Guide to the Geology of the Salem Area, Marion County, Illinois

W.T. Frankie • R.J. Jacobson • M.M. Killey • M.A. Phillips • D.L. Reinertsen • C.J. Zelinsky • R. Barrett • J. Hankinson • M. Redding

Field Trip Guidebook 1995A  April 22, 1995

Department of Energy and Natural Resources
ILLINOIS STATE GEOLOGICAL SURVEY
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ILLINOIS STATE GEOLOGICAL SURVEY
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Cover photo  Large blocks of fossiliferous Omega Limestone at the abandoned Shoots Quarry, Stop 11 (photo by W. T. Frankie).

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

A list of guidebooks of earlier field trips for planning class tours and private outings may be obtained by contacting the Educational Extension Unit, Illinois State Geological Survey, Natural Resources Building, 615 East Peabody Drive, Champaign, IL 61820. Telephone: (217) 244-2427 or 333-4747.
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"Destiny is not a matter of chance;
it is a matter of choice.
It is not a thing to be waited for;
it is a thing to be achieved."

William Jennings Bryan
1860–1925
<table>
<thead>
<tr>
<th>Era</th>
<th>Period or System and Thickness</th>
<th>Age (years ago)</th>
<th>General Types of Rocks</th>
</tr>
</thead>
<tbody>
<tr>
<td>Quaternary</td>
<td>0-500'</td>
<td>10,000</td>
<td>Recent—alluvium in river valleys</td>
</tr>
<tr>
<td></td>
<td></td>
<td>1.6 m.</td>
<td>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</td>
</tr>
<tr>
<td></td>
<td></td>
<td>5.3 m.</td>
<td>Chert gravel, present in northern, southern, and western Illinois</td>
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<tr>
<td></td>
<td></td>
<td>57.8 m.</td>
<td>Mostly micaceous sand with some silt and clay; present only in southern Illinois</td>
</tr>
<tr>
<td></td>
<td></td>
<td>66.4 m.</td>
<td>Mostly clay, little sand, present only in southern Illinois</td>
</tr>
<tr>
<td></td>
<td></td>
<td>144 m.</td>
<td>Mostly sand, some thin beds of clay and, locally, gravel; present only in southern Illinois</td>
</tr>
<tr>
<td></td>
<td></td>
<td>286 m.</td>
<td>Largely shale and sandstone with beds of coal, limestone, and clay</td>
</tr>
<tr>
<td></td>
<td></td>
<td>320 m.</td>
<td>Block 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</td>
</tr>
<tr>
<td></td>
<td></td>
<td>360 m.</td>
<td>Thick limestone, minor sandstones and shales; largely chert and cherty limestone in southern Illinois; black shale at top</td>
</tr>
<tr>
<td></td>
<td></td>
<td>408 m.</td>
<td>Principally dolomite and limestone</td>
</tr>
<tr>
<td></td>
<td></td>
<td>438 m.</td>
<td>Largely dolomite and limestone but contains sandstone, shale, and siltstone formations</td>
</tr>
<tr>
<td></td>
<td></td>
<td>505 m.</td>
<td>Chiefly sandstones with some dolomite and shale; exposed only in small areas in north-central Illinois</td>
</tr>
<tr>
<td></td>
<td></td>
<td>570 m.</td>
<td>Igneous and metamorphic rocks; known in Illinois only from deep wells</td>
</tr>
</tbody>
</table>

Generalized geologic column showing succession of rocks in Illinois.
SALEM AREA

The Salem geological science field trip will acquaint you with the geology*, landscape, and mineral resources for part of Marion County, Illinois. This area is one of the nerve centers of the oil industry in Illinois.

The Salem area is located slightly north of the center of southern Illinois. It is 235 miles southwest-southeast of Chicago, nearly 70 miles east of St. Louis, and about 115 miles north-northeast of Cairo. The western edge of Marion County is the Third Principal Meridian (3rd P.M.), and the southern edge is the Base Line for the 3rd P.M. Therefore, the southwestern corner of the county is the zero point of land surveys for much of Illinois.

Geologic Framework

Precambrian Era  Through several billion years of geologic time, the Marion County area has undergone many changes (see the rock succession column, facing page). The oldest rocks beneath the field trip area belong to the ancient Precambrian basement complex. We know relatively little about these rocks from direct observations because they are not exposed at the surface anywhere in Illinois. Only about 35 drill holes have reached deep enough for geologists to collect samples from Precambrian rocks. From these samples, however, we know that these ancient rocks consist mostly of granitic and rhyolitic igneous, and possibly metamorphic, crystalline rocks formed about 1.5 to 1.0 billion years ago. These rocks, which were deeply weathered and eroded when they were exposed at Earth's surface until about 0.6 billion years ago, formed a landscape that was probably quite similar to that of the present-day Missouri Ozarks. We have no rock record in Illinois for the long interval of weathering and erosion that lasted from the time the Precambrian rocks were formed until the Cambrian sediments accumulated, but that interval is almost as long as the time from the beginning of the Cambrian to the present.

Geologists seldom see Precambrian rocks in Illinois except as cuttings and cores from drill holes. To determine some of the characteristics of the basement complex, they use various techniques, such as surface mapping, measurements of Earth's gravitational and magnetic fields, and seismic exploration. The evidence indicates that in southernmost Illinois, near what is now the Kentucky-Illinois Fluorspar Mining District, rift valleys like those in east Africa, formed as movement of crustal plates (plate tectonics) began to rip apart the Precambrian North American continent. These rift valleys in the midcontinent region are referred to as the Rough Creek Graben and the Reelfoot Rift (fig. 1).

Paleozoic Era  Near the beginning of the Paleozoic Era about 570 million years ago, the rifting stopped and the hilly Precambrian landscape began to sink slowly on a broad, regional scale, allowing the invasion of a shallow sea from the south and southwest. During the several hundred million years of the Paleozoic Era, the area that is now southern Illinois continued to accumulate sediments deposited in the shallow seas that repeatedly covered it. The region continued to sink until at least 15,000 feet of sedimentary strata were deposited. At times during this era the seas withdrew and deposits were weathered and eroded. As a result, there are some gaps in the sedimentary record in Illinois.

In the field trip area, bedrock strata range from more than 520 million years (the Cambrian Period) to less than 290 million years old (the Pennsylvanian Period). Figure 2 shows the succession of rock strata a drill bit would penetrate in this area if the rock record were complete and all the formations were present (the oldest formations are at the bottom right of the column).

*Words in italics are defined in the glossary at the back of the guidebook. Also please note: although all present localities have only recently appeared within the geologic time frame, we use the present names of places and geologic features because they provide clear reference points for describing the ancient landscape.
Pennsylvanian-age bedrock strata consisting of shale, siltstone, sandstone, limestone, coal, and underclay were deposited as sediments in shallow seas and swamps between about 320 and 288 million years ago. They are found immediately beneath a cover of glacial deposits in this area. Some of these rocks are exposed in scattered roadcuts and stream cuts. Pennsylvanian strata increase in total thickness from slightly less than 1,000 feet in northwestern Marion County to somewhat more than 1,800 feet in the southeast corner. Producing oil fields have been developed in Pennsylvanian sandstones in the southwestern part of the county. (See Depositional History of the Pennsylvanian Rocks in the supplemental reading at the back of this guidebook for a more complete description of these rocks.)

In Marion County, Paleozoic sedimentary strata range from about 8,500 feet thick in northwestern Marion County to about 10,500 feet in the southeast. Petroleum has been produced from Ordovician, Devonian, Mississippian, and Pennsylvanian rocks.

**Structural and Depositional History**

As noted previously, midcontinent rift valleys (the Rough Creek Graben and the Reelfoot Rift, figs. 1 and 3) formed during Precambrian tectonic activity. These valleys later filled with sand and gravel that was shed from the adjacent uplands and with limestone that formed in the shallow sea covering the area.

