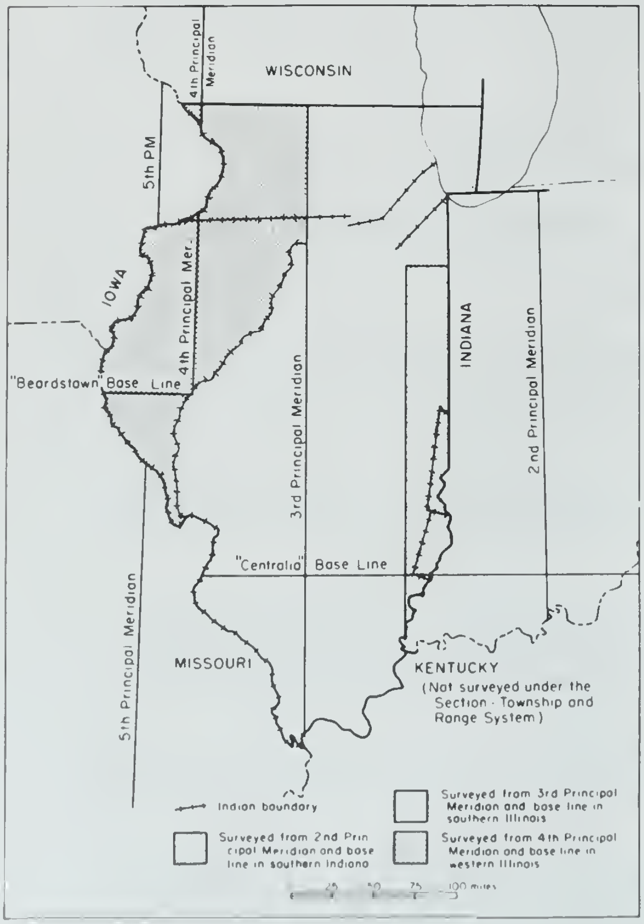


Figure 13 *above* Principal meridians and baselines of Illinois and surrounding states (Cote 1978).

Figure 14 *right* Index map (Cote 1978).

illustrates the offsets for corrections mentioned earlier. The offsets along that line range from slightly less than 0.1 mile to somewhat more than 0.1 mile. Look at the other route maps to see what other differences from the "norm" you can find. If you have other topographic maps at home or school, look at them to see if they have any oddities. They all do! (Some more so than others.) Maybe you need to study this very informative type of map further. ISGS has a free index of topographic maps of Illinois — order one of your area.

0.0	32.65+	Leave Stop 8 and CONTINUE AHEAD (east).
0.9+	33.6	STOP: 1-way at T-intersection with SR 146. TURN LEFT (north). CAUTION: fast traffic.
2.15+	35.75+	Cross Simmons Creek.
1.05	36.8+	See Gowins Corner.
0.2	37.0+	Cross Little Grand Pierre Creek.
1.3	38.3+	ON THE LEFT: new roadcut exposes Mississippian Hardinsburg Sandstone overlying the Golconda *Group* on the left for about 0.1 mile.
0.8+	39.15+	Cross Grand Pierre Creek and prepare to park for next stop.
0.1+	39.25+	PARK on shoulder and as far off the highway as you safely can. DO NOT PARK on the bridge or next to the guardrail. CAUTION: fast traffic! Carefully walk to the access lane.

STOP 9 Collect some mineral specimens and discuss fluorspar mining in this part of Illinois at the abandoned Ozark-Mahoning Parkinson Mine (lane access: SE corner NE NE NW SW Section 22, T12S, R7E, Pope County; Shetlerville 7.5-Minute Quadrangle [37088D4]).

The field trip route lies along the western edge of the Illinois-Kentucky Fluorspar District. This region is a complexly faulted area lying between the Illinois Basin on the north and the Mississippi Embayment to the south. The Illinois portion of the district, with a history of fluorspar mining that dates from 1842, still has important deposits of minable fluorspar and its related minerals.

Illinois was the only state reporting fluorspar production in 1992, when some 50,000 tons of spar were shipped by the main producer. The U.S. production of fluorspar has steadily declined since 1989 when 66,000 tons were produced. Imports from foreign countries, such as Mexico, South Africa, China, and Canada, supplied 87.5% of U.S. needs, 399,000 tons in 1992. Increased competition from foreign sources and a decrease in the use of chlorofluorocarbons were mostly responsible for the decline in domestic production.

Fluorspar from Illinois continues to be in demand because of its high purity and absence of toxic trace elements often found in imported fluorite. Fluorite (fluorspar) is used in the smelting of steel and aluminum, and in the production of enamels, toothpaste, specialty glass, and a variety of chemicals. Hydrofluoric acid is the backbone of the fluorine chemical industry. More than 65% of the U.S. fluorspar consumption goes into the production of hydrofluoric acid. Fluorite (calcium fluoride – CaF_2), was designated Illinois' state mineral by the 74th General Assembly in July 1965 (see *Geogram 9: Fluorite: Illinois State Mineral,* in the back of the guidebook).

Parkinson Mine This mine shaft is along the east side of Big Grand Pierre Creek. Mineralization of the ore body at this mine is classified as a vein type deposit. The ore deposit formed along the northeast-southwest-trending Barnett Fault, which has a dip of 80°. The mine shaft is located between two faults that are part of a series of small faults, which in turn are located between two major northeast-southwest-trending faults, the Stewart Fault to the east and the Hobbs Creek Fault to the west.

The mine was first worked in 1850 from a shaft reportedly 30 feet deep. The average width of the vein was 6 inches. Additional data from this period of operation is scarce. The mine was next operated by the Grand Pierre Mining and Manufacturing Co. (1871–1890) to extract galena. The shaft was deepened to 175 feet in 1871 and then further deepened to approximately 300 feet by 1890. The mine was abandoned prior to the turn of the century and sold for taxes around 1900. The next period of activity was in 1942 when the mine was dewatered by an unknown party to a depth of 180 feet. In October of 1952 Ozark-Mahoning Mining Company obtained a lease and began core drilling and in 1957 they reopened the mine. The shaft was deepened to 402 feet and had working levels at 245 and 366 feet. Between 1957 and 1965 Ozark-Mahoning produced 89,898 tons of ore through the 6 by 9 foot shaft. Between 1965 and 1981 the Parkinson shaft was used as a secondary escape way and ventilation shaft for the Barnett Mine. The Barnett Mine shaft is located approximately 4,000 feet to the southwest along the same northeast-southwest-trending fault as the Parkinson mine.

Illinois fluorspar occurs almost exclusively in Pope and Hardin Counties (fig. 15). The main production has come from the Rosiclare vein system (figs. 16 and 17) and from bedded replacement deposits (fig. 18) north of the Cave in Rock area. Less significant amounts of fluorspar have been mined from several areas outside these main areas.

Ore Deposits

Ore bodies in the Illinois-Kentucky Fluorspar mining district are of three general types: (1) bedded deposits formed by selective replacement of limestone strata, (2) fissure-filling or vein deposits along faults and fractures, and (3) residual deposits derived from one of the other types.

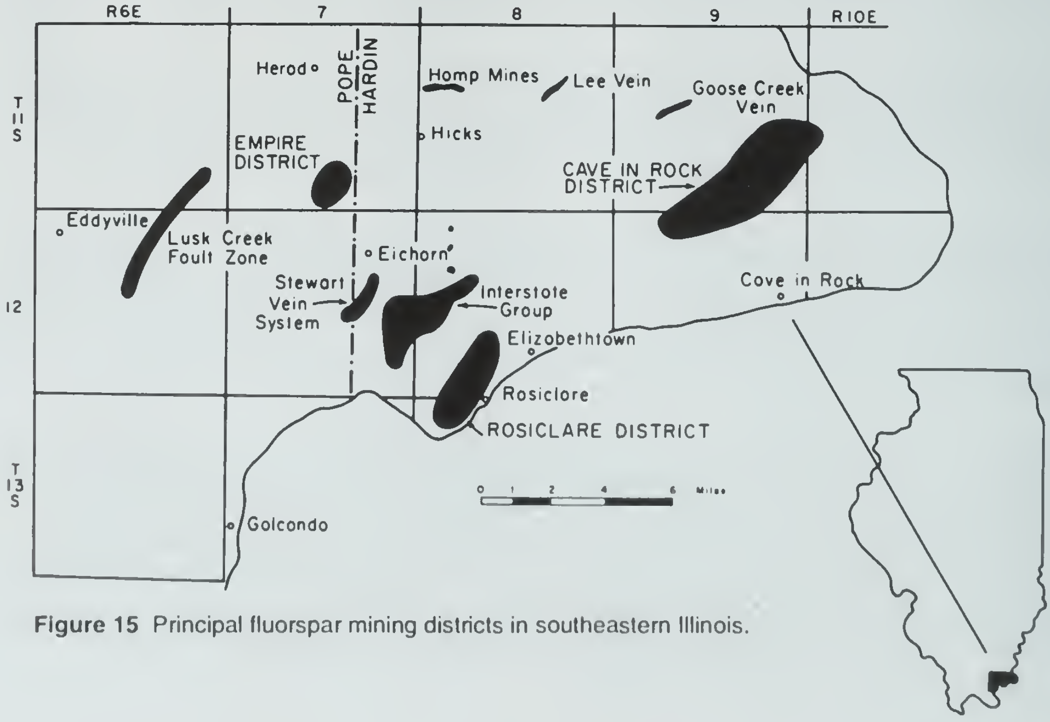
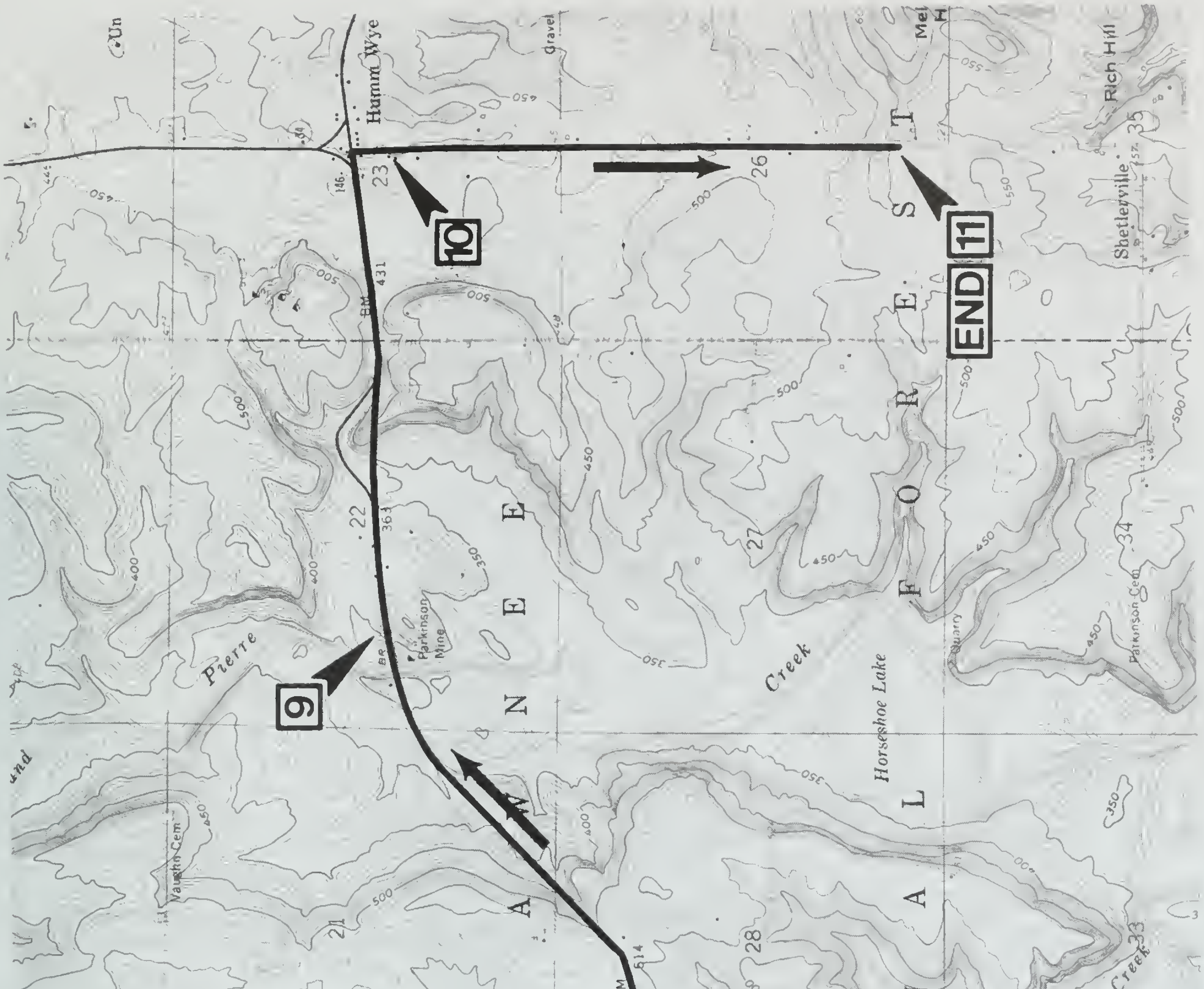


Figure 15 Principal fluorspar mining districts in southeastern Illinois.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Rich Hill
Shetlerville
Parkinson Cem
Parkinson Mine
Quarry
Horseshoe Lake
Creek
Pierre
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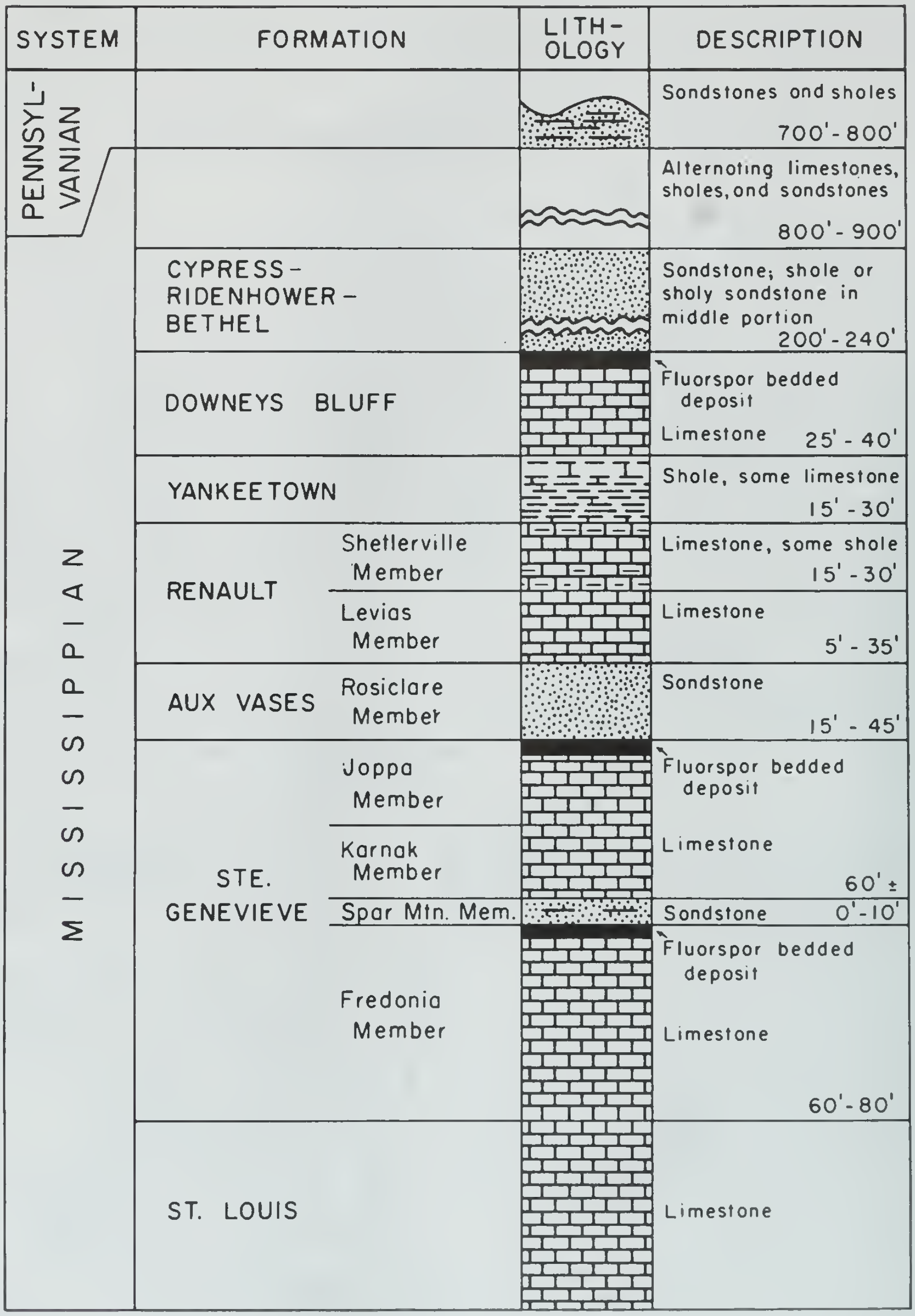


Figure 16 Principal fluorspar-bearing portion of stratigraphic column of the southeastern Illinois fluorspar district. Black bands represent horizons most favorable for the occurrence of bedded deposits. The most productive parts of the veins generally occur below the Rosiclare Sandstone.

Vein deposits The primary controlling factor determining the location and extent of mineralization of vein deposits was faulting. Vein deposits occur in steeply inclined, sheet-like deposits as fissure fillings along faults (fig. 17). A fault is a fracture in the rocks along which relative movement of the opposite sides has taken place. The width and continuity of the vein deposits depend on the size of openings between the fault surfaces in which they were formed. Fault planes (surfaces) are rarely perfectly parallel. The rock surfaces on either side of a fault are usually wavy and irregular, preventing a good fit where one side of the fault plane rests against the other. These irregularities caused the opposite walls of the fault planes to be pushed apart, producing the openings in which the fluorspar veins were deposited by mineralizing solutions. As a result, the veins pinch and swell both vertically and laterally. The veins range in thickness from a feather edge to as much as 30 feet. Major deposits have been found in northeast trending faults of moderate displacement, 25 to 500 feet. These faults evidently provided avenues for the movement of mineralizing solutions and open fissures for mineral deposition. Faults of lesser displacement apparently failed to develop sufficient open space along fault planes, and those of greater displacement had excessive development of gouge and other fault material that decreased the amount of available open space. Vein deposits in the Rosiclare area have been mined at depths greater than 800 feet.