During the Paleozoic Era, sediments accumulated in the seas that covered Illinois and adjacent states. The shallow seas connected with the open ocean to the south during much of the Paleozoic, and the area of southern Illinois was like an embayment. The southern part of Illinois and adjacent parts of Indiana and Kentucky sank more rapidly than the areas to the north, allowing a greater thickness of sediment to accumulate. Earth's thin crust was periodically flexed and warped as stresses built up in places. These worldwide movements caused changes in sea level that re-
Table 1. Stratigraphic column of the southern Illinois Basin. Black dots indicate oil and gas pay zones (variable vertical scale; from Leighton et al. 1991).

<table>
<thead>
<tr>
<th>Thickness: About 2000 ft</th>
<th>Thickness: About 1300 ft</th>
<th>Thickness: About 4000 ft</th>
<th>Thickness: About 8000 ft</th>
</tr>
</thead>
<tbody>
<tr>
<td>ThICKNESS: ABOUT 2000 FT</td>
<td>GROVE CHURCH</td>
<td>ST. LOUIS</td>
<td>EVERTON</td>
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<tr>
<td></td>
<td>KINKAID</td>
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<td></td>
<td>DEGONIA</td>
<td>ULLIN</td>
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<td></td>
<td>CLORE</td>
<td>FT PAYNE</td>
<td></td>
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<tr>
<td></td>
<td>PALESTINE</td>
<td>BORDEN (Osage)</td>
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<tr>
<td></td>
<td>MENARD</td>
<td></td>
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<tr>
<td></td>
<td>WALTERSBURG</td>
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<td></td>
<td>VIENNA</td>
<td></td>
<td></td>
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<td>TAR SPRINGS</td>
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<td></td>
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<td></td>
<td></td>
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<tr>
<td>ThICKNESS: ABOUT 1300 FT</td>
<td>GLEN DEAN</td>
<td>HANLEY</td>
<td></td>
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<tr>
<td></td>
<td>HARDINSBURG</td>
<td>FRAILEYS (Gol.sh.)</td>
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<tr>
<td></td>
<td></td>
<td>Big Clifty, Jackson</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>BEECH CREEK (Barrow, basal Gol.)</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>CYPRESS</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>ThICKNESS: ABOUT 4000 FT</td>
<td>RICHMONDER (U.P.C.)</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Sample (P. Cr. S4, E.III.)</td>
<td></td>
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<tr>
<td></td>
<td>BETHEL</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>DOWNEYS BLUFF (U.P.C., J. Ren.)</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>YANKEETOWN</td>
<td></td>
<td></td>
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<td></td>
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<td></td>
<td></td>
</tr>
<tr>
<td>ThICKNESS: ABOUT 8000 FT</td>
<td>MAQUOKETA</td>
<td></td>
<td></td>
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</tbody>
</table>

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

Sedimentary units: Many of the sedimentary units, called formations, have conformable contacts—that is, no significant interruption in deposition occurred between formations (figs. 2 and 4). In some instances, even though the composition and appearance of the rocks change significantly at the contact between two formations, the fossils in the rocks and the relationships between the rocks at the contact indicate that deposition was virtually continuous. In some places, however, the lower formation was at least partially eroded before deposition resumed. Fossils and other evidence in the two formations indicate that there is a significant age difference between the lower unit and the overlying unit. This type of contact is called an unconformity (fig. 4). If the beds above and below an unconformity are parallel, the unconformity is called a disconformity; if the lower beds...
Figure 3 Diagrammatic illustrations of fault types that may be present in the field trip area.
Figure 4 Schematic drawings of (A) a disconformity and (B) an angular unconformity (x represents the conformable rock sequence and z is the plane of unconformity).

have been tilted and eroded before the overlying beds were deposited, the contact is called an angular unconformity. Five major unconformities are shown as undulating lines across the rock columns in figure 2. Each represents an extended interval of time for which there is no rock record. Smaller unconformities also are shown in figure 2; these generally represent shorter time intervals or more localized events. At these points less material is missing from the record.

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

During the Mesozoic Era, which followed the Paleozoic Era, the rise of the Pascola Arch (fig. 1) in southeastern Missouri and western Tennessee formed the Illinois Basin, closing off the embayment and separating it from the open sea to the south. The Illinois Basin is a broad, subsided region covering much of Illinois, southwestern Indiana, and western Kentucky (figs. 1 and 5). Development of the Pascola Arch, in conjunction with the earlier sinking of deeper parts of the area to the north, gave the basin its present asymmetrical, spoon-shaped configuration (fig. 6). The geologic map (fig. 7) shows the distribution of the rock systems of the various geologic time periods as they would appear if all the glacial, windblown, and surface materials were removed.

The Salem field trip area is in the western part of the Illinois Basin. Smaller subsidiary structures, such as the Salem Anticline and the Fairfield Basin, were superimposed on the larger basin structure at different times. Marion County is near the west-central part of the Fairfield Basin, which is bounded by the La Salle Anticlinorium on the northeast, the Du Quoin Monocline on the west, the Cottage Grove Fault System on the south, and the Wabash Valley Fault System on the southeast (fig. 5). In Perry County, to the south-southwest, the Du Quoin Monocline splits; the east arm extends into Jefferson County where it merges with the east flank of the Salem Anticline. Because tilting of the bedrock layers took place several times during the Paleozoic Era, the dips of successive strata vary from one another.

Other evidence indicates that younger rocks of the latest Pennsylvanian and perhaps the Permian (the youngest rock systems of the Paleozoic) may have at one time covered the Marion County area. It is possible that Mesozoic and Cenozoic (even younger) rocks could also have been present here. Indirect evidence, based on the stage of development (rank) of coal deposits and the generation and maturation of petroleum from source rocks (Damberger 1971), indicates that perhaps as much as 7,900 feet (about 1 1/2 miles) of latest Pennsylvanian and younger
Figure 5  Structural features of Illinois (modified from Treworgy 1981).
Figure 6  Stylized north–south cross section shows the structure of the Illinois Basin. To show detail, the thickness of the sedimentary rocks has been greatly exaggerated and younger, unconsolidated surface deposits have been eliminated. The oldest rocks are Precambrian (Pre-C) granites. They form a depression filled with layers of sedimentary rocks of various ages: Cambrian (C), Ordovician (O), Silurian (S), Devonian (D), Mississippian (M), Pennsylvanian (P), Cretaceous (K), and Tertiary (T). Scale is approximate.

rocks once covered southern Illinois. However, during the more than 240 million years since the Paleozoic Era (and before the onset of glaciation 1 to 2 million years ago), several thousands of feet of strata may have been eroded. Nearly all traces of any post-Pennsylvanian bedrock that may have been present in Illinois were erased.

During this extended period of erosion, deep valleys were carved into the gently tilted bedrock formations. Later, the topographic relief was reduced by repeated advances and melting back of continental glaciers that scoured and scraped the pre-glacial erosion surface. The erosion affected all the formations exposed at the bedrock surface in Illinois. The final melting of the glaciers left behind the non-lithified deposits in which our Modern Soil has developed.

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

Erosion that took place long before the glaciers advanced across the state left a network of deep valleys carved into the bedrock surface (fig. 8a). In the Salem area, a buried bedrock drainage divide undulates south-southwestward from near the northeast corner of the county into the southeastern part of the county (fig. 8b). Drainage east of the divide, via tributaries to the buried Skillet Fork, eventually reached the buried Wabash River Valley. Drainage to the west of the divide flowed through the buried Sandoval Valley via the partially buried Kaskaskia River into the partly buried Lower Mississippi River. Because of the irregular bedrock surface and erosion, glacial drift is unevenly distributed across Marion County. In the buried Sandoval Valley glacial drift is more than 100 feet thick. Uplands, however, frequently have less than 25 feet.
Figure 7 Bedrock geology beneath surficial deposits in Illinois.
Figure 8a  Bedrock valleys of Illinois, with area of figure 8b highlighted (modified from Herzog et al. 1994).
Figure 8b  Buried bedrock surface and valleys of Marion County and surrounding areas (modified from Herzog et al. 1994).