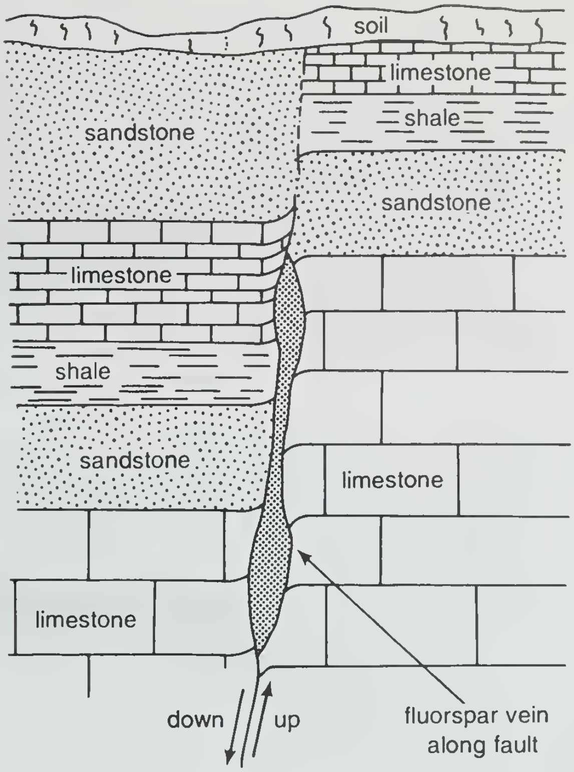
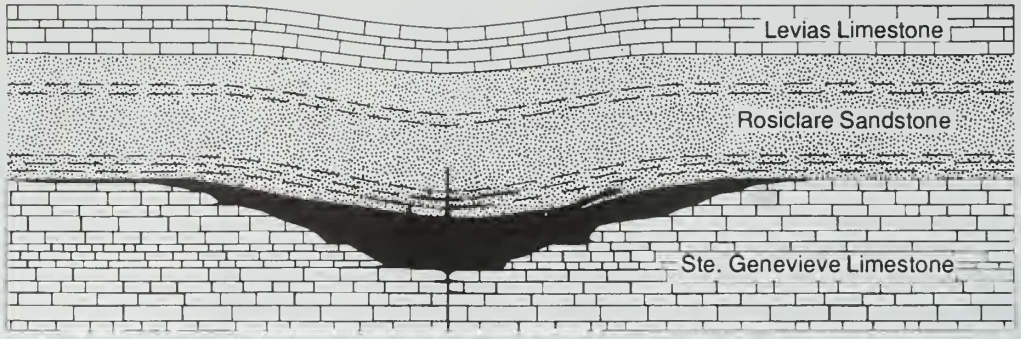


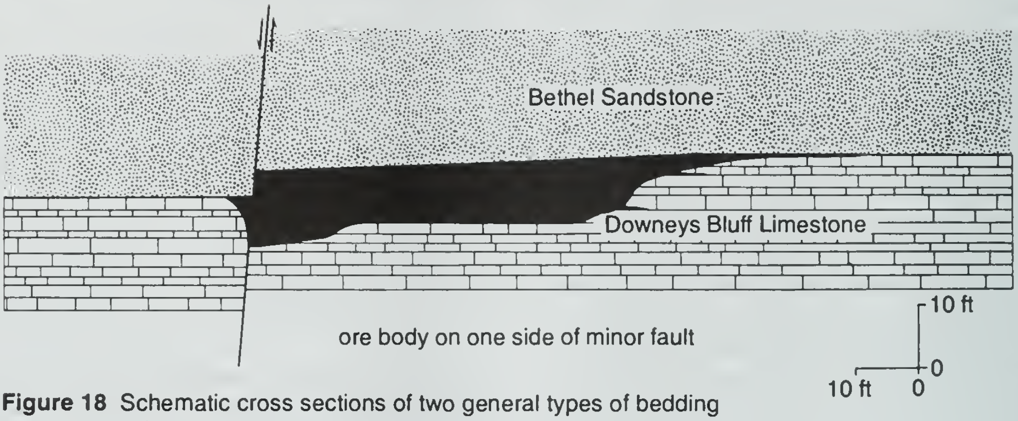
Figure 17 Schematic cross section of fluorspar vein along a fault. The strata on the left side of the fault have moved downward with reference to those on the right.

Vein deposits are best developed in the stronger, more competent limestones and well-cemented sandstones in which adequate open spaces could be maintained along the faults. Weaker rocks, such as shales, sandstones, or shaley limestones, became crushed during faulting and generally filled rather than created openings. The best vein deposits are found in the relatively pure, competent Ste. Genevieve and St. Louis Limestones. Minable vein deposits also occur in competent younger rocks of the overlying Chesterian Series, but these ore bodies are limited in size and occurrence because shale beds associated with these strata generally plugged the faults.

Bedded deposits Bedded fluorspar ores are generally flat-lying, irregular bodies parallel to the *bedding* of the host limestones (fig. 18). Typically, the deposits are elongate and range from 200 to more than 2,500 feet in length and from 50 to 300 feet in width. They are commonly 4 to 15 feet thick and wedge out laterally. Unlike the vein deposits, in which the fluorspar simply filled open fissures, the bedded deposits were formed by a chemical reaction between the fluorine-bearing solutions and the limestone. The calcium carbonate of the limestone was changed to calcium fluoride or fluorite. The mineralizing solutions that formed the bedded deposits moved along minor faults and *joint*-like fractures that had little or no open space to permit deposition. Thus, the solutions spread out laterally along *bedding planes* within the limestone, perhaps even moving through the pore spaces in coarser grained parts of the rock. This close contact with the limestone permitted the chemical reaction to take place. The exact origin of the mineralizing solutions



ore body symmetrical about central fissure



ore body on one side of minor fault

Figure 18 Schematic cross sections of two general types of bedding replacement fluorspar deposits (after Grogan 1949).

that formed the vein and bedded ores is not known. Presumably, they were deposited by hot, fluorine-bearing, aqueous solutions rising from deep within Earth's crust.

The restriction of bedded replacement deposits to certain stratigraphic levels (figs. 16 and 18) indicates that some beds were particularly favorable sites for replacement processes. The three major ore horizons are, in ascending order: (1) the level of the Spar Mountain Sandstone Member of the Ste. Genevieve Limestone, (2) the top of the Joppa Member of the Ste. Genevieve at the base of the Rosiclare Member of the Aux Vases Sandstone, and (3) the top of the Downeys Bluff Limestone at the base of the Bethel Sandstone.

Apparently, the limestone at these levels presented the most favorable conditions (purity, porosity, or fracturing) to allow replacement by fluorite. The lower mineralized zone near the level of the Spar Mountain Sandstone Member is commonly referred to as the "Sub-Rosiclare" zone. The heaviest mineralized portions of the two upper zones occur immediately beneath the Bethel and Aux Vases (Rosiclare) Sandstones. These sandstone units are usually tightly cemented, rendering them relatively impervious, which may have been a factor in limiting the upward movement of the mineralizing solutions. Less extensive replacement deposits have been found at the level of the Karnak Member of the Ste. Genevieve and at the top of the Levias Member of the Renault.

Mineralogy Fluorspar (CaF_2) and *calcite* ($CaCO_3$) are the two chief minerals present in the vein deposits. Minor amounts of galena (PbS,) sphalerite (ZnS), and barite ($BaSO_4$) also occur. In the bedded deposits, fluorite is the principal ore mineral, but galena and sphalerite occur locally. Bedded ores commonly consist of alternating bands of coarse and fine grained fluorspar. Some banded ores also consist of dark, fine grained layers of fluorite, forming the so-called "coontail" spar. Rare or small amounts of strontianite, witherite, *dolomite*, pyrite, ankerite, chalcopyrite, malachite, marcasite, smithsonite, limonite, *gypsum*, aragonite, melanterite, stibnite, and sulfur have also been identified in the fluorspar deposits.

Industrial uses Space does not permit a discussion of the mining, milling, or processing of fluorspar ore. Likewise, only brief mention may be made of its uses in industry. Illinois fluorspar concentrate is marketed in three grades: acid (97% pure), ceramic (85–96% pure), and metallurgical (60–72% pure). More than 60% of the fluorspar consumed in the United States is used by the chemical industry in the manufacture of hydrofluoric acid, the basic chemical for almost all fluorine chemical processes. Fluorine chemicals are used in the manufacture of synthetic cryolite, refrigerants, aerosols, plastics, medicines, high-octane fuels, and a host of other products. The steel industry consumed about 20% of total production in the form of metallurgical spar for use as a fluxing agent in steel smelting. In the ceramic industry, fluorspar is used as a flux and opacifier in the manufacture of special types of glass and enamels.

Origin of the faults The exact cause of the complex faulting is not known. At the end of Pennsylvanian time or during early Permian time (about 260 million years ago), the Paleozoic strata of the present Illinois-Kentucky Fluorspar District may have been arched into a northwest-trending, elongate dome by an enormous rising body of *magma* (molten rock) generated at great depth. Tensional fractures were formed parallel to the long axis of the dome because of the stretching of the sedimentary strata. Some magma was squeezed into these fractures to form the dark igneous dikes now exposed at the surface in southeastern Illinois and western Kentucky.

After the magma had begun to crystallize and ceased to push upwards, the area was broken by a second set of fractures, oriented northeast-southwest, probably by forces related to those that were forming the Appalachian Mountains along the eastern margin of the continent. Relaxation of these forces, plus shrinkage of the body of magma as it continued to cool, caused the domed area to collapse into a series of blocks bounded by the northeast-trending fractures. The resulting *normal faults* trended northeast-southwest and became the channel-ways for the fluorine-bearing solutions that were probably derived from the underlying magma body. These same faults also served as sites of deposition for the fluorite vein deposits. Most of the faults are normal, with fault planes inclined at high angles (70° to 80°) but some are reverse faults (fig. 12). Movement along the faults was largely vertical, but in some places there was also horizontal (sideways) movement. The Shawneetown Fault Zone, a large faulted structure in Gallatin and Saline Counties just north of the Fluorspar District, shows evidence of reverse movement of as much as 3,500 feet. The compressive forces that caused this thrusting were probably also responsible for the northeast-southwest-trending fractures along which the block faulting took place.

Recurrent faulting has occurred throughout the region since Permian time, although these later movements may be unrelated to the earlier period of faulting. Cretaceous and Tertiary strata in extreme southern Illinois and in Kentucky are also cut by faults, and *earthquakes* within recorded history suggest that movements are still taking place. The most recent major earthquakes occurred in southeastern Missouri along the New Madrid Fault in the winter of 1811–1812. Smaller earthquakes have occurred up to the present in several places.

Minerals of fluorite, barite, calcite, and dolomite can be found in the spoil piles surrounding the area of the shaft.

0.0	39.25+	Leave Stop 9 and CONTINUE AHEAD (east).
0.5	38.75+	Relatively new roadcut through Mississippian Bethel Sandstone.
0.25	40.0+	Enter Hardin County.

0.1	40.1+	You are descending into a large sinkhole that extends both north and south of the highway for a distance slightly more than 1.25 miles. It is nearly 0.3 mile across at its widest. On your route map this large sinkhole, also called a solution valley, is represented by contour lines that have hachures along one side. If the internal drainage of this large feature were to become plugged and the *doline* would fill with water somewhat higher than the highest hachured contour line, then we are crossing what would be the spillway for that lake.
0.25	40.35+	Prepare to TURN LEFT.
0.1+	40.5+	TURN RIGHT (south) at the Humm "Wye" crossroad toward the Job Corps Center.
0.05	40.55+	VIEW TO LEFT: two sinkholes.
0.05	40.6+	Road is across a partially filled sinkhole.
0.05	40.65+	PARK on the shoulder as far off the roadway as you safely can. CAUTION: DO NOT block any driveways or stand on the pavement. Heavy and fast truck traffic at times!

STOP 10 View sinkholes to the LEFT on the east side of the road and discuss karst topography (near SW corner NW NW SE Section 23, T12S, R7E, 3rd P.M., Hardin County; Shetlerville 7.5-Minute Quadrangle [37088D4]).

Karst topography The term *karst* is defined as a type of topography that is formed on limestone, gypsum, and other rocks by dissolution and is characterized by sinkholes, caves and underground drainage. The abundance of open fractures in the limestone bedrock is slowly dissolved by rainwater or snowmelt. Features that typify karstic terrain include closed depressions (sinkholes or dolines, as shown on your route map), caves, large and/or numerous springs, and fluted rock outcrops. These features form as surface waters infiltrate the land surface and migrate downward through fractures in the limestone bedrock. Fractures in bedrock are common and are usually the result of stress within the regional tectonic regime. As the water flows through the fractures, it slowly dissolves the limestone over thousands of years.

Karstified bedrock often contains aquifers that are local sources of drinking water. Karst aquifers are susceptible to contamination because of the honeycombed nature of the host bedrock and because there usually is not a thick enough surface cover to filter out impurities. Recharge of water to these aquifers is often rapid and may carry contaminants from the land surface. In most nonkarstic areas, recharge of water to aquifers occurs at a very slow rate through materials that provide an environment for the physical, biological, and chemical degradation of water-borne contaminants. Potential contaminants include agricultural chemicals (fertilizers and pesticides) and septic and landfill effluents. Engineering problems also arise from the susceptibility of the terrain to subsurface erosion and soil collapse (sinkholes). Collapse features such as these can be either initiated or encountered during excavations and site developments and may result in changes in groundwater recharge and flow patterns. These potential problems necessitate location and identification of karst areas.

In Illinois, carbonate rocks comprise approximately 25% of the bedrock surface, most of which is either fissured or karstic in nature. One way to identify karstified areas is by noting the presence of sinkholes (figs. 19 and 20). Karstification, however, takes place primarily in the subsurface and may not be observed at the surface. Sinkholes are the surface manifestation of karstified bedrock; locally the Golconda area shows typical effects of karstification.

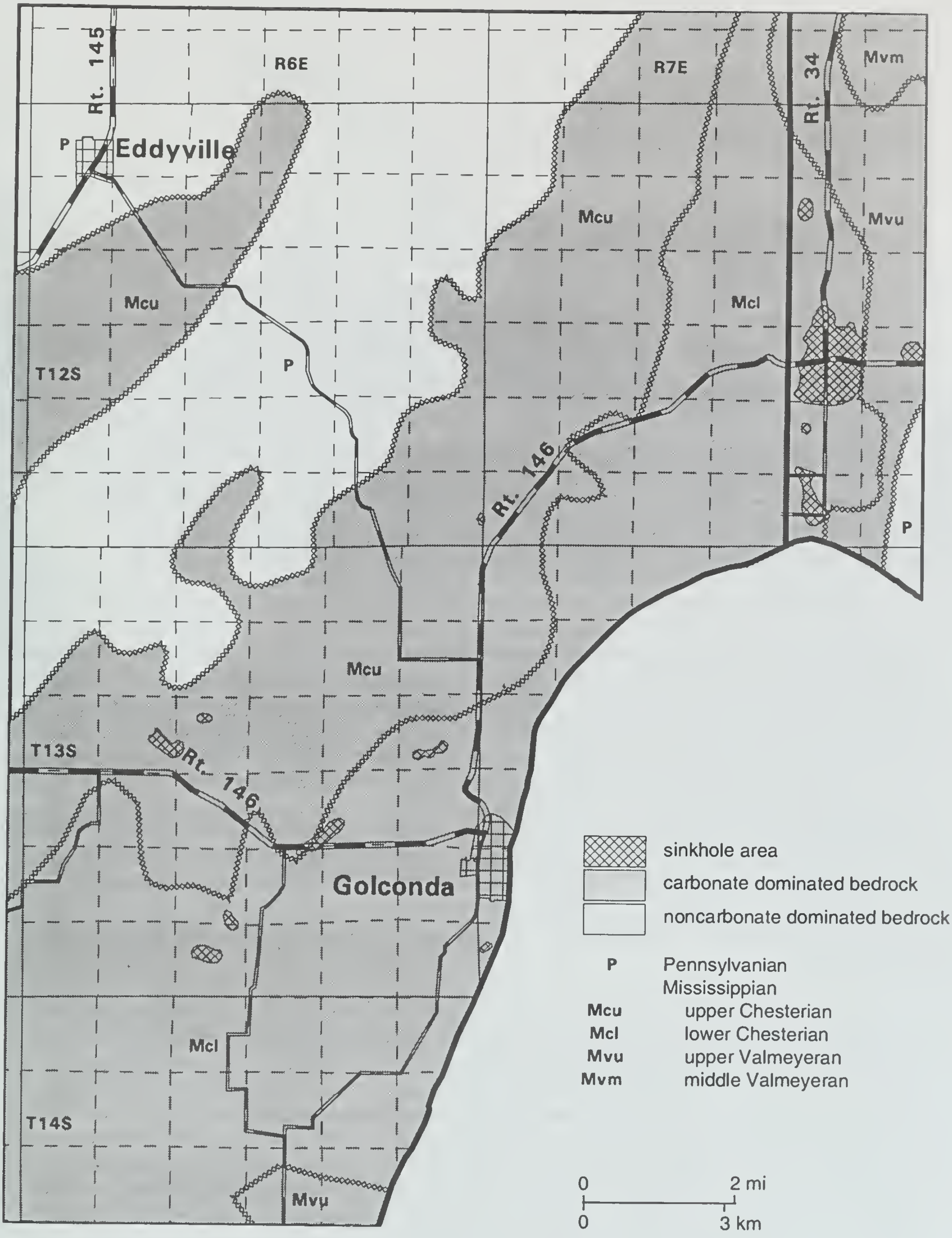


Figure 19 Sinkhole tracts in the Golconda Area.

Figure 20 Karstification in an area of jointed limestone bedrock (Hallberg et al. 1984).

Development of karst topography Karst topography develops in areas of fractured or jointed limestone bedrock where the strata are flat-lying or only gently tilted. The limestone must be relatively dense or else the water will be absorbed by the whole rock rather than along the joints and fissures. There must also be ample rainfall and a level below the limestone upland toward which groundwater can flow. Rainwater charged with carbon dioxide from the atmosphere and humic acids from decaying vegetation percolates downward through the jointed limestone. The water gradually dissolves the limestone and enlarges the joints to form an interconnecting network of subterranean fissures. More and more of the surface drainage will be diverted into the subsurface and, if enough time passes without a change in these conditions, some of the fissures will enlarge into great underground caverns. The roofs of some caverns may collapse to form a sinkhole. Other sinkholes form purely by solutional enlargement of joints from the surface downward. The result of this process is a rolling karst plain, pocked by numerous sinkholes and underlain by cavernous limestone.

Panno and Bourcier (1990) presented an hypothesis for the formation of caves and associated karst features near the southern margins of the Illinois, Michigan, and Appalachian Basins. They noted that the relationships between various features of these basins suggest that Pleistocene glaciations may have induced the discharge of saline waters from the basin margins. The great weight of the glaciers could have resulted in compaction of underlying sediments and in flushing of underlying aquifers as bottom melting of the glaciers occurred in recharge areas of basin aquifers. Pressure-induced upward migration of basin saline waters into near-surface strata caused the saline waters to mix with glacial meltwater and meteoric water followed by dissolution of the limestone. Such dissolution would result in the development of horizontal caves and cave systems and vertical phreatic conduits. Panno and Bourcier noted that after cave formation, lowering of the water table and exposure of the caves to erosion results in further dissolution by vadose mechanisms.

0.0	40.65+	Leave Stop 10 and CONTINUE AHEAD (south).
0.8	41.45+	The drainage lines you see on the east and west sides of the road drain northward into the deeper part of that large sinkhole or doline, which we crossed just before turning south on this road. In other words, the doline has captured the drainage in this local area.
0.4+	41.9+	ON THE RIGHT: water tower on top of the hill.
0.05+	42.0	TURN AROUND at culvert crossing of ditch on east side of road and head north. *PARK along and off the roadway as far as you safely can. CAUTION: parking* is safest along the east side of the road because of limited visibility and frequent heavy truck traffic!

STOP 11 Study and collect from the Chesterian (upper Mississippian) Downeys Bluff Limestone (near SE corner NE SE SW Section 26, T12S, R7E, 3rd P.M., Hardin County; Shetlerville 7.5-Minute Quadrangle [37088D4]).