During the Pleistocene Epoch, beginning about 1.6 million years ago, massive sheets of ice (called continental glaciers), thousands of feet thick, flowed slowly southward from Canada. The last of these glaciers melted from northeastern Illinois about 13,500 years before the present (B.P.). Although ice sheets covered parts of Illinois several times during the Pleistocene, no deposits of drift from the oldest (pre-Illinoian) glaciers have been found this far south. During the Illinoian glacial stage, which began around 300,000 years B.P., North American continental glaciers reached their southernmost position slightly more than 70 miles south of here (fig. 9), in the northern part of Johnson County.

Until recently, glaciologists assumed that these glaciers may have been a mile or more thick. However, the maximum thickness of the ice may have been only about 2,000 feet in the Lake Michigan Basin and about 700 feet across most of the Illinois land surface (Clark et al. 1988). That conclusion was made using several lines of research evidence: (1) the degree of consolidation and compaction of rock and soil materials that must have been under the ice, (2) comparisons between the inferred geometry and configuration of the ancient ice masses and those of present-day glaciers and ice caps, (3) comparisons between the mechanics of ice-flow in modern-
Figure 9  Generalized map of glacial deposits in Illinois (modified from Willman and Frye 1970).
day glaciers and ice caps and those inferred from detailed studies of the ancient glacial deposits, and (4) the amount of rebound of the Lake Michigan Basin as the heavy mass of glacial ice (that had depressed the land beneath it) melted and relieved the pressure.

The topography of the bedrock surface throughout much of Illinois is largely hidden from view by glacial deposits except along the major streams. In many areas, the glacial drift is thick enough to completely mask the underlying bedrock surface. Studies of mine shafts, water-well logs, and other drill-hole information in addition to scattered bedrock exposures in some stream valleys and roadcuts show that the present land surface of this region is largely a reflection of the underlying bedrock surface. Thus, the preglacial bedrock surface has been only slightly modified and subdued by a thin mantle of glacial drift. Salem lies some 50 miles south of the late Wisconsinan Shelbyville Moraine, the earliest moraine of the Woodfordian Substage that was deposited about 22,000 B.P.

Although Illinoian glaciers probably built morainic ridges similar to those of the later Wisconsinan glaciers, Illinoian moraines apparently were not so numerous and have been exposed to weathering and erosion for thousands of years longer than their younger Wisconsinan counterparts. For these same reasons, Illinoian glacial features generally are not as conspicuous as the younger Wisconsinan features.

A thin cover, less than 4 feet thick, of wind-blown silt called Peoria Loess (pronounced "luss") mantles the glacial drift in Marion County. This fine-grained dust, which covers most of Illinois outside the area of Wisconsinan glaciation, reaches thicknesses exceeding 15 feet near the Mississippi and Illinois Rivers. Soils in this area have developed in the loess and the underlying weathered silty, clayey Illinoian till.

Geomorphology
Physiography

The Salem field trip area is near the central part of the boundary between the Mt. Vernon Hill Country on the south and the Springfield Plain on the north. The Mt. Vernon Hill Country and the Springfield Plain are both divisions of the Till Plains Section, Central Lowland Physiographic Province (fig. 10). "The Springfield Plain includes the level portion of the Illinoian drift-sheet in central and south-central Illinois. It is distinguished mainly by its flatness and by shallow entrenchment of drainage... The southern boundary of the district... is drawn along a line south of which the drift thins and bedrock topography becomes the controlling factor... Mt. Vernon Hill Country has a mature topography of low relief with limited upland prairies and broad alluviated valleys along the larger streams" (Leighton et al. 1948). With a few scattered exceptions, glacial landforms are essentially lacking.

According to Horberg (1950) and others (e.g., Leighton et al. 1948), an extensive lowland called the "central Illinois penplain" had been eroded prior to glaciation into the relatively weak rocks of Pennsylvanian age east and south of the present-day Illinois River. In Marion County, this bedrock surface appears to have been an upland several miles wide and more than 550 feet above mean sea level (msl). This upland sloped gently southward in the eastern half of the county (see fig. 8b) and was more extensive in the north than in the south. Herzog et al. (1994) show a couple of small areas on the northern half of the bedrock surface that are slightly above 600 feet msl. A shallow valley, slightly less than 500 feet msl, cuts across the upland just south of its central part. Apparently, just before the advent of glaciation, an extensive system of bedrock valleys was deeply entrenched below the central lowland surface level. The western part of the Marion County upland was eroded by tributaries to the ancient Kaskaskia River. The eastern part was eroded by ancient Skillet Fork and its tributaries and the south by the ancient Big Muddy tributaries. The gross features of the Till Plains Section as well as local features of the Springfield Plain and Mt. Vernon Hill Country are determined largely by this preglacial topography. As glaciation began, streams probably changed from erosion to aggradation, that is, their channels began to
build up and fill in because the streams did not have sufficient volumes of water to carry and move the increased volumes of sediment. To date there is no evidence that indicates the early fills in these preglacial valleys ever were completely flushed out of their channels by succeeding deglaciation meltwater torrents.

**Drainage**  The present-day drainage system is relatively complete. Most streams have narrow to medium width valleys and low gradients (bottom slopes). The uplands have fairly good natural drainage. Lost Fork and Dums Creek and several other small streams are tributaries to Skillet Fork, which drains the eastern part of the field trip area east and south toward the Wabash River. Crooked Creek and its larger tributaries (Brubaker, Town, Vermilion, Turkey, and Raccoon Creeks and Martin Branch) provide drainage south and west from Salem. Crooked Creek generally is relatively sluggish as it flows west to the Kaskaskia River.
Skillet Fork occupies a valley that lies just to the west of the Buried Skillet Fork in eastern Marion County. West of the field trip area and just west of Central City and Centralia, Crooked Creek crisscrosses a buried tributary to the partially buried Kaskaskia Valley.

Relief  The highest land surface on the field trip route is at Stop 7, where the surface elevation is slightly less than 590 feet above mean sea level (msl). The lowest elevation is about 475 feet msl on Crooked Creek north-northwest of Stop 3. The surface relief of the field trip area, calculated as the difference between the highest and lowest surfaces, is about 115 feet. Local relief is most pronounced along Crooked and Dums Creeks and Lost Fork, where it is about 40 feet.

Mineral Resources
Mineral production  Of the 102 counties in Illinois, 98 reported mineral production during 1992, the last year for which complete records are available. Although, "complete" may be somewhat of a misnomer in that stone production is reported for the odd-numbered years, and sand and gravel production is reported for the even-numbered years. Furthermore, not all companies report their production figures and values to the U.S. Bureau of Mines. Estimates for the total stone production for 1992 (actually 1991 production) are included in the total value given for mineral production. The total value of all minerals extracted, processed, and manufactured in Illinois during 1992 was $2,894,300,000, 0.5% lower than the 1991 total. Minerals extracted accounted for 90% of this total. Coal continued to be the leading commodity, accounting for 64% of the total, followed by industrial and construction materials at 21.4%, and oil at 14.2%. The remaining 0.4% included metals, peat, and gemstones. Illinois ranked 13th among the 31 oil-producing states in 1992 and 16th among the 50 states in total production of nonfuel minerals but continues to lead all other states in production of fluorspar, industrial sand, and tripoli.

Marion County ranked 31st among all Illinois counties in 1992 on the basis of the value of all minerals extracted, processed, and manufactured. Slab zinc is processed and glass is manufactured in the county, but quantities and values are unknown. Among the 46 Illinois counties producing...
crude oil, Marion County ranked 5th, with total production of approximately 1,225,000 barrels valued at about $23,590,000.

Oil production in Marion County accounted for 6.4% of the state's total in 1992, an increase of 0.1% from 1991. The county leads the state in oil production from 1888 to 1992, with a cumulative total of 437,782,000 barrels; the state's total for the same period is 3,443,435,000 barrels. Figure 11 shows the annual crude oil production in Illinois between 1905 and 1994.