The Downeys Bluff, 25 to 40 feet thick, consists of gray and brownish gray, fine to coarse grained fossiliferous limestone, locally *oölitic*, occurring in thin to medium beds, some of which are noticeably crossbedded (Baxter et al. 1967). Light gray shale interbeds are present, as is some pink or gray *chert*, especially in the upper part. Its basal contact is transitional and marked with an increase in the amount of shale with the underlying Yankeetown Shale. The limestone is unconformably overlain by the Bethel Sandstone.

End of Golconda Field Trip.

Have a safe journey home.

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GLOSSARY

The following definitions are from several sources, in total or in part, but the main reference is *Glossary of Geology* (third edition) by Robert L. Bates and Julie A. Jackson (American Geological Institute 1987).

Accretion — The process by which an inorganic body increases in size by the external addition of fresh particles, as by adhesion.

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

Alluviated valley — A valley 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 material deposited during comparatively recent time by a stream or other body of running water as a sorted or semisorted sediment in the bed of a stream or on its floodplain or delta, etc.

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

Aquifer — A water-bearing geologic unit that will yield a usable quantity of water to a well or spring.

Arenite — (1) Consolidated sedimentary rocks composed of sand-sized fragments regardless of composition; (2) a nearly pure sandstone containing less than 10% argillaceous matrix; (3) a selectively and slowly deposited sediment well-washed by currents.

Argillaceous — largely composed of clay-sized particles or clay minerals.

Argillic — of or relating to clay minerals.

Base level — The lowest limit of subaerial erosion by running water. It is controlled locally and temporarily by the water level where streams enter lakes or, more generally and semipermanently, where they enter the ocean (mean sea level).

Basement complex — Largely crystalline igneous and/or metamorphic rocks, often having a complex structure and distribution, that underlie a sedimentary sequence.

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

Bedded — Formed, arranged, or deposited in layers or beds, or made up of or occurring in the form of beds.

Bedding — The arrangement of a sedimentary rock in beds or layers of varying thickness and character.

Bedding plane — A planar or nearly planar surface, either between beds or within a bed, that visibly separates successive layers of stratified rock (of the same or different lithology) from preceding or following layers; a plane of deposition. It is often characterized by a preferred plane of breakage and may mark changes in the circumstances of deposition.

Bedrock — The solid rock that underlies the unconsolidated (non-indurated) surface materials, such as soil, alluvium, glacial drift or loess.

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.

Bioturbation — the churning and stirring of a sediment by organisms.

Brackish — Water that is noticeably salty, but less salty than sea water.

Braided stream — A stream that flows through an intricate network of interlacing shallow channels that repeatedly merge and then divide again separated from each other by branch islands or channel bars. Such a stream is generally believed to indicate an inability to carry all of its load. Braiding commonly develops in streams subject to large fluctuations in flow volume.

Breccia — A clastic rock composed of coarse, angular rock fragments.

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

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

Calcite — A common rock-forming mineral with the chemical composition $CaCO_3$ (calcium carbonate). It is usually white, colorless, or pale shades of gray, yellow, and blue; has perfect rhombohedral cleavage; a vitreous luster, and a Moh's hardness of 3. Calcite effervesces (fizzes) readily in cold dilute hydrochloric acid. It is the principal constituent of limestone.

Carbonization — The process of concentrating residual carbon through the slow decay and fossilization of an organism or through the progressive changes that occur in the formation of coal.

Chalcedony — A “cryptocrystalline ” variety of the mineral quartz (silicon dioxide; SiO_2). It commonly consists of a mass of submicroscopic crystallites that appear fibrous under a microscope. Chalcedony may be translucent or semitransparent, has a nearly wax-like luster, a uniform tint, and may be white, pale-blue, gray, brown, or black in color. It has no defined habit and commonly occurs in lumpy nodules (cf. chert; geodes).

Chert — A compact, massive rock composed of minute particles of quartz and/or chalcedony (silicon dioxide; SiO_2). It often occurs as irregular nodules and thin layers in limestone and dolomite. Flint is the name applied to chert that is dark in color.

Clastic — (adj.) Composed of detritus derived from broken fragments of preexisting rocks, including fragments of the hard parts of organisms.

Closure — In a fold, dome or other structural trap, the vertical distance between the structure's highest elevation and the lowest contour that encloses itself; used in estimating petroleum reserves.

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

Conchoidal — (adj.) A fracture surface showing concentric rings or ridges in a shell-like or fan-shaped plan. The conchoidal fracture of flint and chert is the property exploited in making sharp stone tools.

Concretion — A localized accumulation of mineral matter in a spheroidal to irregular nodular mass.

Conglomerate — Lithified gravel; rounded pebbles cemented together.

Cryptocrystalline — (adj.) Exceedingly finely crystalline in texture and appearance with grains essentially indistinguishable even under an ordinary microscope.

Cuesta — An asymmetric hill or ridge with a long, gentle (back or dip) slope, conforming with the resistant bed(s) that form it, on one side and a steep (scarp) slope or cliff on the other, formed by the outcrop of the resistant bed(s).

Delta — A low, nearly flat, alluvial land deposited at or near the mouth of a river where it enters a body of standing water; commonly a triangular or fan-shaped plain sometimes extending beyond the general trend of the coastline. Named for its resemblance to the Greek letter (delta).

Desiccation crack — A crack in sediment produced by drying (e.g., a mud crack).

Detritus — Loose rock or mineral grains produced from older rocks by mechanical disintegration and abrasion.

Diamictite — A comprehensive, nongenetic term for a nonsorted or poorly sorted, noncalcareous, terrigenous sedimentary rock that contains a wide range of particle sizes, such as a rock consisting of sand-size and/or larger particles in a muddy matrix; e.g. a tillite or a pebbly mudstone.

Diamicton — A general term for the nonlithified equivalent of a diamictite; e.g. a till. A till is a diamicton formed by the action of a glacier. The term *till* has a genetic connotation; diamicton does not, it is purely descriptive.

Diastrophism — A general term for all movement of the crust produced by Earth's forces.

Dike — A tabular, intrusive body of igneous rock that cuts across the structure of stratified, metamorphosed, or igneous rocks.

Dip slope — An inclined land surface that is parallel to the dip of the underlying stratified rocks.

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

Distributary — An irregular, divergent stream flowing away from the main stream and not returning to it, as in a delta.

Doline — A closed depression in an area of karst topography that is formed either by solution of the surficial limestone or by collapse of underlying caves. Its form generally is basin-like or funnel-shaped and measured in meters.

Dolomite — A mineral, calcium-magnesium carbonate [$Ca,Mg(CO_3)_2$]. It is white, colorless, or tinged yellow, brown, pink, or gray; has perfect rhombohedral cleavage; appears pearly to vitreous; effervesces feebly in cold dilute hydrochloric acid. The term is also commonly applied to those sedimentary rocks that are composed largely (more than 50%) of the mineral dolomite.

Dolostone — A rock consisting mostly (more than 50%) of the mineral dolomite. This word is sometimes used when there is a possibility of confusion in using the term *dolomite* for both the rock and the mineral.

Dome — A roughly symmetrical upfold (anticline) in which strata are inclined in all directions away from a central point.

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 during the Pleistocene.

Earthquake — A sudden motion or trembling in the Earth caused by the abrupt release of slowly accumulated potential energy (like that in a compressed spring) through the breaking of a rock body to form a fault, or slippage along a preexisting fault plane in the rock body.

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

Englacial — (adj.) Within a glacier.

Eon — The largest division of geologic time; consists of two or more eras.

Epeirogeny — A form of diastrophism which has produce the larger features of the continents and oceans. These movements are primarily vertical and have affected large parts of the continents where they have produced most of the present mountainous topography. Some epeirogenic orogenic structures grade into each other in detail, but most of them contrast strongly.

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

Era — A unit of geologic time that is next in magnitude beneath an eon; consists of two or more periods (e.g. Paleozoic, Mesozoic, Cenozoic).

Esker — Ridges, usually sinuous, of stratified (layered) drift (sand and gravel) in areas of ground moraine. They are deposited by, and mark the channels of, meltwater streams which flowed in, on, or under a glacier.

Estuary — The seaward end or the widened funnel-shaped tidal mouth of a river valley where it meets the sea. The part of a river where freshwater and seawater mix and where the effects of ocean tides are evident.

Facies — (1) The sum of all lithologic and paleontologic characteristics exhibited by a sedimentary rock; (2) an exclusive, mappable, and areally restricted part of a defined stratigraphic rock body; (3) a term applied to intertonguing sedimentary rock masses of differing lithologic and paleontologic characteristics, occurring within a stratigraphic unit, having irregular boundaries. The term is often used by geologists in a general sense to refer to all rocks having a common set of lithologic characteristics, or to rocks formed in a particular environment and, therefore, having a set of characteristics in common.

Fault — A fracture surface or zone in Earth materials along which there has been vertical and/or horizontal displacement or movement of the strata on both sides relative to one another. The amount of displacement may be as little as a few centimeters to as much as many kilometers.

Feldspar — Any of several abundant rock-forming minerals of the general chemical composition alkali-metal alumino-silicate [$MAl(Al,Si)_3O_8$; where M = K, Na, Ca, Ba, Rb, Sr and Fe]. They have a hardness of 6 on Moh's scale. Their normal color is translucent white or near-white, but they are commonly colored by impurities. The potash feldspars are commonly flesh-colored to red. Feldspars are the most widespread of any mineral group; they constitute about 60% of the Earth's crust. They are the primary constituents of most igneous and metamorphic rocks and are present in many sedimentary rocks. There are two major types of feldspars, the alkali or potash feldspars (e.g. orthoclase and microcline) which have potassium and sodium as their main alkali metal cations, and the plagioclase feldspars (e.g. albite, andesine, labradorite) which have sodium and calcium as their main alkali metal cations. The word feldspar is from German and means *field crystal*.

Feldspathic — (adj.) Said of a rock containing an observable quantity of feldspar, but consisting mostly of other components. Rocks that normally consist mostly of feldspar generally are not described as "feldspathic."

Ferruginous — (adj.) Pertaining to or containing iron, e.g. a sandstone that is cemented with iron oxide.

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

Fluvial — (adj.) Of or pertaining to a river or rivers.

Fluviolacustrine — (adj.) Pertains to sedimentation partly in lake water and partly in streams, or to sediments deposited under alternating or overlapping lacustrine and fluvial conditions.

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

Geology — (a) The science of the earth; it includes, in a large sense, all acquired or possible knowledge of the natural phenomena on and within the globe. (b) Earth science including physical geology and geophysics; the history of the earth, stratigraphy and paleontology; mineralogy; petrology; and engineering, mining, and petroleum geology.

Geomorphology — A branch of both physiography and geology that deals with the form of the earth, the general configuration of its surface, and the changes that take place in the evolution of land forms.

Geophysics — The study of the Earth as a planet, generally by employing quantitative measurements of phenomena such as the Earth's electrical, magnetic and gravity fields or the movement of energy through the rocks.

Glacier — A large, slow-moving mass of ice grounded, at least in part, on land. The Arctic ice cap of the Earth is NOT a glacier because, for the most part, it is floating on the ocean surface. The Antarctic ice cap IS a glacier

Graben — A block that has moved down along bounding faults relative to the rocks on either side.

Gradient — A measurement of the degree of inclination or rate of ascent or descent of an inclined part of the Earth's surface with respect to the horizontal; commonly expressed as a ratio (ft/mi; m/km). Also, the part of a surface feature of the Earth that slopes upward or downward; a slope, as of a stream channel or of a land surface. In engineering, the synonymous term is *grade*.

Ground moraine — A sheet-like accumulation of glacial drift, principally till, deposited beneath a glacier to form an extensive area of low relief devoid of transverse linear features.

Groundwater — Water that is present below the ground surface in the soil and rocks of Earth's outer crust. Geologists generally restrict the term to that part of the subsurface water that is within the zone where the rocks are saturated with water (i.e., below the water table). Also commonly spelled as *ground water.*

Group — A geologic rock unit consisting of two or more formations.

Gypsum — A mineral having the composition hydrous calcium sulfate {$CaSO_42H_2O$}; it is characteristically white or colorless when pure. The most common sulfate mineral, it generally occurs in thick, extensive beds formed by the evaporation of large quantities of seawater.

Hematite — A common iron mineral having the composition ferrous oxide {Fe_2O_3}. The principal ore for iron, the mineral occurs in steel-gray or iron-black rhombohedral crystals, in globular and fibrous masses and, most commonly, in deep red to red-brown earthy forms. It has a characteristic brick red color when powdered.

Hiatus — A gap in the sedimentary record, with or without accompanying removal of sediment by erosion (signifies an unconformity).

Ice cap — A dome-shaped or plate-like cover of perennial ice and snow, covering the summit area of a mountain mass so that no peaks emerge through it, or covering a flat landmass such as an Arctic island...and having an area less than 50,000 sq. km.; it is considerably smaller than an *ice sheet.*

Ice sheet — A glacier of considerable thickness and more than 50,000 sq. km. in area, forming a continuous cover of ice and snow over a land surface spreading outward in all directions and not confined by the underlying topography; a *continental glacier.*

Igneous — (adj.) Said of a rock or mineral that has solidified from molten or partly molten material, i.e., from magma.

Indurated — (adj.) Said of a compacted 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 significant relative movement of the rock masses on opposing sides of the crack.

Kame — A hill, mound, knob or hummock formed of poorly sorted and stratified sand and/or gravel deposited against the terminal margin of a melting glacier by a subglacial or englacial melt water stream.

Karst — A type of topography formed in areas underlain by limestone, dolomite or gypsum. Karst topography is characterized by sinkholes separated by steep ridges or irregular hills. Tunnels and caves resulting from solution by groundwater honeycomb the subsurface. Named for the Karst region of the Dinaric alps in Yugoslavia where the topography is especially well developed. (Adj.) karstic.

Karstification —The formation of the features of a karstic topography by solutional, and sometimes mechanical, action of water in a region of limestone, dolomite, or gypsum bedrock.

Lacustrine — (adj.) Produced by or belonging to a lake.

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

Lava — A general term for molten material extruded onto the Earth's surface from a volcano; also, applies to the rock that solidified from the extruded material.

Limestone — A sedimentary rock consisting primarily (more than 50%) of calcium carbonate $CaCO_3$ (the mineral, calcite). Most limestones were deposited in the ocean and consist primarily of fragments of the hard parts of living organisms.

Litharenite — A sandstone, regardless of texture, containing more than 25% fine grained rock fragments, less than 10% of the feldspar minerals, and less than 75% quartz, quartzite, and chert.

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

Lithology — The description of a rock on the basis of its color, particle size, mineral composition, bedding and other directly observable characteristics; 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 within a limited area.

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

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

Marble — Metamorphosed limestone or dolostone generally with a more or less coarse grained crystalline texture.

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 its channel swings from side to side across its valley bottom.

Meander scars — Crescent-shaped, concave marks along a river's floodplain that mark the positions of abandoned meanders. Although generally filled in with sediments and vegetation, they are generally low swales and may contain water during wet seasons. Often invisible from the ground, they make striking patterns when viewed from the air, and may also be readily apparent on topographic maps.

Metamorphic rock — Any rock derived from pre-existing rocks through mineralogical 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 (e.g. gneiss, schist, slate, marble, quartzite, etc.).

Metamorphism — The processes by which metamorphic rocks are formed and the changes in a preexisting rock induced by those processes. In general, metamorphism does not alter the chemical composition of the preexisiting rock. The processes only rearrange the preexisting chemical elements in the rock from one set of minerals to a new set of minerals more closely in equilibrium with the new temperature and pressure conditions imposed on the rock.

Mica — Any of the members of a group of minerals known as phyllosilicates (having sheet-like structures) that can be easily split apart into thin, tough, slightly bendable sheets. The micas are common minerals in igneous and metamorphic rocks and can range in color from colorless through yellow, green, brown or black. The most common members of the family are muscovite (colorless to pale yellow) and biotite (dark brown to black).

Micaceous — (adj.) Said of an Earth material containing an observable amount of mica.

Monocline — Strata inclined in a single direction, such as a step-like fold or downwarp.

Moraine — A mound, ridge, or other distinct accumulation of glacial drift, predominantly till, deposited chiefly by the direct action of glacial ice in a variety of topographic landforms whose position and shape are not affected by the topography of the former land surface on which the drift lies.

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

Neap tide — A tide having an unusually small or reduced tide range (usually 10-30% less than the mean range). Such tides occur when the Moon and Sun are at right angles to each other with respect to the Earth (quadrature).

Nonconformity — An unconformity resulting from the deposition of sedimentary strata on top of older crystalline rocks that have been exposed to weathering and erosion. The general term *unconformity* is currently used more commonly.

Normal fault — A fault in which the hanging wall (the rock mass above the fault plane) has moved downward relative to the foot wall (the rock mass below the fault plane).

Oolith — A small round or ovate accretionary body in a sedimentary rock, resembling fish eggs, and having diameters of 0.25 to 2 mm. It is usually composed of calcium carbonate and occurs in successive concentric layers, commonly around a nucleus such as a shell fragment.

Oolitic — Pertaining to an oolite (a rock or mineral made up of ooliths).

Orogeny — Literally, the process of mountain formation. By present geological usage it is the process by which structures within mountain areas were formed, including thrusting, folding, and faulting in the upper and higher layer of the Earth's crust, and plastic folding, metamorphism, and plutonism in the inner and deeper layers.

Outwash — Stratified detritus (gravel, sand, silt and clay) that was "washed out" from a glacier by meltwater streams and deposited in channels, deltas, outwash plains, floodplains, and lakes in front of (beyond) the terminal moraine or the margin of an active glacier.

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

Overburden — Barren rock material, either loose or consolidated, overlying a mineral deposit, which must be removed prior to mining.

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

Paleosol — A buried soil horizon of the geologic past. When uncovered, it is said to be exhumed. (Syn.: buried soil; fossil soil).

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

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

Period — An interval of geologic time; a division of an era (e.g. Cambrian, Jurassic, Tertiary).

Phreatic water — A term applied to all water in the zone of saturation.

Plutonic — Pertaining to igneous rocks formed at great depth.

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.

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.

Polycheate worms — A class of annelid (segmented) marine worms common to seacoasts where some live in U-shaped tubes in beach sands; its chitinous jaws may be preserved in many systems of rocks from ?Precambrian to Recent.

Proglacial — (adj.) In front of a glacier.

Prograding (shoreline) — A shoreline that is being built forward or outward into a sea or lake by deposition and accumulation of sediments.

Quartz — An important rock-forming mineral having the chemical composition silicon dioxide (SiO_2). It is second only to feldspar in abundance in the Earth's crust. It occurs in either colorless and transparent hexagonal crystals (sometimes colored pink, yellow, brown, purple, red, green, blue, or black by impurities) or in crystalline or cryptocrystalline masses; it forms the major portion of most sands, and is widely distributed in igneous, metamorphic, and sedimentary rocks. It appears vitreous to greasy, has a conchoidal fracture, no cleavage, and a hardness of 7 on Moh's scale (scratches glass easily, but cannot be scratched by a knife).

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

Residuum — An accumulation of relatively insoluble materials and weathering products remaining essentially in place after the more soluble materials have been removed.

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

Sedimentary rock — A rock resulting from the compaction, consolidation and cementation of loose sediment. The term also includes evaporites, rocks such as gypsum or rock salt formed by the evaporation of sea water.