**Groundwater**  
Groundwater is a mineral resource frequently overlooked in assessments of an area's natural resource potential. The availability of this mineral resource is essential for orderly economic and community development. More than 48% of the state's 11 million citizens and 97% of those who live in rural areas depend on groundwater for their water supply. Groundwater is derived from underground formations called aquifers. The water-yielding capacity of an aquifer can only be evaluated by constructing wells into it. After construction, the wells are pumped to determine the quality and quantity of groundwater available for use.

Because glacial deposits generally are thin in this area, sand and gravel deposits are scarce throughout most of the county, especially in the eastern and southern parts. The buried Sandoval Valley in the west-central part of the county contains thick deposits of unconsolidated materials that appear to include thick sand and gravel zones. This area would need further exploration for industrial and municipal water supplies. Pennsylvanian age sandstones are a source of farm and domestic water supplies, particularly southeast of Salem. Where present, water-bearing sandstones occur within the upper 150 to 200 feet of bedrock.
GUIDE TO THE ROUTE

Assemble near shelter one in Bryan Memorial Park (SE SW SE Sec. 2, T2N, R2E, 3rd P.M., Marion County; Salem North 7.5-Minute Quadrangle [38088F8]*). Mileage calculations will start at the intersection of East Boone Street and Broadway/State Route (SR) 37.

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

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

• 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 (because of trespass laws and liability constraints) get permission from property owners or their agents before entering private property.

<table>
<thead>
<tr>
<th>Miles to next point</th>
<th>Miles from start</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.0</td>
<td>0.0</td>
</tr>
<tr>
<td>STOP (2-way): Intersection of East Boone Street and North Broadway. TURN RIGHT (south) onto Broadway (SR 37).</td>
<td></td>
</tr>
<tr>
<td>0.4</td>
<td>0.4</td>
</tr>
<tr>
<td>CAUTION: Enter Salem business district. CONTINUE AHEAD (south).</td>
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</tr>
<tr>
<td>0.1</td>
<td>0.5+</td>
</tr>
<tr>
<td>CAUTION: Stoplight with US 50. CONTINUE AHEAD STRAIGHT (south) on Broadway (SR 37).</td>
<td></td>
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<tr>
<td>0.1+</td>
<td>0.6+</td>
</tr>
<tr>
<td>William Jennings Bryan's boyhood home on the left, 408 South Broadway, 2nd building south of Elm street. CONTINUE AHEAD (south).</td>
<td></td>
</tr>
<tr>
<td>0.2</td>
<td>0.8</td>
</tr>
<tr>
<td>CAUTION: Baltimore and Ohio (B&amp;O) railroad crossing (2 tracks). CONTINUE AHEAD (south).</td>
<td></td>
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<tr>
<td>0.15+</td>
<td>0.95</td>
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<tr>
<td>CAUTION: Missouri-Illinois (MI) railroad crossing (1 track, abandoned). CONTINUE AHEAD (south).</td>
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</tr>
<tr>
<td>0.05+</td>
<td>1.0</td>
</tr>
<tr>
<td>On both sides of the highway, notice that a number of firms from here on south in Salem have oil-field equipment (tanks, pumps, and drilling supplies) for sale. CONTINUE AHEAD (south).</td>
<td></td>
</tr>
</tbody>
</table>

* The number in brackets [38088F8] 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.
Prepare to turn right just ahead, part way through the left curve.

BEAR RIGHT (south) on South Washington, a blacktop street.

STOP (1-way); T-intersection, South Washington with West Kell. TURN RIGHT (west).

Intersection of S. College and West Kell, Stop (2-way); CONTINUE AHEAD (west).

Cross over I-57. CONTINUE AHEAD (west).

STOP (2-way); T-intersection (900N, Cross Rd., and 900E, Hotze Rd.). TURN LEFT (south) on blacktop.

Road curves to the right.

Cross Vermilion Creek. Road curves to the left.

CAUTION: T-intersection with 2-way stop (850N, Red Stripe Rd., and 875E, Hotze Rd.). BEAR LEFT (south) on 875E.

T-road (dead end) from the left. CONTINUE AHEAD (south).

CAUTION: T-intersection with 1-way stop (750N, Lazy Acres Rd., and 875E, Hotze Rd.). TURN LEFT (east). CAUTION: Traffic from right is obscured by a hill.

CAUTION: Road curves to the RIGHT 90 degrees, heading south.

CAUTION: Road jogs to the right, crosses Crooked Creek, and jogs to the right again. Note the illegal trash dump below the bridge.

T-intersection from left (700N, Church Rd.). CONTINUE AHEAD (south).

Pull over and park vehicles on the right edge of the road.

STOP 1 We'll discuss the abandoned coal drift mines (probably from the middle 1800s) in the Belle Rive Coal bed located on the west side of the road (fig. 12) and examine the upper Pennsylvanian section exposed in the creek (SE NE SE NE, Sec. 33, T2N, R2E, 3rd P.M., Marion County; Salem South 7.5-Minute Quadrangle [38088E8]).

Note the disrespect shown to the earth and the landowner by the amount of trash that has been dumped into the creek at the culvert.

Here we have our first opportunity to examine exposures of Pennsylvanian bedrock as they are typically found in the field trip area. Pennsylvanian bedrock is present at shallow depths throughout the area beneath a thin veneer of soil and unconsolidated Illinoian glacial material. The Pennsylvanian rocks consist primarily of clastic material (e.g., shale, siltstone, and sandstone) with minor amounts of coal, black shales, limestones, and underclays.
Outcrop exposed along creek

<table>
<thead>
<tr>
<th>Top</th>
<th>Covered</th>
<th>Sandstone</th>
<th>Clay/siltstone</th>
<th>Shale</th>
<th>Coal</th>
<th>Base</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Soil</td>
<td>Medium to thin bedded with thin cross bedded laminations, lower part contains plant material; 3–4 ft.</td>
<td>Thin, fissile; 2 ft.</td>
<td>Black, fissile weathered and slumped; 2 ft.</td>
<td>Weathered, covered by slumped shale and talus; 2 ft.</td>
<td>At creek bed</td>
</tr>
</tbody>
</table>

The Pennsylvanian rocks are normally not found in large exposures but are usually quite limited in extent. Most exposures in Marion County are restricted to the more resistant units such as sandstones (as we see here and at a couple of other stops) or limestones (as we will see later in the day). The other clastics that typify the Pennsylvanian (i.e., shales and siltstones) are not very resistant to erosion. They typically become weathered, slumped, covered by the overlying unconsolidated materials, and overgrown with vegetation.

We can see the lower Mattoon Formation at this site (fig. 13) where a thin coal was mined many years ago in the old drift mines, represented by the scars seen in the lower part of the slopes above the streams (fig. 12). Although we know very little about these mines, which probably operated sometime in the middle 1800s, some information indicates that this coal is likely correlative with the Belle Rive Coal. At this location, the coal was about 2 feet thick, but it is highly variable. Old notes indicate that the coal was only 15 inches thick just 1 mile east-southeast of here.

We are able to place this location stratigraphically in the lower Mattoon because of the presence of the Belle Rive Coal, which can be identified by specific fossils (spores) in the coal. Thus, we know the sandstone here occurs just above the Belle Rive Coal. Later in the trip, we will examine similar sandstones that are somewhere in the middle of the Mattoon but, because of the similarity of sandstones, we are not able to place them as precisely within the formation. Without the presence of some distinctive features and widespread exposures that would allow physical correlation, geologists find it difficult to map the sandstones in the upper Pennsylvanian of this area. Many of these sandstones are discontinuous lenticular bodies of rock, so we encourage you to note how this sandstone looks and compare it with sandstones at stops to be visited later in the trip.