Series — A geologic time–rock unit; the strata deposited during an epoch; a division of a system (e.g. the Chesterian Series and the Valmeyeran Series of the Mississippian System).

Sill — A tabular, intrusive body of igneous rock that conforms with the structure of the stratified sedimentary, metamorphic, or igneous rocks into which it is intruded.

Sinkhole — A circular depression formed by solution in areas underlain by soluble rocks, most commonly limestone and dolomite. Sinkholes are characteristic in areas of karst topography. They are also called *dolines*, especially outside North America.

Sluiceway — An overflow channel.

Spring tide — (a) A tide of greater-than-average range that occurs twice each month, during new and full moons, when the moon and sun are approximately in line with each other and with the Earth; (b) a strong or heavy flow.

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

Stratigraphy — (a) The branch of geology that deals with the study, definition, and description of major and minor natural divisions of rocks, especially the study of the form, arrangement, geographic distribution, chronologic succession, classification, correlation, and mutual relationships of rock strata. (b) The description of the characteristics of the stratified rocks of a region and their interrelationships and arrangement in geologic time and space within that region; sometimes called *stratigraphic geology*.

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

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

Stylolite — A surface or contact, usually occurring in otherwise homogeneous carbonate rocks, that is marked by an irregular and interlocking penetration of the two sides: the columns, pits, and teeth-like projections on one side fit into their counterparts on the other. The seam is characterized by a concentration of the dark-colored, insoluble constituents of the rock and, as usually seen in cross section, it resembles a suture, or the tracing of a stylus, approximately parallel to the bedding.

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

Sublitharenite — A sandstone that does not have enough rock fragments to be classed as a litharenite; (5-25% fine grained rock fragments, 65-95% quartz, quartzite, and chert, and less than 10% feldspar).

Surficial — Pertaining to, situated at, or formed or occurring on a surface especially the surface of the Earth.

Syncline — A concave upward rock fold in which the rocks are bowed down and dip inward from both sides toward the axis. The core contains younger rocks than does the perimeter of the structure; the opposite of an anticline.

System — The largest and fundamental geologic time-rock unit; the strata of a system were deposited during a *period* of geologic time (e.g. the Cambrian System includes all the rocks deposited during the Cambrian Period).

Tectonic — (adj.) Pertaining to the global forces involved in mountain-building, the movement of crustal plates and the deformation or movement of other large-scale features, or the structures or features resulting from Earth's movements.

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

Terrigenous deposits — Shallow marine sediments consisting of material eroded from the land surface.

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

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

Topography — (1) The general configuration of the land surface. (2) The natural or physical surface features of a region, considered collectively as to form; the features revealed by the contour lines of a map.

Type section — The original sequence of strata as described for a given locality or area. It serves as an objective standard with which spatially separated outcrops of a stratigraphic unit can be compared for purposes of recognition. Type sections preferably show the maximum thickness of a stratigraphic unit and are completely exposed, or at least show the top and bottom contacts of a unit; there is only one type section for any stratigraphic unit, but additional *reference sections* may be described.

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

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

Vadose water — Water in the aeration zone.

PLEISTOCENE GLACIATIONS IN ILLINOIS

Origin of the Glaciers

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

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

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

Effects of Glaciation

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

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

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

Glacial Deposits

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

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

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

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

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

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

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

Loess, Eolian Sand and Soils

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

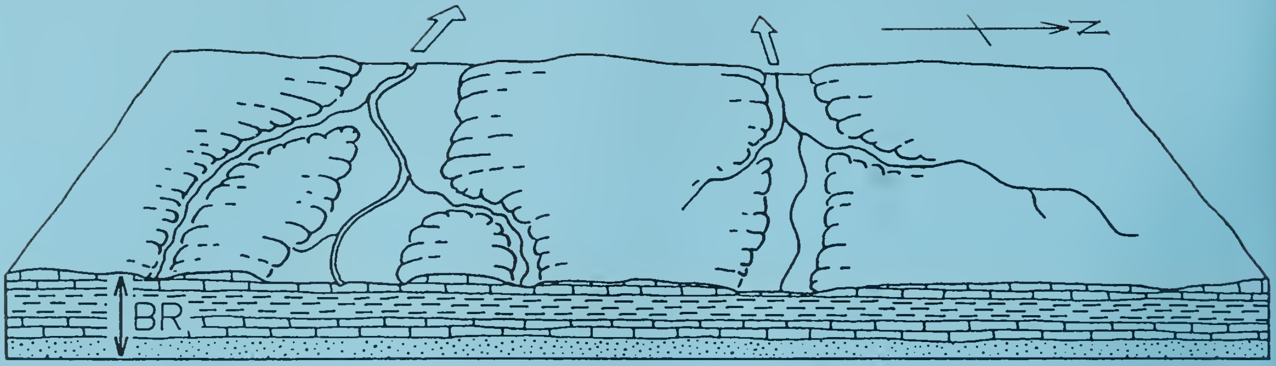
Eolian deposition occurred when certain climatic conditions were met, probably in a seasonal pattern. Deposition could have occurred in the fall, winter or spring season when low precipitation rates and low temperatures caused meltwater floods to abate, exposing the surfaces of the valley trains and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

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

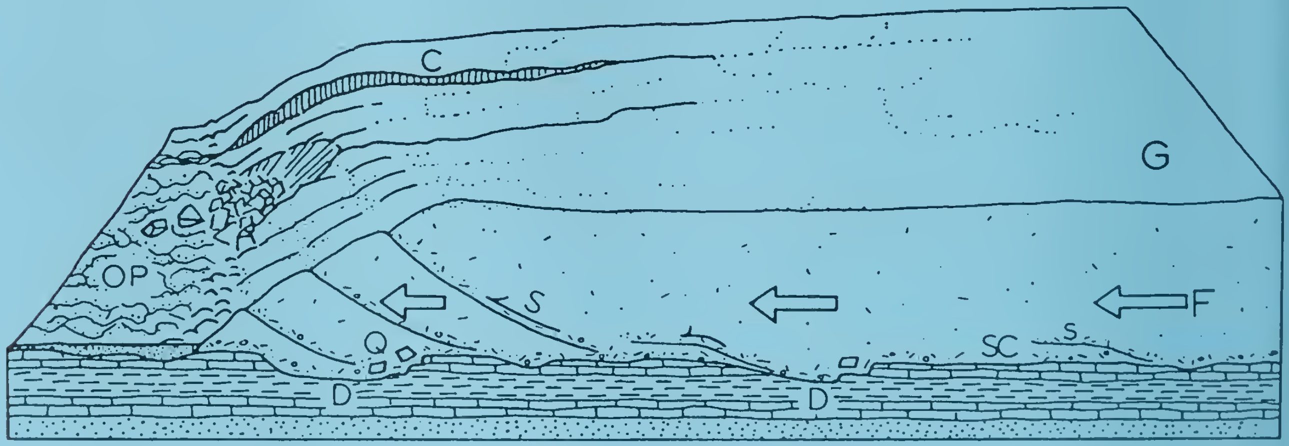
Glaciation in a Small Illinois Region

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

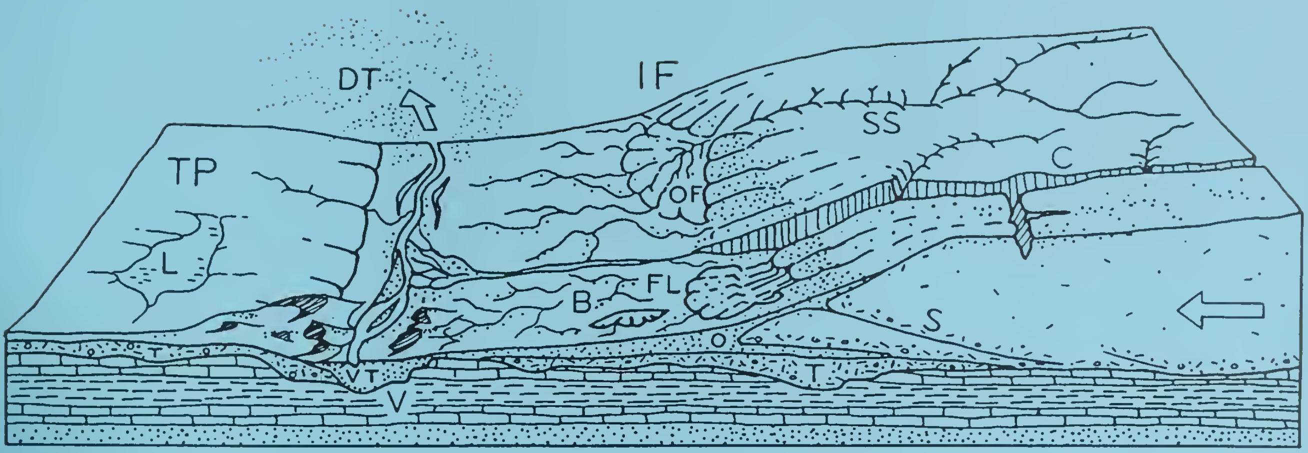
The block of land in the diagrams is several miles wide and about 10 miles long. The vertical scale is exaggerated—layers of material are drawn thicker and landforms higher than they ought to be so that they can be easily seen.



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



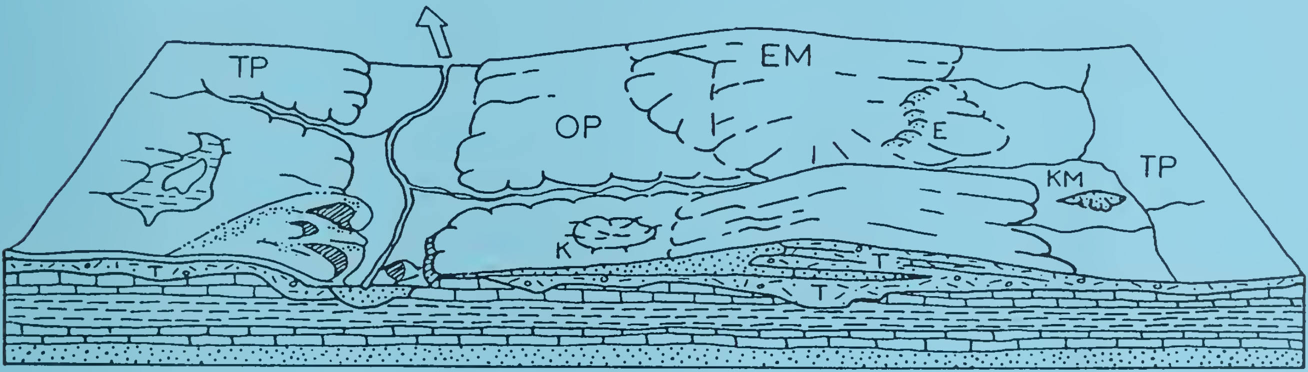
2. **The Glacier Advances Southward** — As the Glacier (G) spreads out from its ice snowfield accumulation center, it scours (SC) the soil and rock surface and quarries (Q)—pushes and plucks up—chunks of bedrock. The materials are mixed into the ice and make up the glacier's "load." Where roughnesses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



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

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

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



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

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

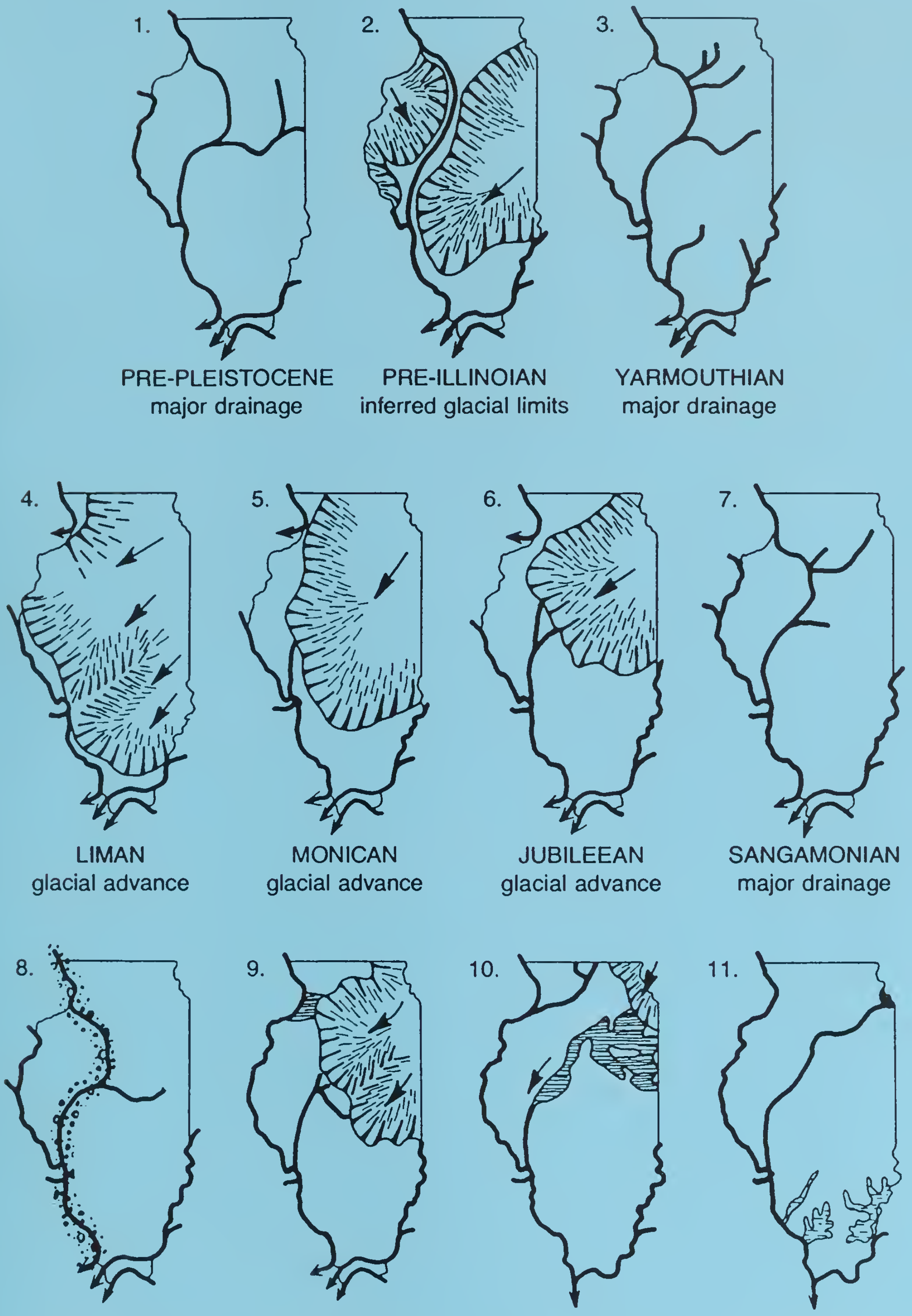
TIME TABLE OF PLEISTOCENE GLACIATION

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

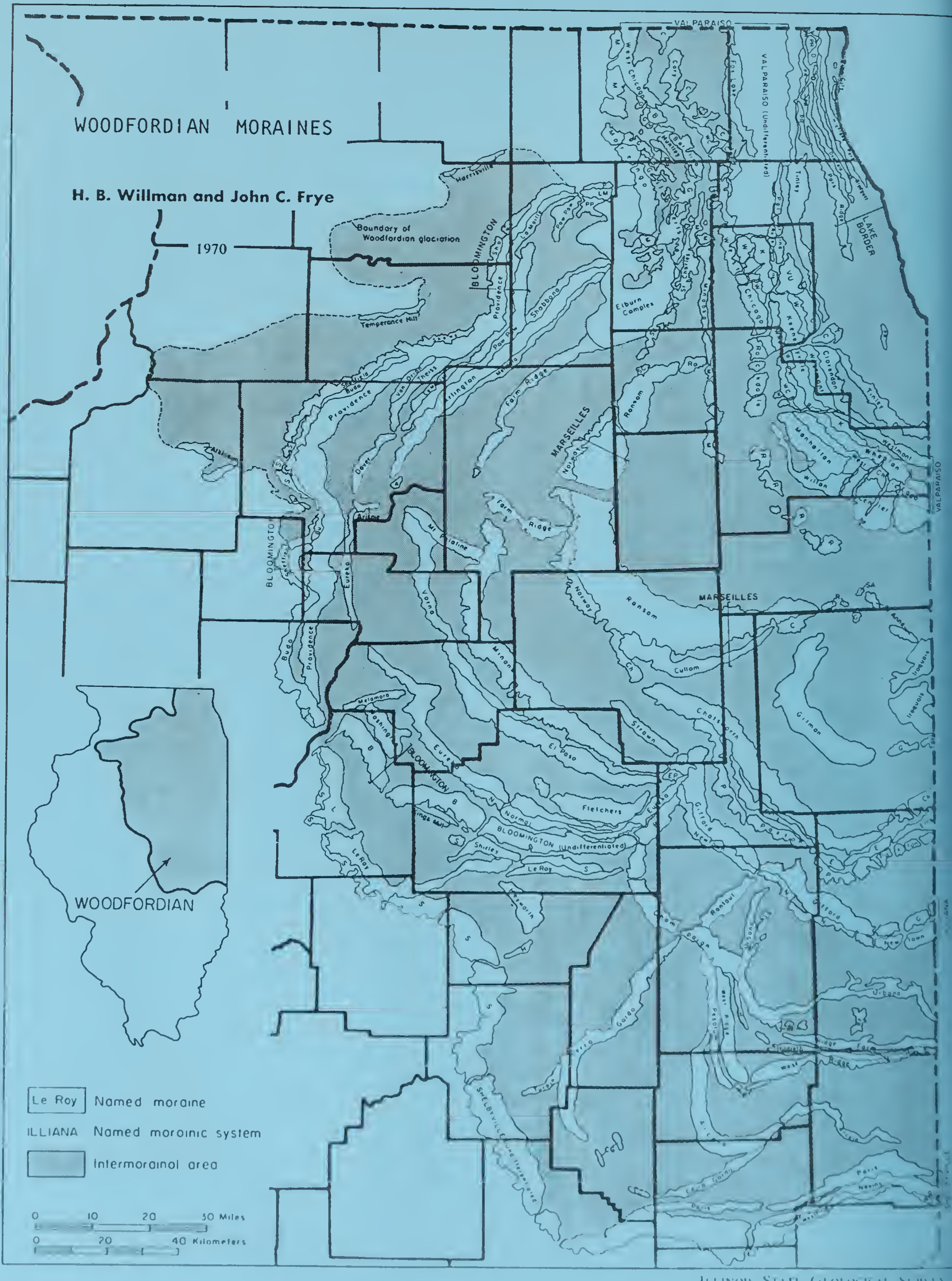
*Old oversimplified concepts, now known to represent a series of glacial cycles.