Figure 12 Old collapsed drift mine entrances at Stop 1.
<table>
<thead>
<tr>
<th>System</th>
<th>Series</th>
<th>Group</th>
<th>Formation</th>
<th>Coal</th>
<th>Limestone and sandstone</th>
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<tr>
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<td></td>
<td></td>
<td></td>
<td></td>
<td>Woodbury Ls</td>
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<td></td>
<td>Gila Ls</td>
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<td>Greenup Ls</td>
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<td></td>
<td>Reisner Ls</td>
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<td></td>
<td></td>
<td>Sequence uncertain</td>
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<td></td>
<td>Bogota Ls</td>
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<td>Effingham Ls</td>
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<td>Shumway Ls</td>
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<td>Omega-Bonapas Ls</td>
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<td>Miller'sville-Livingston Ls</td>
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<td>Reel Ls</td>
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<td>Mt. Carmel Ss</td>
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<td>Carthage Ls</td>
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<td>Macoupin Ls</td>
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<td>Cramer Ls</td>
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<td>Trivoli Ss</td>
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<td></td>
<td>West Franklin and Lonsdale Ls</td>
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<td>Danville</td>
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<td>Herrin</td>
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<td>Springfield</td>
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Figure 13 Generalized Pennsylvanian stratigraphic column showing key middle and upper Pennsylvanian named members in the field trip area (adapted from Nance and Treworgy 1981).
0.0 6.3 Leave Stop 1 and CONTINUE AHEAD (south).

0.2 6.5 STOP (1-way); T-intersection (650N, Nation Rd., and 900E, Hotze Rd.). TURN RIGHT (west). CAUTION: Fast moving traffic.

0.25 6.75 T-intersection, 1-way stop from the left (875E, Branch Rd). CONTINUE AHEAD (west).

0.5 7.25 T-intersection from the right (825E, Miles Ln.). CONTINUE AHEAD (west).

0.15 7.4 To the right are several pump jacks in the Salem Oil Field.

0.1 7.5 T-intersection from the left (800E, Shag Bark Rd.). CONTINUE AHEAD (west).

0.15+ 7.65 CAUTION: Cross culvert; road is very rough ahead.

0.15 7.8 STOP (1-way). Intersection (650N, Nation Rd., and 775E, Selmaville Rd.). CAUTION: visibility from the right is poor because of the curve; traffic is fairly fast. CONTINUE AHEAD (west and then south) on the Selmaville blacktop.

0.05 7.85 T-intersection from the right occurs in middle of large curve (760E, Watson Ln.). CONTINUE AHEAD.

0.15 8.0 T-intersection from the right (unmarked). CONTINUE AHEAD (south).

0.35 8.35 CAUTION: Enter "S" curve.

0.1 8.45 T-intersection from the left (600N, Scout Rd.). CONTINUE AHEAD (south).

0.15 8.6 Cross Martin Branch, which drains Lake Centralia, just to the left (east). PREPARE TO TURN LEFT, 200 FEET AFTER CROSSING THE BRIDGE. Turn left onto the spillway-access road. We will resume our mileage from the blacktop.

STOP 2 We’ll examine and discuss one of the best exposures of loess in the area. The outcrop is about 18 to 20 feet thick and is located at the west end of the concrete spillway, on the north side of Martin Branch (SW NW NE, Sec. 5, T1N, R2E, 3rd P.M., Marion County; Centralia East 7.5-Minute Quadrangle [38089E1]).

The Lake Centralia spillway exposes the Peoria Loess and Roxana Silt overlying the Vandalia Till Member of the Glasford Formation (figs. 14 and 15). These sediments have been highly altered by soil-forming processes during three different warm intervals between glaciation; they are all leached of their original calcite and dolomite content. Some study is required to distinguish between these sediments. Leon R. Follmer, ISGS geologist and soil scientist, was most helpful in interpreting the soil characteristics encountered here.

The Modern Soil is developed in the top of the Peoria Loess, which is about 5 to 6 feet thick here. Tiny pores, iron and manganese stains, brown clay skins on some ped faces, insect or worm burrows, and rootlets and root traces can all be found here. A sample taken approximately 4 1/2 feet
from the top is leached; the clay content and the clay skins indicate that this depth is a weakly expressed B horizon of the Modern Soil developed in the Peoria Loess.

The slightly sandier, browner Roxana Silt underlies the Peoria here and is approximately 3 feet thick. The features exhibited in the Roxana, such as ped faces covered with iron-stained thin clay coats and lighter colored surfaces on some of the peds, indicate that this is near the top of an earlier soil, the Farmdale Soil. (The Farmdale is a weakly developed soil formed during a cool climate in a boreal [northern] forest prior to the last glaciation.) Some of the complexities in this unit are evidence of its burial by a later material (the Peoria Loess) with the modern soil development superimposed on it.

Underlying the Roxana is about 6 1/2 feet of Berry Clay, an accretionary sandy sediment that accumulated during the formation of the Sangamon Soil. It is a more strongly weathered zone commonly referred to as a paleosol, a general term for old soil, which is usually buried by younger sediments. Typical of the Berry Clay are several characteristics: it lacks pebbles and coarse sand, the sand fraction of the material is commonly very rich in fine sand, and it exhibits a gray color with a brownish yellow tint in exposures, indicating that it is mildly oxidized. The Berry Clay can be a bluish or greenish gray in fresh exposures. A sample collected about 10 inches from the top is from a B horizon that has dark clay skins on some of the peds.
About 2 feet of a heterogeneous mixture of grain sizes is exposed beneath the Berry Clay. This mixture could represent an ablationary phase of the Vandalia Till Member of the Glasford Formation, or it could be a sandy diamicton often found as part of the Hagarstown Member of the Pearl Formation. Because the mounds and ridges of the Hagarstown generally occur on the Illinoian Till Plain, whereas this exposure is in a valley tributary to Crooked Creek, we interpret this diamicton as ablationary-phase Vandalia Till rather than Hagarstown. The weathered nature of this interval represents the lower part of the B horizon of the Sangamon Soil, with large peds and multi-colored stains and mottles.

The lowest unit exposed is a clayey, silty, fine to medium sand with a few coarser grains; it is less oxidized than the overlying material. Although the material underlying this sand is not exposed here, experience elsewhere across the region leads us to expect that Vandalia Till underlies this material. Our interpretation is that this is either ice-contact material at the surface of the Vandalia or a lens of sand within the uppermost Vandalia.

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### STOP 3

We'll discuss the history of the Texas Oil Company, No. 1 Tate well and the geology of the Salem Oil Field (NW SE NW NW, Sec. 5, T1N, R2E, 3rd P.M., Marion County; Centralia East 7.5-Minute Quadrangle [38089E1]).

The Salem Oil Field is located in T1–2N, 1S, and R1–2E, Marion and Jefferson Counties. Surrounding this location are a number of oil fields that produce from various formations. Each field lies over an area where oil is trapped in porous rocks. Figure 16 is a small-scale map of the oil fields in the Illinois Basin. There are several kinds of oil traps found in Illinois (fig. 17), and they are rarely easy to locate. Geologists use many techniques to predict the type of trap, as well as how and where to find them.

The Pennsylvanian rocks occur immediately beneath the surficial deposits at this stop. They were deposited about 290 million years ago. If we could see these rocks, we would notice that they are very slightly arched or folded into an anticline that trends in a northern direction. It is common for oil to become trapped in porous rocks along the crest of such structures (fig. 17b).
Figure 16 Oil fields of the Illinois Basin.