(Illinois State Geological Survey, 1973

SEQUENCE OF GLACIATIONS AND INTERGLACIAL DRAINAGE IN ILLINOIS


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

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

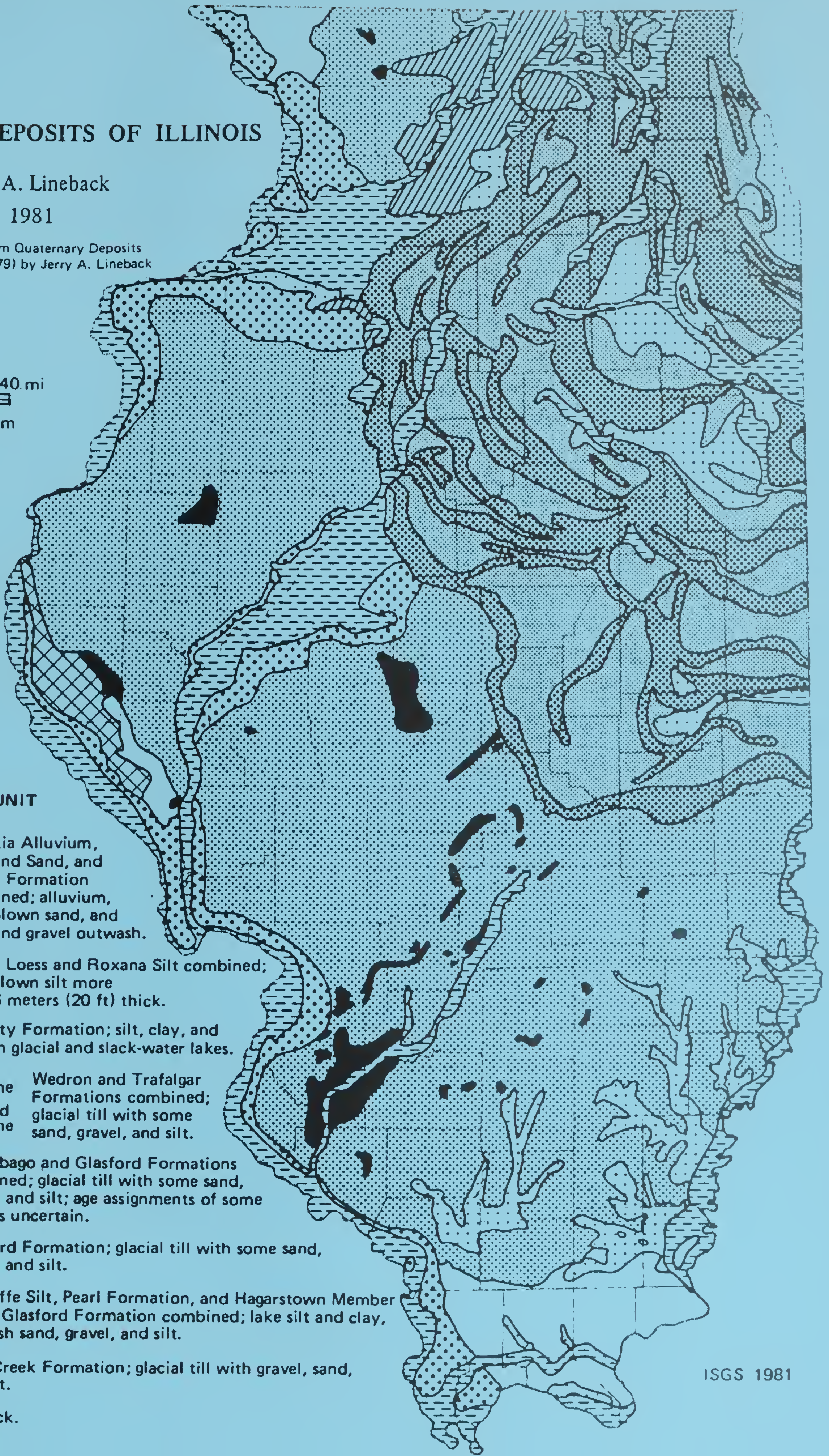

WOODFORDIAN MORAINES
H. B. Willman and John C. Frye
1970
Boundary of Woodfordian glaciation
Harrisville
Temperance Hill
BLOOMINGTON
Providence
Paw Paw
Shabbona
Farm Ridge
MARSEILLES
Norway
Ransom
Elburn Complex
VALPARAISO
VALPARAISO (Undifferentiated)
West Chicago
Fox Lake
Tinley
Park Ridge
LAKE BORDER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

QUATERNARY DEPOSITS OF ILLINOIS

Jerry A. Lineback

1981

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



AGE		UNIT
Holocene and Visconsinan	▤	Cahokia Alluvium, Parkland Sand, and Henry Formation combined; alluvium, windblown sand, and sand and gravel outwash.
Visconsinan	⁙	Peoria Loess and Roxana Silt combined; windblown silt more than 6 meters (20 ft) thick.
	∴	Equality Formation; silt, clay, and sand in glacial and slack-water lakes.
	▩	Moraine — Wedron and Trafalgar Formations combined; glacial till with some sand, gravel, and silt.
	▒	Ground moraine — Wedron and Trafalgar Formations combined; glacial till with some sand, gravel, and silt.
Visconsinan and Illinoian	▨	Winnebago and Glasford Formations combined; glacial till with some sand, gravel, and silt; age assignments of some units is uncertain.
Illinoian	░	Glasford Formation; glacial till with some sand, gravel, and silt.
	■	Teneriffe Silt, Pearl Formation, and Hagarstown Member of the Glasford Formation combined; lake silt and clay, outwash sand, gravel, and silt.
re-Illinoian	▦	Wolf Creek Formation; glacial till with gravel, sand, and silt.
	☐	Bedrock.

MISSISSIPPIAN DEPOSITION

(The following quotation is from Report of Investigations 216: Classification of Genevievian and Chesterian...Rocks of Illinois [1965] by D. H. Swann, pp. 11-16. One figure and short sections of the text are omitted.)

During the Mississippian Period, the Illinois Basin was a slowly subsiding region with a vague north-south structural axis. It was flanked by structurally neutral regions to the east and west, corresponding to the present Cincinnati and Ozark Arches. These neighboring elements contributed insignificant amounts of sediment to the basin. Instead, the basin was filled by locally precipitated carbonate and by mud and sand eroded from highland areas far to the northeast in the eastern part of the Canadian Shield and perhaps the northeastward extension of the Appalachians. This sediment was brought to the Illinois region by a major river system, which it will be convenient to call the Michigan River (fig. 4) because it crossed the present state of Michigan from north to south or northeast to southwest....

The Michigan River delivered much sediment to the Illinois region during early Mississippian time. However, an advance of the sea midway in the Mississippian Period prevented sand and mud from reaching the area during deposition of the St. Louis Limestone. Genevievian time began with the lowering of sea level and the alternating deposition of shallow-water carbonate and clastic units in a pattern that persisted throughout the rest of the Mississippian. About a fourth of the fill of the basin during the late Mississippian was carbonate, another fourth was sand, and the remainder was mud carried down by the Michigan River.

Thickness, facies, and crossbedding...indicate the existence of a regional slope to the southwest, perpendicular to the prevailing north 65° west trend of the shorelines. The Illinois Basin, although developing structurally during this time, was not an embayment of the interior sea. Indeed, the mouth of the Michigan River generally extended out into the sea as a bird-foot delta, and the shoreline across the basin area may have been convex more often than concave.

....The shoreline was not static. Its position oscillated through a range of perhaps 600 to 1000 or more miles. At times it was so far south that land conditions existed throughout the present area of the Illinois Basin. At other times it was so far north that there is no suggestion of near-shore environment in the sediments still preserved. This migration of the shoreline and of the accompanying sedimentation belts determined the composition and position of Genevievian and Chesterian rock bodies.

Lateral shifts in the course of the Michigan River also influenced the placement of the rock bodies. At times the river brought its load of sediment to the eastern edge of the basin, at times to the center, and at times to the western edge. This lateral shifting occurred within a range of about 200 miles. The Cincinnati and Ozark areas did not themselves provide sediments, but, rather, the Michigan River tended to avoid those relatively positive areas in favor of the down-warped basin axis.

Sedimentation belts during this time were not symmetrical with respect to the mouth of the Michigan River. They were distorted by the position of the river relative to the Ozark and Cincinnati shoal areas, but of greater importance was sea current or drift to the northwest. This carried off most of the mud contributed by the river, narrowing the shale belt east of the river mouth and broadening it west of the mouth. Facies and isopach maps of individual units show several times as much shale west of the locus of sand deposition as east of it. The facies maps of the entire Chesterian...show maximum sandstone deposition in a northeast-southwest belt that bisects the basin. The total thickness of limestone is greatest along the southern border of the basin and is relatively constant along that entire border. The proportion of limestone, however, is much higher at the eastern end than along the rest of the southern border, because little mud was carried southeastward against the prevailing sea current. Instead, the mud was carried to the northwest and the highest proportion of shale is found in the northwestern part of the basin.

Genevievian and Chesterian seas generally extended from the Illinois Basin eastward across the Cincinnati Shoal area and the Appalachian Basin. Little terrigeneous sediment reached the Cincinnati Shoal area from either the west or the east, and the section consists of thin limestone units representing all or most of the major cycles. The proportion of inorganically precipitated limestone is relatively high and the waters over the shoal area were commonly hypersaline... Erosion of the shoal area at times is indicated by the presence of conodonts eroded from the St. Louis Limestone and redeposited in the lower part of the Gasper Limestone at the southeast corner of the Illinois Basin...

The shoal area included regions somewhat east of the present Cincinnati axis and extended from Ohio, and probably southeastern Indiana, through central and east-central Kentucky and Tennessee into Alabama....

Toward the west, the seaway was commonly continuous between the Illinois Basin and central Iowa, although only the record of Genevievian and earliest Chesterian is still preserved. The seas generally extended from the Illinois and Black Warrior regions into the Arkansas Valley region, and the presence of Chesterian outliers high in the Ozarks indicates that at times the Ozark area was covered. Although the sea was continuous into the Ouachita region, detailed correlation of the Illinois sediments with the geosynclinal deposits of this area is difficult.

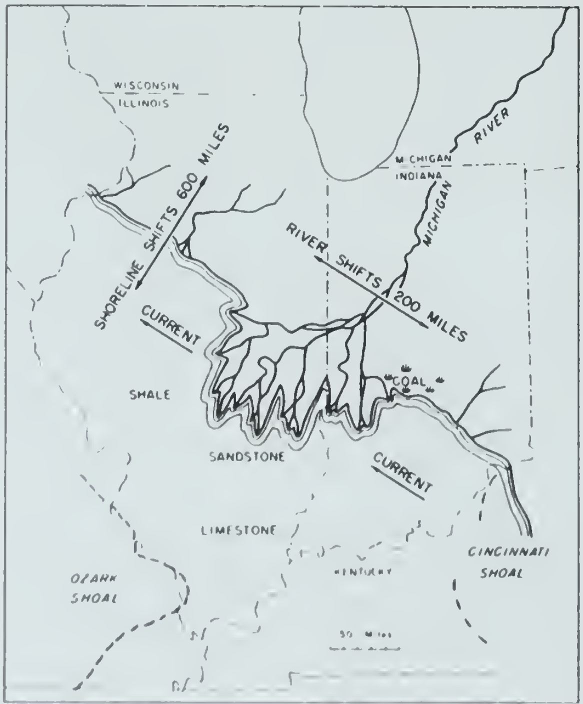


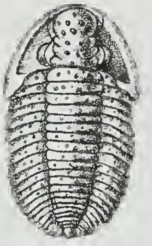
Figure 4: Paleogeography at an intermediate stage during Chesterian sedimentation.

BRYOZOANS


Rhambopora 1x


Archimedes 1x

TRILOBITE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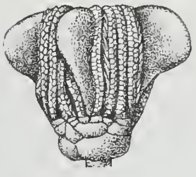
CRINOIDS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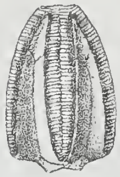
Platycrinus 1x

BLASTOIDS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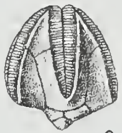
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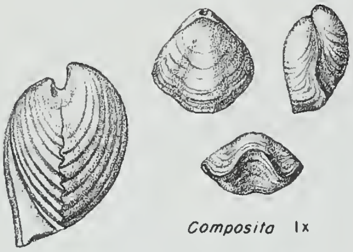
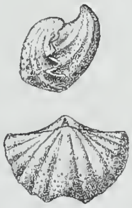
BRACHIOPODS

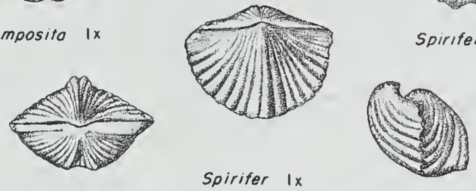

Composita 1x


Leptaena 1x


Spiriferina 1x

CORALS


Triplophyllites 1x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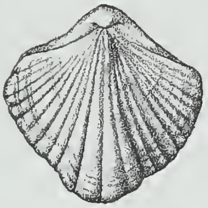
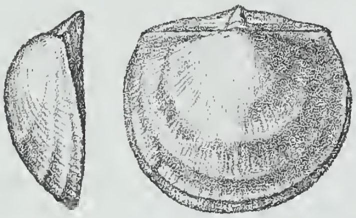
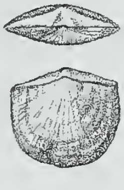

Brachythyris 1x


Pugnaides 1x


Girtyella 1x


Caninia 2/3 x


Orthotetes 1x


Schuchertella 1x


Echinaconchus 1x

ILLINOIS STATE GEOLOGICAL SURVEY
Urbana, Illinois 61801

GEOGRAM 5
October 1975

ANCIENT DUST STORMS IN ILLINOIS

Myrna M. Killey

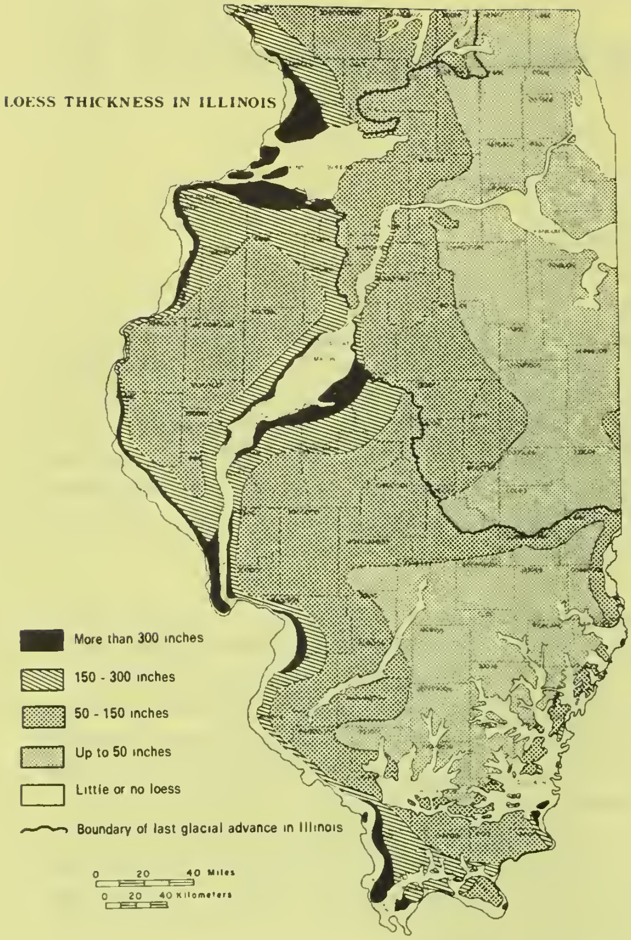
Fierce dust storms whirled across Illinois long before human beings were here to record them. Where did all the dust come from? Geologists have carefully put together clues from the earth itself to get the story. As the glaciers of the Great Ice Age scraped and scoured their way southward across the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

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

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

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

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



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

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

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

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

ILLINOIS STATE GEOLOGICAL SURVEY
Urbana, Illinois 61801

GEOGRAM 6
October 1975

DO YOU LIVE ABOVE AN UNDERGROUND RIVER?

Myrna M. Killey

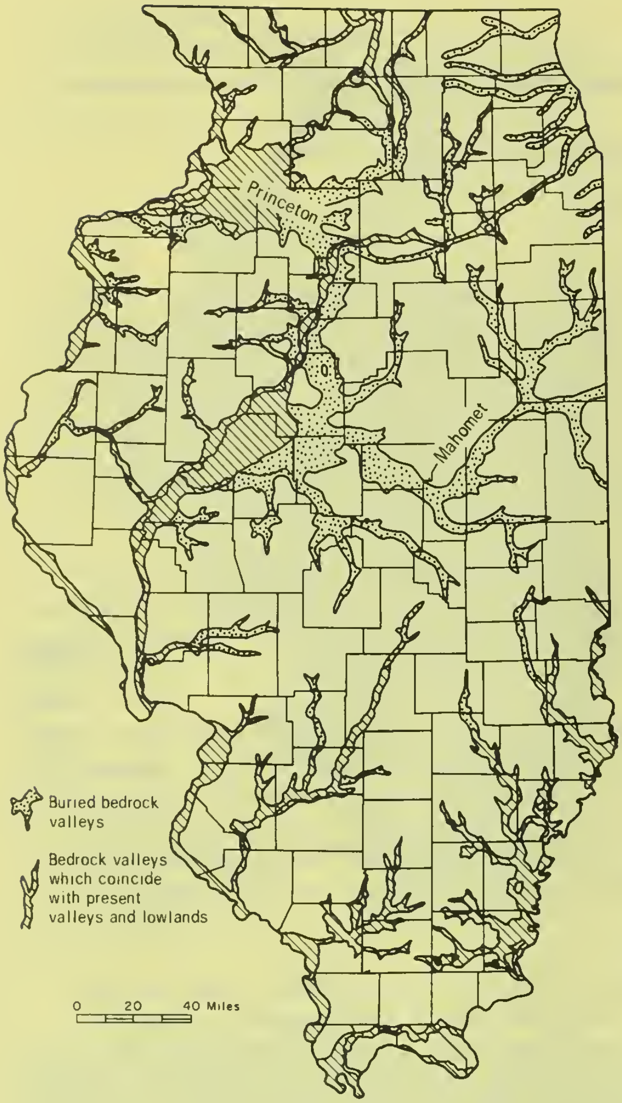
Do you think of an underground river as a hidden stream rushing through a tunnel in solid rock? Such subterranean rivers do exist in some states—in Alabama and Missouri, for example. In Illinois, however, except in a few areas where water flows through cracks and channels it has created by dissolving the limestone bedrock, underground "rivers" are not really rivers at all. The Mahomet "river" that underlies part of east-central Illinois is a good example. So is the eastern part of this "river," which is called the Teays (rhymes with "days"). Such rivers are vital to many towns, for they are a reliable source of water.

The Mahomet-Teays river system was discovered more than 25 years ago when numerous water wells were drilled in the eastern and midwestern United States. The story of this vast river system has been pieced together largely from information obtained from records made during the drilling of the wells.

More than a million years ago, before the glaciers of the Great Ice Age crept down over the Midwest, a river as large as the present Mississippi flowed generally westward from its probable source in the mountains of West Virginia, crossed Ohio and Indiana, and traversed east-central Illinois from Hoopeston to Havana. At Havana it joined another ancient river system that occupied what is now the Illinois River Valley (see map). All along its course it cut a deep valley in the bedrock.

When the successive glaciers invaded Illinois from Canada, the fringes of the ice melted during the warmer periods, and the water (meltwater) carried with it great quantities of sand and gravel that had been embedded in the ice. This material, called *outwash*, was deposited in thick layers in the Mahomet Valley. As the later glaciers advanced southward, both the valley and its outwash were buried by ice. When the ice finally melted, tremendous amounts of unsorted rock debris (pebbly, sandy clay called *till*) that had been held in the ice blanketed the land surface, including the former river valley, to depths of 50 to more than 100 feet. (The outwash and till deposits are collectively called *drift*.) The great Mahomet River Valley was obliterated from the landscape and the river no longer existed. Instead, on the new land surface the river patterns we know today developed.

The buried Mahomet Valley is invaluable to east-central Illinois because its porous sand and gravel deposits act as vast underground sponges, storing the rainwater that seeps downward from the land surface. Water flows easily through the sand and gravel into wells drilled in the porous materials. In contrast, glacial till is too fine-grained to allow the water it holds to flow easily and, therefore, cannot supply large amounts of water to wells. Towns such as Hoopeston, Champaign-Urbana, Mahomet, Monticello, and Clinton that are situated above the buried Mahomet Valley have large ground-water supplies available to them, but towns away from the valley have more difficulty obtaining their water. Perhaps the term "underground river" is still applied to the Mahomet Valley because it is easier to imagine great volumes of well water coming from a river than from beds of sand and gravel in a buried valley.



The Mahomet Valley has been traced for about 150 miles across Illinois, it lies at an average depth of more than 200 feet below land surface, and its bottom is at an average elevation of 350 feet above sea level. In some places the ancient valley varies in width from 5 miles at the Indiana line to almost 10 miles near Clinton in De Witt County.

Another major "underground river" is the Princeton Bedrock Valley in the north-central part of Illinois. Many smaller bedrock valleys in the state contain sand and gravel deposited by glacial meltwater. The Mississippi, Illinois, Kaskaskia, and Wabash Rivers also contain beds of outwash deposited by glacial meltwaters, but their courses were not obliterated by the glaciers, and their valleys have remained open as drainageways.

The water supplies in these deposits in the ancient river valleys of Illinois are one of many resources contributing to the state's natural wealth. Of the 3.3 billion gallons of water a day used by Illinois, about 450 million gallons are pumped from sand and gravel deposits, mainly of glacial origin. The value of ground water from these deposits is over $115 million per year.

Do you live above an underground "river"? Look at the map and see. Locate the source of the water you use in your town. If you should see a well being drilled, stop and ask if you can look at the earth materials brought up from the well. These are the kinds of material used to interpret the geologic history of Illinois.

DEPOSITIONAL HISTORY OF THE PENNSYLVANIAN ROCKS IN ILLINOIS

At the close of the Mississippian Period, about 310 million years ago, the sea withdrew from the Midcontinent region. A long interval of erosion that took place early in Pennsylvanian time removed hundreds of feet of the pre-Pennsylvanian strata, completely stripping them away and cutting into older rocks over large areas of the Midwest. Ancient river systems cut deep channels into the bedrock surface. Later, but still during early Pennsylvanian (Morrowan) time, the sea level started to rise; the corresponding rise in the base level of deposition interrupted the erosion and led to filling the valleys in the erosion surface with fluvial, brackish, and marine sands and muds.

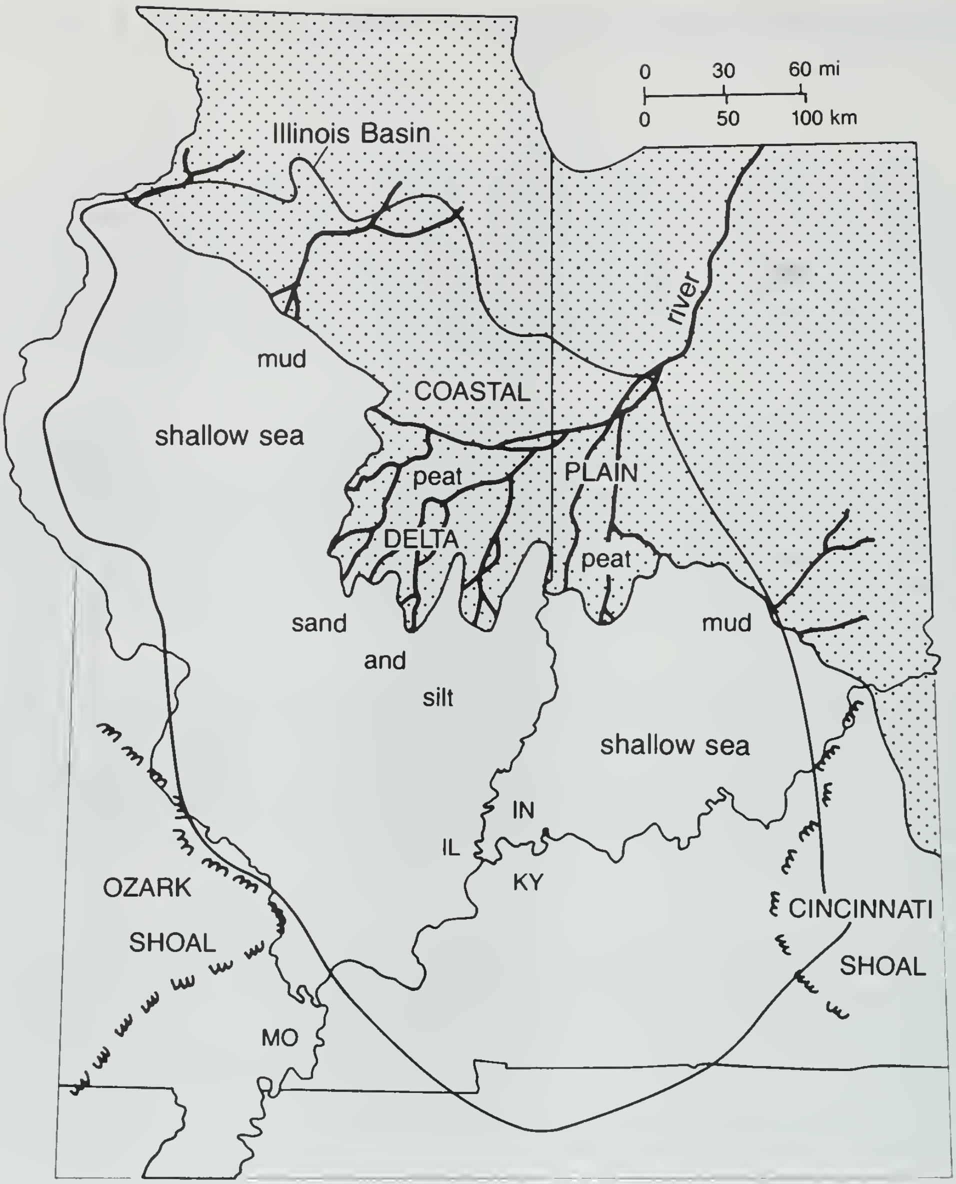
Depositional conditions in the Illinois Basin during the Pennsylvanian Period were somewhat similar to those of the preceding Chesterian (late Mississippian) time. A river system flowed southwestward across a swampy lowland, carrying mud and sand from highlands to the northeast. This river system formed thin but widespread deltas that coalesced into a vast coastal plain or lowland that prograded (built out) into the shallow sea that covered much of present-day Illinois (see paleogeographic map, next page). As the lowland stood only a few feet above sea level, slight changes in relative sea level caused great shifts in the position of the shoreline.

During most of Pennsylvanian time, the Illinois Basin gradually subsided; a maximum of about 3000 feet of Pennsylvanian sediments are preserved in the basin. The locations of the delta systems and the shoreline of the resulting coastal plain shifted, probably because of worldwide sea level changes, coupled with variation in the amounts of sediments provided by the river system and local changes in basin subsidence rates. These frequent shifts in the coastline position caused the depositional conditions at any one locality in the basin to alternate frequently between marine and nonmarine, producing a variety of lithologies in the Pennsylvanian rocks (see lithology distribution chart).

Conditions at various places on the shallow sea floor favored the deposition of sand, lime mud, or mud. Sand was deposited near the mouths of distributary channels, where it was reworked by waves and spread out as thin sheets near the shore. Mud was deposited in quiet-water areas — in delta bays between distributaries, in lagoons behind barrier bars, and in deeper water beyond the nearshore zone of sand deposition. Limestone was formed from the accumulation of limy parts of plants and animals laid down in areas where only minor amounts of sand and mud were being deposited. The areas of sand, mud, and limy mud deposition continually changed as the position of the shoreline changed and as the delta distributaries extended seaward or shifted their positions laterally along the shore.

Nonmarine sand, mud, and lime mud were deposited on the coastal plain bordering the sea. The nonmarine sand was deposited in delta distributary channels, in river channels, and on the broad floodplains of the rivers. Some sand bodies 100 or more feet thick were deposited in channels that cut through the underlying rock units. Mud was deposited mainly on floodplains. Some mud and freshwater lime mud were deposited locally in fresh-water lakes and swamps.

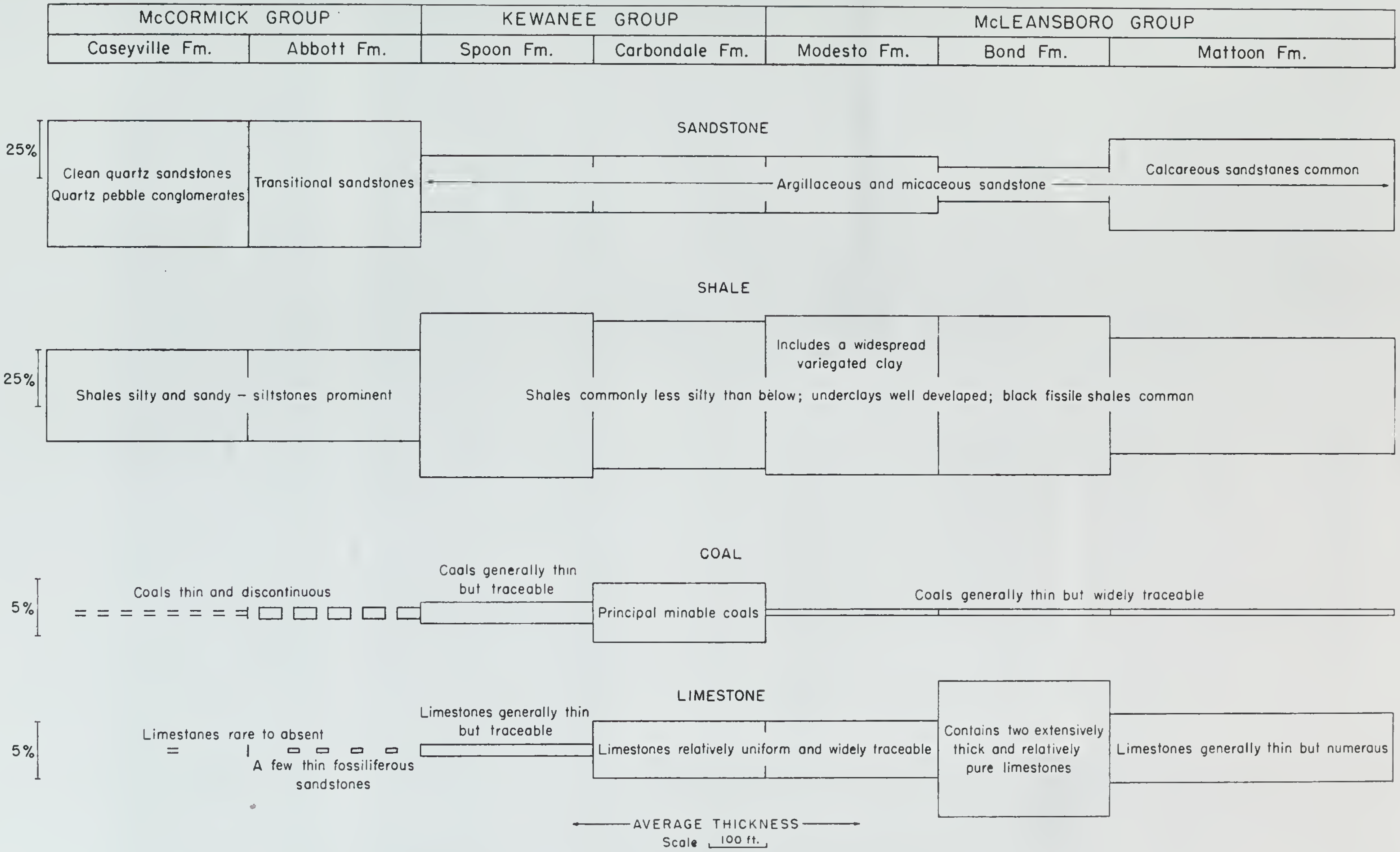
Beneath the quiet water of extensive swamps that prevailed for long intervals on the emergent coastal lowland, peat was formed by accumulation of plant material. Lush forest vegetation covered the region; it thrived in the warm, moist Pennsylvanian-age climate. Although the origin of the underclays beneath the coal is not precisely known, most evidence indicates that they were deposited in the swamps as slackwater mud before the accumulation of much plant debris. The clay underwent modification to become the soil upon which the lush vegetation grew in the swamps. Underclay frequently contains plant roots and rootlets that appear to be in their original places. The vast swamps were the culmination of nonmarine deposition. Resubmergence of the borderlands by the sea interrupted nonmarine deposition, and marine sediments were laid down over the peat.



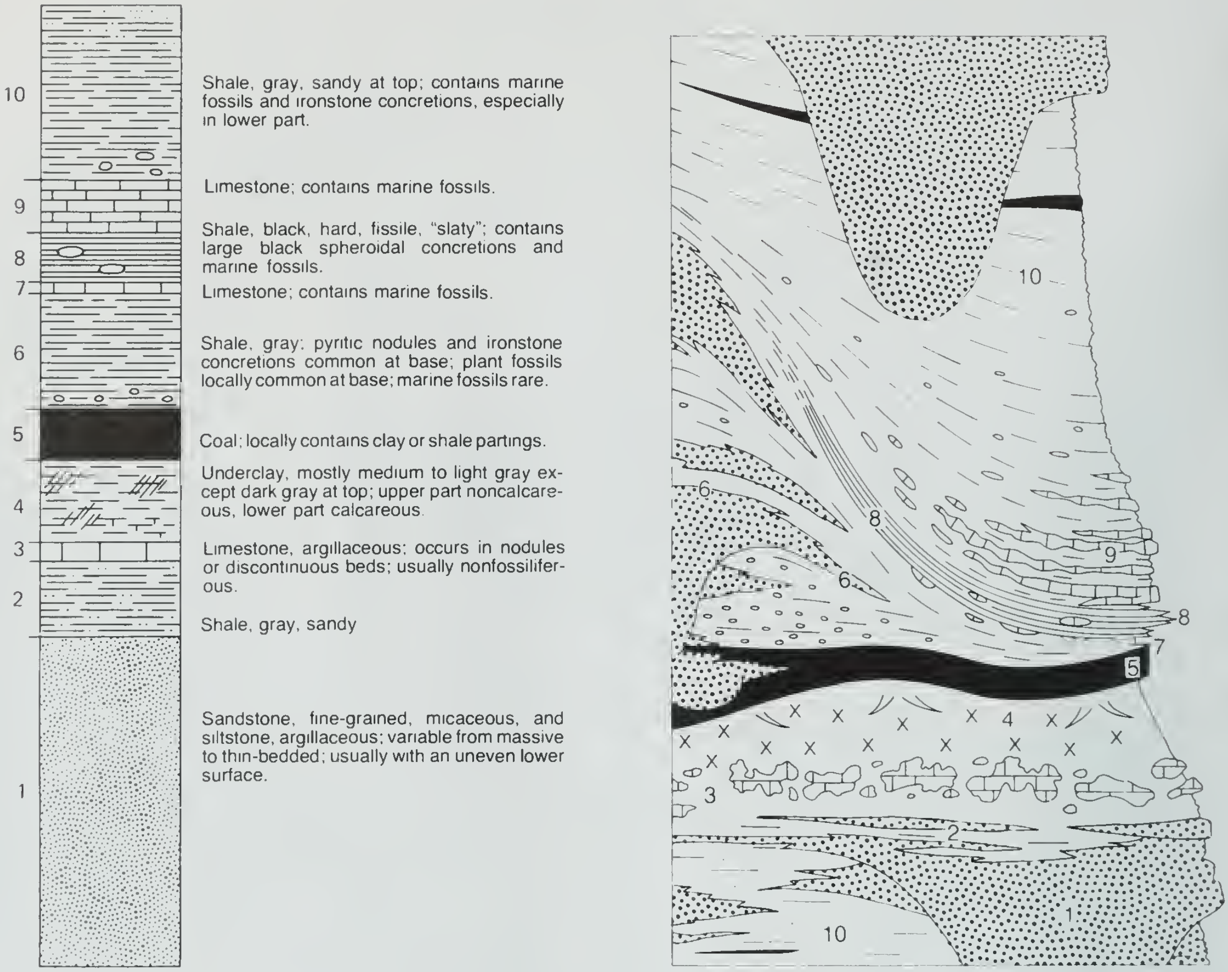
Paleogeography of Illinois-Indiana region during Pennsylvanian time. The diagram shows a Pennsylvanian river delta and the position of the shoreline and the sea at an instant of time during the Pennsylvanian Period.

Pennsylvanian Cyclothems

The Pennsylvanian strata exhibit extraordinary variations in thickness and composition both laterally and vertically because of the extremely varied environmental conditions under which they formed. Individual sedimentary units are often only a few inches thick and rarely exceed 30 feet thick. Sandstones and shales commonly grade laterally into each other, and shales sometimes interfinger and grade into limestones and coals. The underclays, coals, black shales, and some limestones, however, display remarkable lateral continuity for such thin units. Coal seams have been traced in mines, outcrops, and subsurface drill records over areas comprising several states.



General distribution of the four principal lithologies in Pennsylvanian strata of Illinois.



The idealized cyclothem at left (after Willman and Payne, 1942) infers continuous, widespread distribution of individual cyclothem units, at right the model of a typical cyclothem (after Baird and Shabica, 1980) shows the discontinuous nature of many units in a cyclothem.

The rapid and frequent changes in depositional environments during Pennsylvanian time produced regular or cyclical alternations of sandstone, shale, limestone, and coal in response to the shifting shoreline. Each series of alternations, called a cyclothem, consists of several marine and nonmarine rock units that record a complete cycle of marine invasion and retreat. Geologists have determined, after extensive studies of the Pennsylvanian strata in the Midwest, that an "ideally" complete cyclothem consists of ten sedimentary units (see illustration above contrasting the model of an "ideal" cyclothem with a model showing the dynamic relationships between the various members of a typical cyclothem).

Approximately 50 cyclothems have been described in the Illinois Basin but only a few contain all ten units at any given location. Usually one or more are missing because conditions of deposition were more varied than indicated by the "ideal" cyclothem. However, the order of units in each cyclothem is almost always the same: a typical cyclothem includes a basal sandstone overlain by an underclay, coal, black sheety shale, marine limestone, and gray marine shale. In general, the sandstone-underclay-coal-gray shale portion (the lower six units) of each cyclothem is nonmarine: it was deposited as part of the coastal lowlands from which the sea had withdrawn. However, some of the sandstones are entirely or partly marine. The units above the coal and gray shale are marine sediments deposited when the sea advanced over the coastal plain.