The Salem Oil Field has an interesting history. The Benoist brothers from the Sandoval area, about 7 miles northwest of here, leased a considerable acreage in this vicinity in the late 1920s and early 1930s to test for oil. Two of their tests failed and when they sought additional funding from bankers to deepen their third well, they were refused and had to give up. Four years after the Benoist's lease expired, the Texas Company, which had been conducting seismic exploration in this area since 1934, drilled a test well that recovered a 17-foot, oil-saturated core of "Benoist sand" from a depth of 1,692 to 1,709 feet (fig. 2); this was only 36 feet deeper than the Benoist brothers had drilled nearby! The well was drilled into the Mississippian Ste. Genevieve Limestone at a total depth of 1,918 feet and completed as a commercial producer on July 1, 1938. Oil gushed out of the hole and shot upwards and over the top of the derrick ("a gusher") with such
force that it took nearly an hour to get the well under control. Initial production from this well, which included oil from the Benoist, Renault, and underlying Aux Vases sands, was 534 barrels of oil and no water in 12 hours. In March 1959, the well was plugged back to 1,728 feet and converted into an injection well into the Benoist sand. The Benoist sand averages 45 feet thick in the Salem field and the closure on the top of the sand is 200 feet. The concrete monument commemorating this event (fig. 18) reads as follows:

THE TEXAS COMPANY
No.1 TATE
This monument marks the site of the discovery well, opening the Lake Centralia-Salem Oil Pool
Completed June 21, 1938
Presented to
The Texas Company by the members of the Salem Lions Club in the name of the City of Salem, Illinois

Figure 17 Places where oil is found in Illinois: (a) coral reefs, (b) anticlines, (c) pinchouts, and (d) channel sandstones.
In January 1938, The Texas Company had no production in the state. By December 1, 1939, the Salem Oil Field became the second largest producer in the nation. The average daily production from the field during June 1939 was 133,643 barrels; by July 1, 1939, total field production was 20,080,000 barrels, at a price of $1.05/barrel. By February 1940, the average daily production increased to 229,000. Production peaked in May 1940 at 261,000 barrels of oil per day. The Salem Field has 10 producing horizons (layers): Benoist (Miss.), Renault (Miss.), Aux Vases (Miss.), Ohara (Miss.), Spar Mountain (Miss.), McClosky (Miss.), St. Louis (Miss.), Salem (Miss.), Devonian, and Trenton (Ord.). By the end of 1987, a total of 2,918 wells had been completed in the field, but only 1,310 currently produce oil.

Oil and Water Production

In a typical oil production unit, the water produced with the oil is removed using separators—large cylindrical tanks with stacks protruding from the top (fig. 19). Separators work by using the tendency of oil to float on water. The oil and water mixture is pumped into the separator, and the oil is skimmed off from the top of the tank. Separators are heated in the winter with gas from the field to speed the separation.

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**Texaco Exploration and Production Inc.**
(prepared by Michael Redding of Texaco Pipeline, Inc.)

Texaco has been a viable part of this area for 57 years and is still looking to invest in the future. The Salem field was discovered June 21, 1938, by the Texas Company, now known as Texaco. Over the years, Texaco has been a strong economic force in the community.

According to Texaco's Salem Area Manager Jim Hankinson, Texaco still has a considerable economic impact on the area and the potential for long-term profitability. Reviewing Texaco's current producing field operations Jim Hankinson said, "We currently employ 39 people, down considerably from the field's prolific years, but it still translates into a payroll of $1,600,000 a year. In addition, Texaco uses $950,000 a year for contractors. This, combined with the $600,000 worth of supplies purchased in the area and taxes of $210,000, means the economic impact on the Salem community is over $3.3 million dollars during last year. We've also made considerable capital investments over the years. Just in the last 5 years Texaco has spent $20 million to drill new wells, work-over existing wells, replace equipment, and make facility and field modifications. Over the years we've invested a considerable amount to make this a viable and productive field, and we're proud to be a part of the Salem community."

"Texaco still has extensive plans for the Salem unit. Plans include drilling additional wells, performing more work-overs, and possibly conducting extensive high-technology geological research. We still have great expectations for this unit and plan to produce in this area well into the future," said Jim Hankinson. However, Hankinson said that several issues remain for Texaco and the entire oil industry in the Illinois Basin. Unstable oil prices, increased costs, and declining production are all challenges that must be overcome to ensure the future of the industry. "We're meeting these challenges head-on and are optimistic about the future," said Hankinson.

Texaco's Salem Unit achieved peak production of 261,000 barrels of oil per day in 1940. Today the unit produces 2,600 barrels of oil per day from 200 producing wells. Total production to date from the Salem field is 362 million barrels. The Salem field, over its life span, is one of the largest producing fields in the United States.
Petroleum Geology
In the search for petroleum, geologists must attempt to identify four factors to develop a clear understanding of the potential a location has for an accumulation of oil and gas. The first consideration is locating an original source for the oil and gas. Source rocks must be rich in organic matter and must have been naturally heated to a point where the organic material began to be converted to hydrocarbons and expelled from the source. The hydrocarbons must then migrate toward a layer of reservoir rock. A reservoir, which can be thought of as a natural underground container of oil, gas, and water, is the second factor that must be identified. A reservoir must have enough porosity (the amount of voids, pores, and other openings in the rock) to store the oil and gas, and enough permeability (the amount of interconnected porosity) to deliver the oil and gas into a well bore drilled through the rock. The third factor that must be identified is the nature of the reservoir's seal. A seal is another layer of rock, usually overlying the reservoir, that has poor porosity and/or permeability. It effectively seals the reservoir and generally prohibits the vertical migration of oil and gas from the reservoir rock.

The fourth factor is the trapping mechanism. A trap is the geometric arrangement of reservoir rocks and seals so that the migration of petroleum is halted, and can be thought of as the final resting place for a given accumulation of oil and gas. In order to drill for a possible accumulation of oil and gas, the trap must be large enough and/or thick enough to make its development economic. Generally, traps are either structural or stratigraphic in nature. Structural traps are the most common type because they are generally the easiest to find. They typically form when layers of rock are folded (bent) by Earth's natural forces into geometric shapes called anticlines (see fig. 17). An anticline is a fold that is convex upward and can be thought of as an underground hill. Stratigraphic traps are typically formed when the physical properties of a reservoir rock change along its length or lateral extent. An example of a stratigraphic trap would be a sandstone bed with good porosity and permeability that laterally changes into a shale bed. The shale would have poor permeability and would trap the oil and gas in the sandstone.

The Geological Samples Library
The ISGS manages one of the largest collections of geological samples in the United States. The Geological Samples Library (GSL) is the repository for drilling samples in Illinois, as mandated by the state. The Natural Resources Studies Annex on the campus of the University of Illinois at Urbana-Champaign houses the Geological Samples Library. As of December 31, 1994, the collections contained 68,044 sets of drill cuttings from oil and water wells, representing more than 743 million total feet of drilling. The collection also includes 1 million feet of core from 13,932 drill holes. This database has long been of value to the oil and coal industries, hydrogeologists, engineers, landowners, ISGS staff, and others.

Most drill cuttings on file in the GSL collection were obtained from oil tests. The Oil and Gas Division of the Illinois Department of Mines and Minerals requests samples on permits issued by their office and administers the compliance program regarding requested samples. Samples are requested for any permit issued for a site that is (1) in an area where no samples have been obtained previously, or (2) located more than 1/2 mile from a previously drilled well for which samples are on file at the GSL. Samples are also requested if a permit is issued for a well targeted for a deeper formation within the same 1/2-mile radius. Drill cuttings from 5- or 10-foot intervals are typically saved. Upon receipt at GSL, they are sorted, washed, filed in paper envelopes, and then stored in cardboard boxes with a unique file number. The collection of cuttings presently comprises 1.5 million individual samples in more than 103,730 boxes. Data such as scout tickets and electric logs from the oil and gas wells are available at the GSL in microfiche form. The GSL also maintains a large collection of sample sets from water wells drilled throughout Illinois and holds about 37,265 miscellaneous items from various research projects. All items in the GSL collections are listed in a card catalog according to county, geographic location (township and range grid), company, lease name, depth of drill hole, type of sample, and number of boxes. For information about the availability of sample material for a particular location, you may contact the GSL staff.
1. Oil and salt water flow into the well chamber through fractures, cavities, and spaces between the grains of the rock bed that is the PRODUCING LAYER (the "oil sand" or "pay zone").

2. Motor- or engine-driven PUMP lifts the fluid out of the producing layer and pushes it through the system.

3. Gravity and heat in an oil-fired HEATER TREATER separate the oil from the salt water. Oil flows out of the top and water out the bottom.

4. Separated oil is held in the STOCK TANK until it is purchased.

5. Salt water from the heater treater either flows to a disposal well or is pumped back into the oil reservoir to help maintain pressure.

Figure 19 Schematic diagram of a common type of oil production unit in Illinois.
The core collection was obtained primarily from coal, oil, stratigraphic and mineral tests, and various shallow engineering borings. Most of the core on file was condensed from its original form, although in the last 9 years, saving the continuous core sets has been emphasized.