Origin of Coal

It is generally accepted that the Pennsylvanian coals originated by the accumulation of vegetable matter, usually in place, beneath the waters of extensive, shallow, fresh-to-brackish swamps. They represent the last-formed deposits of the nonmarine portions of the cyclothems. The swamps occupied vast areas of the coastal lowland, which bordered the shallow Pennsylvanian sea. A luxuriant growth of forest plants, many quite different from the plants of today, flourished in the warm, humid Pennsylvanian climate. (Illinois at that time was near the equator.) The deciduous trees and flowering plants that are common today had not yet evolved. Instead, the jungle-like forests were dominated by giant ancestors of present-day club mosses, horsetails, ferns, conifers, and cycads. The undergrowth also was well developed, consisting of many ferns, fernlike plants, and small club mosses. Most of the plant fossils found in the coals and associated sedimentary rocks show no annual growth rings, suggesting rapid growth rates and lack of seasonal variations in the climate (tropical). Many of the Pennsylvanian plants, such as the seed ferns, eventually became extinct.

Plant debris from the rapidly growing swamp forests — leaves, twigs, branches, and logs — accumulated as thick mats of peat on the floors of the swamps. Normally, vegetable matter rapidly decays by oxidation, forming water, nitrogen, and carbon dioxide. However, the cover of swamp water, which was probably stagnant and low in oxygen, prevented oxidation, and any decay of the peat deposits was due primarily to bacterial action.

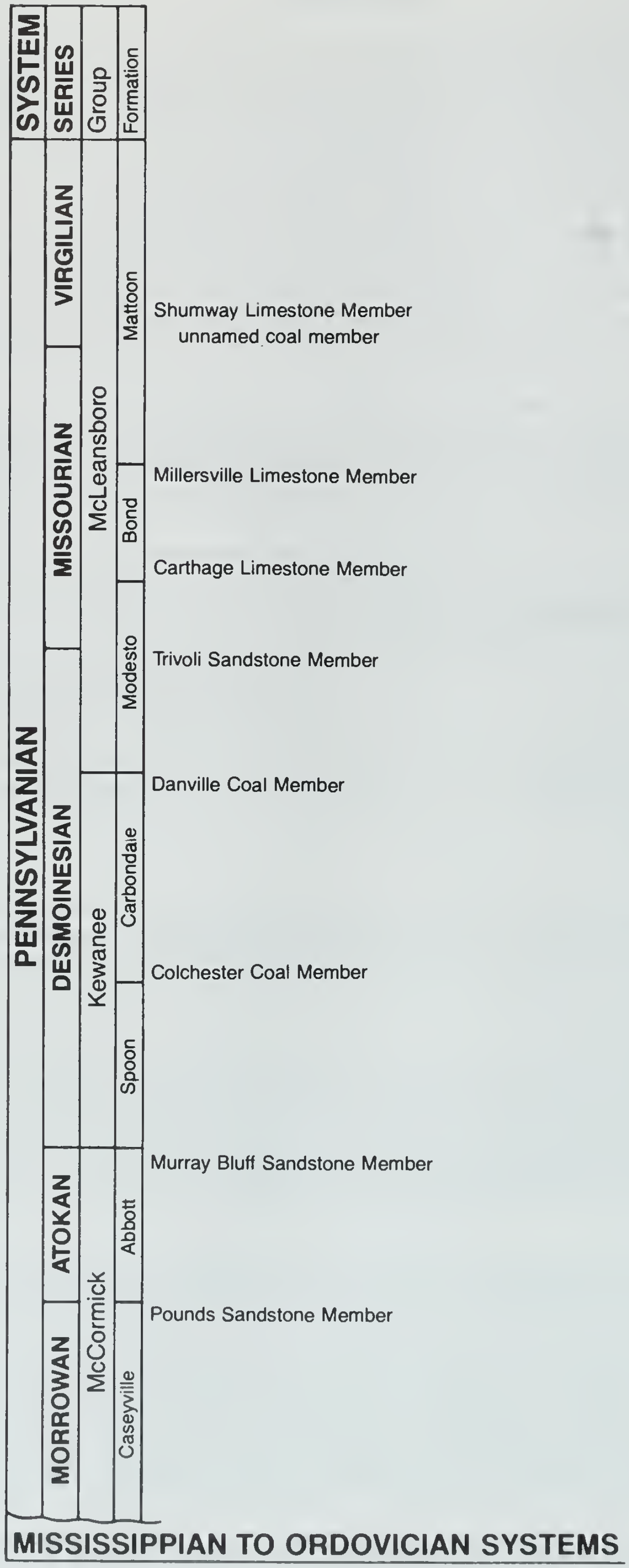
The periodic invasions of the Pennsylvanian sea across the coastal swamps killed the Pennsylvanian forests, and the peat deposits were often buried by marine sediments. After the marine transgressions, peat usually became saturated with sea water containing sulfates and other dissolved minerals. Even the marine sediments being deposited on the top of the drowned peat contained various minerals in solution, including sulfur, which further infiltrated the peat. As a result, the peat developed into a coal that is high in sulfur. However, in a number of areas, nonmarine muds, silts, and sands from the river system on the coastal plain covered the peat where flooding broke through levees or the river changed its coarse. Where these sediments (unit 6 of the cyclothem) are more than 20 feet thick, we find that the coal is low in sulfur, whereas coal found directly beneath marine rocks is high in sulfur. Although the seas did cover the areas where these nonmarine, fluvial sediments covered the peat, the peat was protected from sulfur infiltration by the shielding effect of these thick fluvial sediments.

Following burial, the peat deposits were gradually transformed into coal by slow physical and chemical changes in which pressure (compaction by the enormous weight of overlying sedimentary layers), heat (also due to deep burial), and time were the most important factors. Water and volatile substances (nitrogen, hydrogen, and oxygen) were slowly driven off during the coal-forming ("coalification") process, and the peat deposits were changed into coal.

Coals have been classified by ranks that are based on the degree of coalification. The commonly recognized coals, in order of increasing rank, are (1) brown coal or lignite, (2) sub-bituminous, (3) bituminous, (4) semibituminous, (5) semianthracite, and (6) anthracite. Each increase in rank is characterized by larger amounts of fixed carbon and smaller amounts of oxygen and other volatiles. Hardness of coal also increases with increasing rank. All Illinois coals are classified as bituminous.

Underclays occur beneath most of the coals in Illinois. Because underclays are generally unstratified (unlayered), are leached to a bleached appearance, and generally contain plant roots, many geologists consider that they represent the ancient soils on which the coal-forming plants grew.

The exact origin of the carbonaceous black shale that occurs above many coals is uncertain. Current thinking suggests that the black shale actually represents the deepest part of the marine transgression. Maximum transgression of the sea, coupled with upwelling of ocean water and accumulation of mud and animal remains on an anaerobic ocean floor, led to the deposition of black organic mud over vast areas stretching from Texas to Illinois. Deposition occurred in quiet-water areas where the very fine-grained iron-rich



Generalized stratigraphic column of the Pennsylvanian in Illinois (1 inch = approximately 250 feet).

mud and finely divided plant debris were washed in from the land. Most of the fossils found in black shale represent planktonic (floating) and nektonic (swimming) forms — not benthonic (bottom-dwelling) forms. The depauperate (dwarf) fossil forms sometimes found in black shale formerly were thought to have been forms that were stunted by toxic conditions in the sulfide-rich, oxygen-deficient water of the lagoons. However, study has shown that the "depauperate" fauna consists mostly of normal-size individuals of species that never grew any larger.

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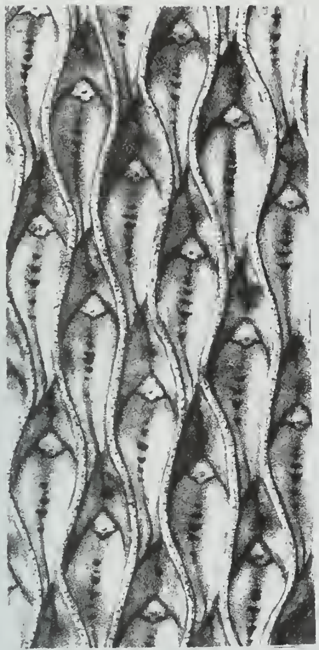
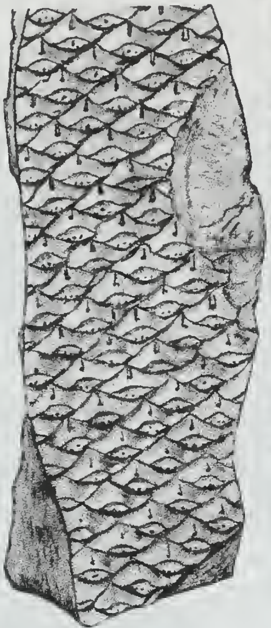
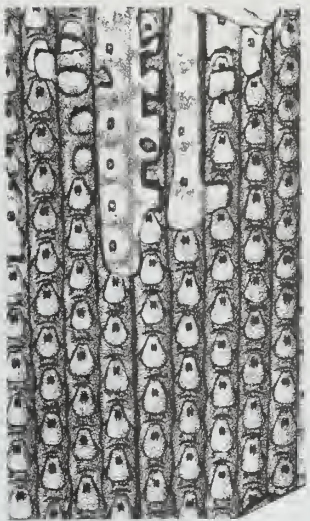
Common Pennsylvanian plants: lycopods, sphenophytes, and ferns



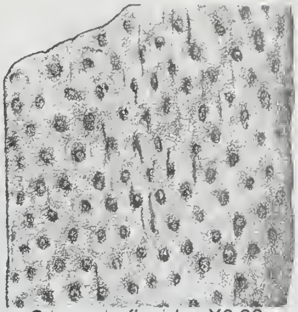
Lepidodendron aculeatum X0.8



Lepidophloios laricinus X0.63

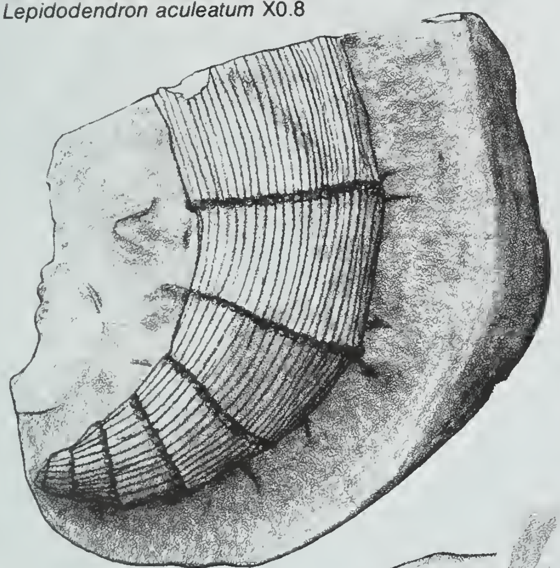


Sigillaria mammilaris X0.5



Stigmaria ficoides X0.32

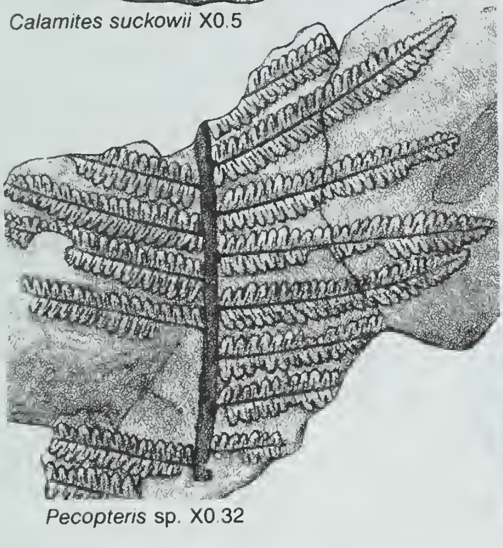
Lepidostrobus ovatifolius X0.8



Calamites suckowii X0.5

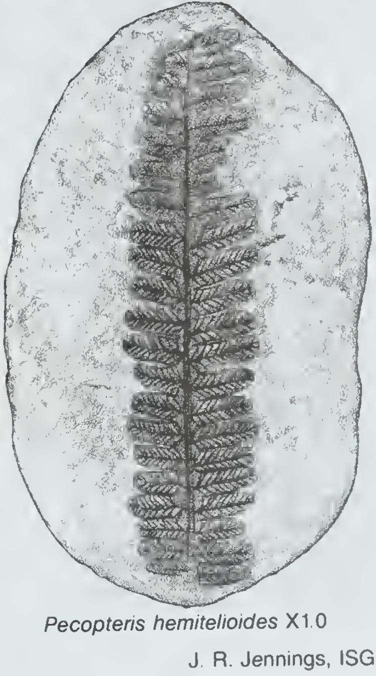
Annularia stellata X0.63

Sphenophyllum cuneifolium X0.4



Pecopteris sp. X0.32

Pecopteris miltonii X2.0

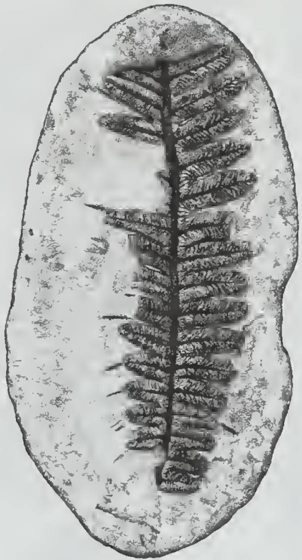


Pecopteris hemitelioides X1.0

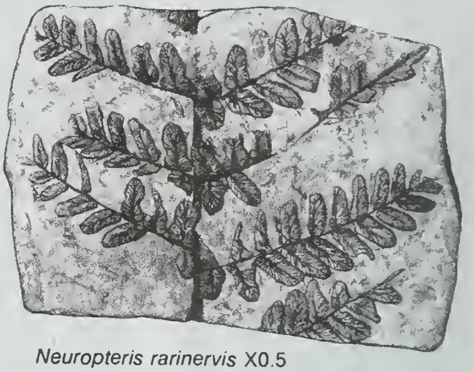
J. R. Jennings, ISGS

Common Pennsylvanian plants: seed ferns and cordaiteans

Alethopteris serlii X0.63



Alethopteris ambigua X0.63



Neuropteris rarinervis X0.5

Mariopteris nervosa X0.8

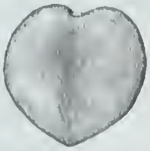
Neuropteris scheuchzeri X0.63

Sphenopteris rotundiloba X0.8

Trigonocarpus parkinsonii X1.25

Cordaicladus sp X1.0

Artisia transversa X0.63

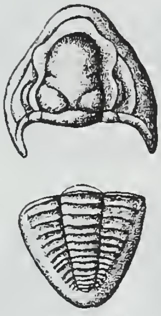


Cordaicarpon major X2.0

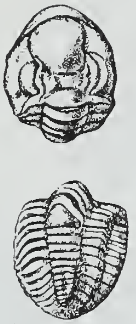
Cordaites principalis X0.63

J R Jennings, ISGS

TRILOBITES

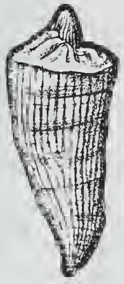


Ameura sangamonensis 1 1/3 x



Ditomopyge parvulus 1 1/2 x

CORALS



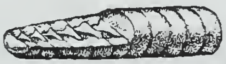
Lophophllidium proliferum 1 x

FUSULINIDS

Fusulina acme 5 x

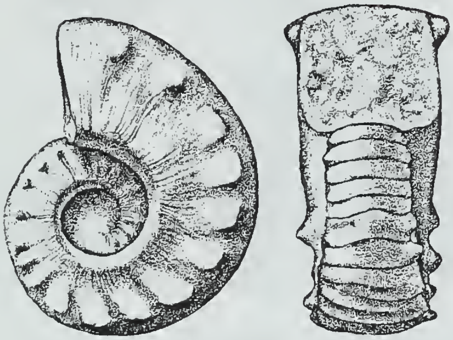
Fusulina girtyi 5 x

CEPHALOPODS



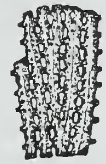
Pseudorthoceras knoxense 1 x

Glaphrites welleri 2/3 x



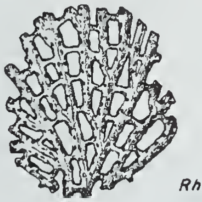
Metacoceras cornutum 1 1/2 x

BRYOZOANS

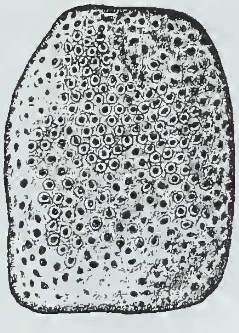


Fenestrellina mimica 9 x

Rhombopora lepidodendroides 6 x



Fenestrellina modesta 10 x



Fistulipora carbonaria 3 1/3 x

Prismopora triangulata 12 x

PELECYPODS


Nucula (Nuculopsis) girtyi 1x


Edmonia ovata 2x


Astartella concentrica 1x


Dunbarella knighti 1½x


Cardiomorpha missouriensis
"Type A" 1x

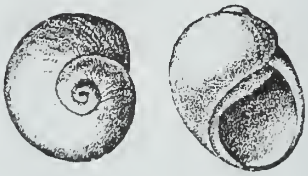

Cardiomorpha missouriensis
"Type B" 1½x

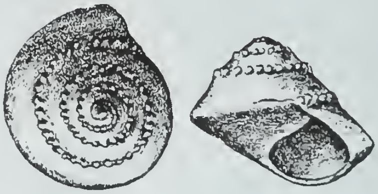
GASTROPODS

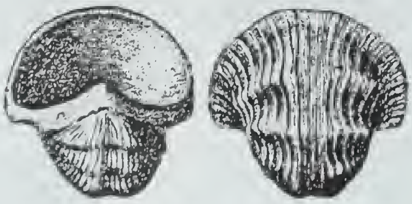

Euphemites carbonarius 1½x


Trepospira illinoisensis 1½x


Donaldina robusta 8x


Naticopsis (Jedria) ventricosa 1½x


Trepospira sphaerulata 1x


Knightites montfortianus 2x


Glabrocingulum (Glabrocingulum) grayvillense 3x

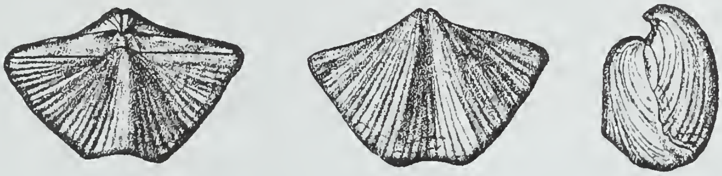
BRACHIOPODS

Juresania nebrascensis $2/3$ x

Wellerella tetrahedra $1\frac{1}{2}$ x

Derbya crassa 1x

Composita argentia 1x



Neospirifer cameratus 1x

Chonetes granulifer $1\frac{1}{2}$ x

Mesolobus mesolobus var. evampygus 2x

Marginifera splendens 1x

Crurithyris planoconvexa 2x

Linoproductus "cora" 1x

PREFACE

The mineral resources of the U. S. midcontinent were instrumental in the development of the U. S. Mineral resources are an important and essential component of the current economy and will continue to play a vital role in the future. Mineral resources provide essential raw materials for the goods consumed by industry and the public. To ensure the availability of mineral resources and contribute to the ability to locate and define mineral resources, the U.S. Geological Survey (USGS) has undertaken two programs in cooperation with the State Geological Surveys in the midcontinent region.

In 1975, under the Conterminous U.S. Mineral Assessment Program (CUSMAP) work began on the Rolla 1° X 2° Quadrangle at a scale of 1:250,000 and was continued in the adjacent Springfield, Harrison, Joplin, and Paducah quadrangles across southern Missouri, Kansas, Illinois, Arkansas and Oklahoma. Public meetings were held in 1981 to present results from the Rolla CUSMAP and in 1985 for the Springfield CUSMAP.

In 1984, the Midcontinent Strategic and Critical Minerals Project (SCMP) was initiated by the USGS and the State Geological Surveys of 16 states to map and compile data at 1:1,000,000 scale and conduct related topical studies for the area from latitude 36° to 46°N. and from longitude 88° to 100°W. Precambrian basement compilations for the SCMP were extended even farther north and west.

In an effort to reach a larger number of those who might be interested in midcontinent mineral resource data and research, a symposium, patterned after the U.S.G.S. McKelvey Forums was held at St. Louis, Missouri, April 1989. The purpose of the meeting was to present summaries or progress reports on the regional compilations and topical research done during the first five years of the SCMP midcontinent project and more detailed reports on the geology, stratigraphy, sedimentology, geochemistry, geophysics and mineral-resource potential of the Harrison and Joplin 1° X 2° quadrangles. The first results and status of the Paducah CUSMAP were presented at this meeting. Progress reports on the CUSMAP and SCMP projects were presented and continue to be presented at various national and regional meetings.

Plans to undertake the assessment of the mineral resource potential of the Paducah Quadrangle were approved in 1985 and work by the USGS, the Illinois State Geological Survey (ISGS), the Kentucky Geological Survey, the Missouri Division of Geology and Land Survey, and the Indiana Geological Survey began in 1987. In 1986, a joint USGS/ISGS pilot study extended the insoluble residue analysis methods developed for the Rolla Quadrangle to a traverse of core and rotary drill holes along western Illinois and across the Paducah Quadrangle. Results from this traverse indicate that the mineralization documented on the east side of the Ozark Uplift on the Rolla Quadrangle extended into the Illinois Basin.

The Illinois State Geological Survey, the Indiana Geological Survey and the Kentucky Geological Survey formed the Illinois Basin Consortium (IBC) in 1989 to foster cooperative research projects on basin-wide geologic and mineral resource-related problems. The USGS Evolution of Sedimentary Basins Program has undertaken a number of research projects on the Illinois Basin that complement the IBC program.

Results from the Paducah CUSMAP resource evaluation and topical studies and the IBC and USGS Evolution of Sedimentary Basin studies are presented in this open file abstract volume. This volume contains the program and abstracts from the January 1992 St. Louis Paducah-IBC meeting. The abstracts are arranged in alphabetical order by the first author's name.

This symposium on the Paducah CUSMAP and IBC efforts presents the results of cooperative research programs that utilized the talent, equipment and other resources of the federal and state geological surveys. Without this federal-state cooperation, this assessment could not have taken place. This open file volume records the contributions of these organizations:

U. S. Geological Survey
Illinois State Geological Survey
Kentucky Geological Survey
Missouri Division of Geology and Land Survey
Indiana Geological Survey

The USGS and State Geological Surveys welcome discussions from our colleagues in industry and academia.

Marty Goldhaber
Jim Eidel

BLR:CUSMAP\PREFACE.CUS

COOPERATIVE GEOLOGIC MAPPING PROGRAM IN SOUTHERN ILLINOIS

Background

The southern Illinois region, while rich in some areas in mineral resources, especially coal, oil and gas and fluorspar, is underdeveloped. The geology of the southernmost portion of the region is more complex than other parts of the state, and its details are only now beginning to be understood. In 1981, the Illinois State Geological Survey (ISGS), a division of the Department of Energy and Natural Resources (ENR), undertook a program of detailed geological mapping in southern Illinois with support from the Nuclear Regulatory Commission (NRC). Mapping in the area was renewed in 1984 with federal matching funds from the Cooperative Geologic Mapping Program (COGEOMAP) of the U.S. Geological Survey (USGS) and with state appropriations for this new initiative. The area being mapped extends northward and westward from the southeastern Illinois Fluorspar Mining District, mapped by the Survey's scientists 20 years ago.

Geologic mapping by the ISGS' geologists at a scale of 1:24,000 (one inch equals 2,000 feet) revealed extensive fault zones in the region but no evidence of modern rejuvenation that would suggest the potential for damage to nuclear power plants in the event of a New Madrid earthquake. Instead, the Survey's geologists found new details about the geology of the region that were broadly encouraging for mineral resource exploration. Faults outside the Illinois Fluorspar Mining District have been mapped in detail and are potential targets for mineral exploration. Renewed efforts by the Survey's mappers have located new seams of coal. However, these are generally thinner and less easily mined than other coals in the state, and their sulfur content is moderate to high. Detailed mapping also is changing geologic concepts of the region in ways that could provide new tools for successful oil and gas exploration.

Since the mid-1980s, the ISGS, through COGEOMAP, has completed and published nine 7.5-minute quadrangle maps in southern Illinois. An additional 11 maps are in various stages of production. In FY92, field mapping of four quadrangles is under way. The program also has been expanded to include research into the methodology for presenting maps that show the subsurface variation in thickness and character of surficial deposits. The result of this effort will be a 1:100,000-scale (one inch equals 1.6 miles) map of the Champaign 30′ x 60′ Quadrangle in central Illinois.

The USGS has obtained up to $2.7 million annually to support the nationwide COGEOMAP program since federal FY85. For federal FY92, the program in Illinois receives $105,000 in direct federal support and $15,000 in additional in-kind services from the USGS. This federal support is matched by the state-supported mapping program at the ISGS. The Illinois COGEOMAP program is an excellent example of successful cooperation between the USGS and State Geological Surveys to address the pressing need for a national geologic mapping program.

Benefits

In a $23-million program supported by state and federal funds over about 18 years, the Commonwealth of Kentucky cooperated with the USGS to complete detailed geologic maps of the entire state. Officials from Kentucky and the USGS estimate that the cost of the mapping program has been repaid 50 times over through discovery of new resources, reduction in construction and engineering costs, attraction of new businesses, and avoidance of geologic hazards.

Benefits of detailed geologic mapping have also been quantified by the ISGS in a definitive study for Boone and Winnebago counties. Benefits, calculated from avoided costs associated with the clean up of landfills and industrial disposal sites, were compared to the cost of mapping. The return on an investment of $300,000 in 1990 dollars was about 23 to 54 times the investment for the best-case scenario, and five to 11 times the investment for the worst-case scenario. The most probable case indicated benefit/cost ratios of 11.7 to 27.2. The benefit/cost analysis excludes other benefits that are not currently quantifiable such as identifying and recovering natural resources and providing basic data to industry and government for siting facilities--data indicating water supplies, foundation conditions, and areas suitable for the installation of septic tanks. These benefits would increase the benefit/cost ratios significantly.

SM2/92

MINERAL ASSESSMENT PROGRAM FOR SOUTHERN ILLINOIS

Background

The Conterminous U.S. Mineral Assessment Program (CUSMAP) of the U.S. Geological Survey (USGS), carried out in cooperation with state geological agencies, provides for detailed geological, geochemical and geophysical (seismic) studies in regions known to contain or have potential for mineral deposits. The purpose is to develop sufficient knowledge to determine the likelihood of finding new mineral resources or extensions of known deposits. A CUSMAP study of the Paducah 1 X 2 degree quadrangle, covering approximately 7,500 square miles in southern Illinois and adjacent parts of Missouri, Kentucky and Indiana, was begun in the Fall of 1986 as a cooperative effort of the USGS; the Illinois State Geological Survey (ISGS), a division of the Department of Energy and Natural Resources; and the State Geological Surveys of Missouri, Kentucky and Indiana.

The Paducah quadrangle includes significant numbers of active and inactive mines (fluorspar, lead, zinc and barite); extensive quarries and pits for extraction of limestone, sand, gravel, silica and clay; active coal mines; and producing oil fields. The Illinois-Kentucky Fluorspar District in Hardin and Pope counties has accounted for as much as 90 percent of the domestic fluorspar production. The quadrangle lies just east of the world-class southeast Missouri Lead District and, based on recent preliminary subsurface geochemical surveys and known minor surface occurrences of ore minerals, appears to hold potential for deep lead and zinc sulfide mineralization.

The CUSMAP evaluation of the Paducah quadrangle is being made on the basis of ongoing studies that include: 1) compilation and evaluation of pre-existing geological, geochemical and seismic data; 2) new geological mapping, geochemical analysis and geophysical measurements to expand the data base and test new hypotheses; 3) topical studies on the origin and development of coal, oil, gas, and non-fuel (metallic and non-metallic) mineral resources; and 4) based on the data gathered, an appraisal of the potential for the discovery of additional mineral wealth. The ISGS is coordinating much of this research effort and data input from the states and, with the USGS, is taking the lead in developing a Geographic Information System (GIS) data base that incorporates new techniques in computerized spatial data analysis and cartography. The efficacy of the GIS for assessing mineral potential was demonstrated in January 1992 at a workshop held in St. Louis, Mo., for representatives of industry, government and academia.

Research and data acquisition for the Paducah CUSMAP project is completed; maps have been prepared showing areas of high, moderate, and low potential and high, moderate and low confidence for mineral discovery. Results of the assessment were released in early 1992.

Benefits

A series of reports on the geology and mineral resources of the Paducah 1 X 2 degree quadrangle are in preparation. These will include new and innovative compilations of resource data related to coal, oil, gas, and the industrial mineral and metal resources; detailed surficial, bedrock and subsurface maps and cross sections; topical studies; and a general assessment of the mineral potential of the area. Availability of published and open-file data, coupled with the development of new theories and models, could make southern Illinois more attractive for mineral exploration and entrepreneurial activity.

SM7/93

COOPERATIVE GEOLOGIC MAPPING PROGRAM IN SOUTHERN ILLINOIS

Background

The southern Illinois region, while rich in some areas in mineral resources, especially coal, oil and gas and fluorspar, is economically stressed. Mapping of geologic resources in the region may have long-term, beneficial, economic impact. The geology of the southernmost portion of the region is more complex than other parts of the state, and its details are only now beginning to be understood. In 1981, the Illinois State Geological Survey (ISGS), a division of the Department of Energy and Natural Resources, undertook a program of detailed geological mapping in southern Illinois with support from the Nuclear Regulatory Commission. Mapping in the area was renewed in 1984 with federal matching funds from the Cooperative Geologic Mapping Program (COGEOMAP) of the U.S. Geological Survey (USGS) and with state appropriations for this new initiative. The area being mapped extends northward and westward from the southeastern Illinois Fluorspar Mining District, mapped by the Survey's scientists 20 years ago.

Geologic mapping by the ISGS' geologists at a scale of 1:24,000 (one inch equals 2,000 feet) has revealed extensive fault zones in the region and recently uncovered evidence suggestive of more recent fault displacements than previously demonstrated. In addition, the Survey's geologists have found new details about the geology of the region that are broadly encouraging for exploration of mineral resources. Faults outside the Illinois Fluorspar Mining District have been mapped in detail and are potential targets for mineral exploration. Renewed efforts by the Survey's mappers have located new seams of coal. However, these are generally thinner and less easily mined than other coals in the state, and their sulfur content is moderate to high. Detailed mapping also is changing geologic concepts of the region in ways that could provide new tools for successful oil and gas exploration.

Since the mid-1980s, the ISGS, through COGEOMAP, has completed and published 10 7.5-minute quadrangle maps in southern Illinois. An additional 12 maps are in various stages of production. In FY93, field mapping of three quadrangles was under way. The program also has been expanded to include research into the methodology for mapping the thickness and character of surficial deposits. The result will be a 1:100,000-scale (one inch equals 1.6 miles) map of the Champaign 30' x 60' Quadrangle in central Illinois.

The USGS has obtained up to $2.7 million annually to support the nationwide COGEOMAP effort since federal FY85. For federal FY92, the program in Illinois received $105,000 in direct federal support and $15,000 in additional in-kind services from the USGS. This federal support was matched by the state-supported mapping program at the ISGS. COGEOMAP has been an excellent example of successful cooperation between the USGS and State Geological Surveys to address pressing mapping needs. The federal COGEOMAP program was terminated in FY93. Future cooperative mapping will be done under the National Geologic Mapping Act of 1992. Appropriations are not yet in place to fully fund state mapping activities authorized by the act.

Benefits

In a $23-million program supported by state and federal funds over about 18 years, the Commonwealth of Kentucky cooperated with the USGS to complete detailed geologic maps of the entire state. Officials from Kentucky and the USGS estimate that the cost of the mapping program has been repaid 50 times over through discovery of new resources, reduction in construction and engineering costs, attraction of new businesses, and avoidance of geologic hazards.

Benefits of detailed geologic mapping have also been quantified by the ISGS in a definitive study for Boone and Winnebago counties. Benefits, calculated from avoided costs associated with the clean up of landfills and industrial-disposal sites, were compared to the cost of mapping. The return on an investment of $300,000 in 1990 dollars was about 23 to 54 times the investment for the best-case scenario, and five to 11 times the investment for the worst-case scenario. The most probable case indicated benefit/cost ratios of 11.7 to 27.2. The benefit/cost analysis excludes other benefits that are not currently quantifiable such as identifying and recovering natural resources and providing basic data to industry and government for siting facilities--data indicating water supplies, foundation conditions, and areas suitable for the installation of septic tanks. These benefits would increase the benefit/cost ratios significantly.

SM7/93

GEOLOGIC MAPPING FOR THE FUTURE

- A Cooperative Federal/State Program -

Background

A serious gap exists in Illinois and the nation in the availability of large-scale, detailed geologic maps to solve everyday Earth-related problems. Geologic maps illustrate the nature and distribution of earth materials at and below the Earth's surface. Citizens, industry and government require this knowledge because:

- earth materials--sand and gravel, limestone, dolomite, shale, clay, coal and other mineral resources--and groundwater are essential raw materials for modern society;
- roads, dams and buildings are constructed from and on earth materials;
- potential environmental problems from consumption of mineral resources need to be minimized;
- potential hazards from earthquakes, landslides and subsidence must be avoided or their impacts reduced;
- potential problems from burial of wastes must be kept as low as possible.

Problem

Although most states, including Illinois, have been geologically mapped at small scales covering larger regions, such maps are not detailed enough for today's planning and decision-making purposes. Detailed geologic maps that range in scale from one inch equals 2,000 feet (1:24,000) to one inch equals about 1.6 miles (1:100,000) are required. Less than 20 percent of the nation and only about four percent of Illinois have been mapped at the 1:24,000 scale.

A recent intensive review by the Illinois State Geological Survey (ISGS), a division of the Department of Energy and Natural Resources, with assistance from the Illinois Geologic Mapping Advisory Committee, identified the following needs, priorities and uses for detailed geologic maps for the state:

- to ensure sufficient supplies of groundwater for the present and future;
- to protect groundwater resources in areas of high usage and to assess the impact of agricultural chemicals on the quality of groundwater;
- to plan sites for landfills in counties where capacity is most limited and plans indicate imminent need for a suitable location;
- to assess hazards, especially seismic risks and threats from landslides, coastal erosion and subsidence;
- to select industrial and other sites for development;
- to permit comprehensive assessments of strategic and critical mineral resources;
- to identify the location and extent of sand, gravel, limestone, dolomite and deposits of other industrial minerals;
- to locate fossil fuel resources;
- to introduce the public to Earth Science in parks, national corridors and other recreational areas;
- to provide educational materials and opportunities for future scientists.

Similar needs exist in nearly every other state except Kentucky and possibly Massachusetts, Rhode Island and Puerto Rico. Those states, which already have been mapped at the suggested detailed scales, may require some updating of existing maps.

The geologic mapping of Kentucky and the other states was aided by the availability of detailed topographic maps at a scale of one inch equalling 2,000 feet. These maps are now available for the lower 48 states, thus making detailed geologic mapping feasible.

Benefits

Benefits of detailed geologic mapping have been quantified by the ISGS. In a definitive case study of a mapping project for Boone and Winnebago counties, the potential value of benefits derived from having detailed geologic maps of the region were compared to the cost of the mapping project in 1990 dollars. The only benefits considered were the costs associated with the cleaning up of landfills and industrial disposal sites that could have been avoided had the geologic maps been available at the time decisions on siting were made. The most probable case indicated that the value of these benefits (avoided costs) were 12 to 27 times the $300,000 cost of the mapping project. This benefit/cost analysis excluded other benefits from geological mapping that are not currently quantifiable such as identifying and recovering the Earth's resources and providing basic data to industry and government for siting facilities--data indicating supplies of water, conditions of foundations, and areas suitable for the installation of septic tanks. These benefits would significantly increase the benefit/cost ratios.

Needed Federal and State Action

In May 1992, Congress passed and the President signed Public Law 102-285 (**The National Geologic Mapping Act of 1992**), authorizing a new program to produce the required detailed maps. The Act calls for a National Geologic Mapping Program, coordinated by the U.S. Geological Survey (USGS) as the lead federal agency, working in cooperation with the 50 states. The program includes four elements — federal geologic mapping, support for geologic mapping, geologic mapping in cooperation with state geological survey agencies, and support for education in geologic mapping. The key element for the individual states, geologic mapping in cooperation with state survey agencies, calls for matched state and federal funds and is authorized at $18 million in the second year, increasing to $25 million by the fourth year of the program.

To be successful, the National Geologic Mapping Program must be a sustained, multi-year effort, receiving dedicated funds as a separate line item in the budget of the USGS. Unfortunately, this level of financial support for state mapping and education in geologic mapping has been minimal. Actual appropriations were only 8.9 percent of $15 million authorized for state mapping and no support for education in geologic mapping last year. Data obtained from the state geological survey agencies show that they have ongoing mapping projects already in place that come very close to matching the $18 million in federal funding authorized for the second year of the program. Support is needed for funding all elements of the National Geologic Mapping Program at the authorized levels. Equity funding for the state mapping and education in mapping components is especially needed to ensure an effective effort.

Anticipated Results for Illinois

The ISGS has estimated that a geologic mapping program funded at approximately $1.1 million per year would require about 50 years to map all 1,100 of the 1:24,000-scale quadrangles in the state. A federal appropriation at the full $25 million level should provide between $750,000 and $1,000,000 per year in federal matching funds for the mapping program in Illinois. With these matching funds, the time required to map the entire state could be reduced to between 25 and 35 years, depending on the level of funding. Additional support from local governmental agencies and industries in Illinois could reduce the time required to as few as 17 or 18 years.

Benefit/cost studies have shown that the return on an investment in geologic mapping ranges from about 12 to 27 times the cost, based on the costs for cleaning up leaking landfills and other disposal sites that could have been avoided. Other benefits that will accrue from a National Geologic Mapping Program include: delineation of mineral resources that will aid in building and rebuilding the nation's infrastructure; delineation of groundwater resources and their potential for contamination; and delineation of geologic hazards and their risks to public health, safety and property values.

SM7/93


ATIONAL FOREST
Raum
Lookout
Gowins
Rising Sun
Brownfield
Golconda
Homberg
Rosebud
Humm Wye
Shetlerville
START
1
2
3
4
5 LUNCH
6
7
8
9
10
END 11
146
151
152
Lusk
Simmons
Pierre Creek
Horseshoe Lake
Quarrel Creek
Beatty Branch
Creek
Miller
Bay
ABANDONED
T 12 S
T 13 S
T 14 S
R 6 E
R 7 E
LIVINGSTON CO
KENTUCKY
OHIO
0 2 4 mi
0 2 4 6 km