**Using The Samples Library** Room 102E of the Natural Resources Studies Annex contains both the Samples Library Office and the Sample Study Laboratory. The Samples Library provides visitors with ample space for studying samples.

Visitors are required to register with Samples Library Office to obtain permission to study the collections. The library staff assists visitors in sample retrieval and layout. Samples are not loaned, but selected sampling of the collection is permitted with prior approval of the Technical Services Group Head. A study area equipped with a microscope and an ultraviolet light is available for examination of samples. No fee is charged for studying samples and no appointment is necessary. For more information, contact the Geological Samples Library, Illinois State Geological Survey, Natural Resources Building, 615 E. Peabody Dr., Champaign, Illinois 61820. Phone (217) 333-3567. Hours are 8:00 a.m. to 5:00 p.m., Monday through Friday.

**ISGS Geological Records Unit**

The Geological Records Unit (GRU) is the repository for drilling records in Illinois, as mandated by law. This collection includes records from oil and gas wells, water wells, engineering borings, and miscellaneous test holes. This database has long been of value to the oil industry, coal industry, hydrogeologists, engineers, land-use planners, academic institutions, landowners, the general public, and ISGS staff.

The primary function of GRU is to collect and integrate well data into the existing database and make this information available to staff and the public. The Illinois Department of Mines and Minerals (IDMM) provides permit information about new oil and gas wells to the ISGS. Drilling operators are responsible for providing data to the Survey as required by IDMM rules. The Survey also cooperates with the Illinois Department of Public Health, the Illinois Environmental Protection Agency, and the State Water Survey to add information from public, private, and municipal water wells to the database.

The extensive GRU well-data collection contains more than 375,000 records from oil, water, and other miscellaneous wells. This ongoing collection of data contains well records from the early 1900s to the 1990s. Customer services provided by GRU include a telephone information service, visitor access to paper data files, computer searches, and the sale of paper copies of records.

**Using the Geological Records Unit** The Geological Records Library is located in room 227 of Natural Resources Building on the University of Illinois campus. There is ample space for visitors to examine records, but visitors are required to sign in at the reception desk to obtain permission to use the facility. A well-log copy service is provided at a minimal cost by GRU staff. Requests for information can also be taken by phone, mail, or telefax. For more information, contact the Geological Records Unit, Illinois State Geological Survey, Natural Resources Building, 615 E. Peabody Drive, Champaign, Illinois 61820. Phone (217) 333-5109. Telefax (217) 333-2830. Hours are 8:00 a.m. to 5:00 p.m., Monday through Friday. No appointment is necessary.

<table>
<thead>
<tr>
<th>0.0</th>
<th>9.55</th>
<th>Leave STOP 3 and CONTINUE AHEAD (north).</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.05</td>
<td>9.6</td>
<td>On the right is a pump jack, which produces from one formation, and an injection well, which is part of a secondary recovery project in a different formation.</td>
</tr>
<tr>
<td>0.1</td>
<td>9.7</td>
<td>CAUTION: Descend hill, which is pretty rough in the middle.</td>
</tr>
</tbody>
</table>
Y-intersection at the bottom of the hill. BEAR LEFT (northerly).

Y-intersection. BEAR LEFT (northwesterly).

T-intersection. TURN RIGHT (north) onto Hoots Chapel Rd..

Cross Crooked Creek.

Ascend hill (north valley wall).

TURN RIGHT: Road curves to the right. CAUTION: There is a steel pipe under the blacktop. If you cut the corner too sharply, you will drop into a hole.

TURN LEFT: Road curves to the left.

TURN RIGHT: Road curves to the right. CAUTION: Another steel pipe is under the blacktop. If you cut the corner too sharply, you will drop into a hole.

TURN LEFT: Road curves to the left.

CAUTION: Road intersection (725N, Soper Rd., and 700E, Hoots Chapel Rd.); only one stop sign from the left. TURN RIGHT (east) onto a Texaco private road. Note the five old steel derricks on this property.

Pull over and park vehicles on the right edge of the road.

STOP 4 We'll visit and discuss the North Tank Battery, Salem Unit, Texaco Pipeline Inc., Consolidated Battery No. 4, Tract 72 (SW NE SW, Sec. 29 T2N, R2E, 3rd P.M., Marion County; Centralia East 7.5-Minute Quadrangle [38089E1]).

The North Tank Battery Unit (fig. 20) serves as a centralized collection facility for a portion of the Salem Field. Production fluids (oil and water) from surrounding wells are piped to this facility and stored in the holding tanks. The oil and water is then separated via gravity and subsequently

Figure 20 View of North Tank Battery, Salem Unit, Texaco Pipeline Company, Stop 4.
piped into separate tanks. The oil is then piped to the Salem Pump Station where it is then pumped to a refinery. The separated water is piped to the water treatment plant where it is processed and recycled as an injection fluid.

The Salem Pump Station is located approximately half a mile southeast of the North Tank Battery Unit in the (NW NW NE Sec. 32 T2N, R2E, 3rd P.M., Marion County; Centralia East 7.5-Minute Quadrangle [38089E1]).

Texaco Pipeline Company Salem Pump Station
(prepared by Rick L. Barrett of Texaco Pipeline, Inc.)

Salem Pump Station is a typical crude-oil pipeline pump station that gathers crude oil from various oil leases through smaller pipelines and pumps it to a refinery. It consists of a storage tank, measurement equipment, pumps, Supervisory Control and Data Acquisition (SCADA) equipment, and corrosion prevention equipment.

The storage tank is used to gather oil coming into the station at different flow rates from many leases and allows the pump station to operate efficiently. Pipeline pumps are most efficient when they can pump 24 hours a day, 7 days a week. This tank is equipped with an internal floating roof and efficient scales to minimize any air emissions.

The measurement equipment is sometimes referred to as an ACT, or Automatic Custody Transfer, unit when it is equipped like the unit at Salem Station. It measures oil through a positive displacement meter and corrects the volume for temperature and pressure effects. This unit is also equipped with a sample probe and sample tank that allow us to verify the quality of the crude pumped through the skid.

The pumps consist of two duplex piston pumps and a small centrifugal charge pump on the ACT unit. The positive displacement pumps are 95% efficient. They are configured to pump fluid on each stroke of the piston. The centrifugal pump uses centrifugal force from a rotating impeller to pump the fluid. Larger versions of the centrifugal pumps are used at major pipeline pump stations.

The SCADA system consists of computer control and communication equipment that allows us to remotely control and monitor the pipeline system. An operator from a central control point monitors and commands a computer that is constantly monitoring the pipeline system. The operator and the computer system can take measurement information from both ends of the pipeline and determine the integrity of the pipeline system at all times.

The Corrosion Prevention System consists of an Internal Cleaning system and a Cathodic Protection system.

1 The Internal Cleaning process prevents internal corrosion by removing any paraffin buildup and water in the pipelines. The receiving trap, seen south of the station, is where the cleaning scrapers or "pigs" are removed. A similar trap is used to insert the pigs.

2 The Cathodic protection system consists of a pole mounted DC Rectifier unit and impressed current Anodes that apply a Potential or Voltage to the pipeline system to prevent external corrosion. The Pipeline is also coated with special coatings to prevent corrosion.

3 Another form of Cathodic Protection is a sacrificial Magnesium Anode. This is the same anode that is used in water heaters to prolong the life of the tank.

Another way we protect our pipeline systems is by using airplanes to patrol our lines. The pilots report any digging activity near our lines so that we can prevent damage to our pipeline systems. Pipelines are the safest and most efficient way to transport petroleum liquids today. We ask that you always call JULIE at 1-800-892-0123 before you dig so that we can continue to keep pipelines safe by preventing excavation damage.
<table>
<thead>
<tr>
<th>Mileage</th>
<th>Time</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.0</td>
<td>11.65</td>
<td>Leave Stop 4 and CONTINUE AHEAD (northerly).</td>
</tr>
<tr>
<td>0.2</td>
<td>11.85</td>
<td>T-road intersection; TURN LEFT (west) on 750N, Lazy Acres Rd.</td>
</tr>
<tr>
<td>0.3+</td>
<td>12.15</td>
<td>STOP (1-way), T-intersection (750N, Lazy Acres Rd., and 700E, Hoots Chapel Rd.). TURN RIGHT (north) onto Hoots Chapel Rd.</td>
</tr>
<tr>
<td>0.25</td>
<td>12.4</td>
<td>Illegal trash dump at an old home site on the left side of road.</td>
</tr>
<tr>
<td>0.6</td>
<td>13.0</td>
<td>Abandoned railroad crossing of Missouri-Illinois (MI).</td>
</tr>
<tr>
<td>0.1</td>
<td>13.1</td>
<td>STOP (2-way), crossroad (850N, Red Stripe Rd., and 700E, Hoots Chapel Rd.). TURN RIGHT (east) onto Red Stripe Rd.</td>
</tr>
<tr>
<td>0.25</td>
<td>13.35</td>
<td>Abandoned railroad crossing of Missouri-Illinois (MI).</td>
</tr>
<tr>
<td>0.5</td>
<td>13.85</td>
<td>CAUTION: Approaching dangerous intersection (775E, Selmaville Rd., and 850N, Red Stripe Rd.). CONTINUE AHEAD (east) but look to the right (south) to note approaching traffic that might affect you.</td>
</tr>
<tr>
<td>0.05+</td>
<td>13.9+</td>
<td>STOP (1-way). You are entering Selmaville blacktop road on the far side of the curve from the right. CONTINUE AHEAD (east) with EXTREME CAUTION.</td>
</tr>
<tr>
<td>0.15-</td>
<td>14.05</td>
<td>Leave the Selmaville blacktop (800E) where it curves to the left and CONTINUE AHEAD (east) on Red Stripe Rd. (850N) past the Youngs Grand Prairie Christian Church. The community of Selmaville lies to the left (north).</td>
</tr>
<tr>
<td>0.15</td>
<td>14.2</td>
<td>T-intersection from the right (800N, Telford Ln.). CONTINUE AHEAD (east).</td>
</tr>
<tr>
<td>0.6</td>
<td>14.8</td>
<td>STOP (2-way), T-intersection (850N, Red Stripe Rd., and 875E, Hotze Rd.). TURN LEFT (northerly) onto 875E, Hotze Rd. and retrace a portion of the itinerary.</td>
</tr>
<tr>
<td>0.25+</td>
<td>15.05</td>
<td>Cross Vermilion Creek.</td>
</tr>
<tr>
<td>0.15</td>
<td>15.2</td>
<td>Road curves to the left.</td>
</tr>
<tr>
<td>0.25</td>
<td>15.45</td>
<td>CAUTION: T-road from the right (900N, Cross Rd). CONTINUE AHEAD (north) on 900E, Hotze Rd.</td>
</tr>
<tr>
<td>0.5+</td>
<td>15.95</td>
<td>Abandoned (MI) railroad crossing, the rails are still on the right side of the road.</td>
</tr>
<tr>
<td>0.45</td>
<td>16.4</td>
<td>CAUTION: Road curves to the right and then to the left.</td>
</tr>
<tr>
<td>0.15</td>
<td>16.55</td>
<td>CAUTION: Unguarded Baltimore and Ohio (B&amp;O) railroad crossing (1-track). CONTINUE AHEAD (north).</td>
</tr>
<tr>
<td>0.15-</td>
<td>16.7</td>
<td>STOP (2-way), crossroads (Hotze Rd. and West Main St.). TURN RIGHT (east) onto West Main St. (US 50). There should not be too much trouble making a right turn here because it is a divided 4-lane highway. In addition,</td>
</tr>
</tbody>
</table>
there is a turn lane for the interstate and a wide emergency strip on the right side. TURN RIGHT toward Salem.

0.2 16.9 Pass beneath the I-57 overpass.

0.4 17.3 CAUTION: TURN RIGHT (south) from West Main Street onto Westgate Avenue (not marked) across from McDonald's.

0.2+ 17.5 CAUTION: Cross unguarded (B&O) railroad crossing (1 track). CONTINUE AHEAD (south).

0.1+ 17.6 STOP (1-way); T-intersection (Westgate Avenue and West Blair). TURN LEFT (east) onto West Blair.

0.1+ 17.7 CAUTION: Road jogs to the right and crosses an unguarded (MI) railroad crossing (1 track). CONTINUE AHEAD (east).

0.35 18.05 CAUTION: Narrow bridge over culvert. The street jogs right slightly and then straightens out eastward.

0.15 18.2 Pull over and park on the right side of the road near (but do not block) the fire hydrant.

**STOP 5** We will view (to the north) the abandoned site of the Salem Coal Co. No. 1 Mine. (680 fsl and 1400 fwl, Sec. 11, T2N, R2E, 3rd P.M., Marion County; Salem South 7.5-Minute Quadrangle [38088E8]).

The Salem Coal Company operated a shaft mine in this area between 1887 and 1908. The coal is located 885 feet below the surface and is 48 to 58 inches thick. The mine was operated as a room and pillar mine and removed 101,142 tons of coal. The mined-out area covers approximately 10 acres.

0.0 18.2 Leave Stop 5 and CONTINUE AHEAD (east) on West Blair Street.

0.25 18.45 STOP (1-way), T-intersection with South College Avenue. TURN LEFT (north) and immediately cross one set of unguarded tracks of the abandoned MI railroad.

0.15- 18.6 CAUTION: guarded (B&O) railroad crossing (3 tracks), with a siding beyond them. CONTINUE AHEAD (north).

0.3 18.9 CAUTION: stoplight. Intersection of West Main Street (US 50) and College Avenue. CONTINUE AHEAD (north) on College Avenue.

0.55+ 19.45 CAUTION: Intersection of College Avenue and Boone Street. TURN RIGHT (east) onto Boone Street.

0.05 19.5 Cross Town Creek

0.1 19.6 TURN LEFT: Into Bryan Memorial Park.
STOP 6  LUNCH, ARE YOU HUNGRY NOW? We will be using shelters number 1 and 2. Note: We will restart our mileage at 0.0 at the park entrance on Broadway. Immediately after lunch we will discuss some of the environmental geological research that is conducted by the Environmental Geology Section of the ISGS.

Across the park, you can see the statue of William Jennings Bryan ("The Great Commoner" and "The Silver Tongued Orator"). Gutzon Borglum of Mt. Rushmore fame created this bronze statue in 1934. The statue was displayed in Washington, D.C., briefly before Salem obtained it and moved it here. Although Bryan only spent his first 15 years in Salem beginning in March 1860, he often visited during his career as an attorney, newspaper editor, and politician. He was the prosecutor in the famous Scopes "Monkey Trial," a congressman, Secretary of State under Woodrow Wilson, and three-time Democratic candidate for the presidency of the United States. The local newspaper, the Salem Times-Commoner, was named for the Great Commoner (Anonymous 1994).

Environmental Assessments
An environmental assessment is performed to identify environmental hazards and concerns that may be associated with a piece of property. Assessments are typically performed to alert a new owner to current property conditions when ownership of property changes. Assessments are most commonly performed on commercial property, but residential property can be subject to environmental problems as well. State law requires property owners to disclose environmental conditions of which they are aware, but it is often a good idea for buyers to do their own research to identify additional concerns.

An environmental assessment generally includes research of published environmental documents and historical property uses, a visit to the property and, if warranted, professional testing of soil and water. The ISGS has many publications and resources useful for identifying and understanding environmental hazards including mine subsidence, flooding, earthquakes, landslides, wetlands, and radon gas. Other sources of information include the owner, the real estate agent, neighbors, city and county government, state and federal agencies, the local library, the local historical society, and the nearest university.

ISGS-IDOT Program
To identify environmental conditions that should be included in highway construction plans, the Illinois Department of Transportation (IDOT) and the ISGS began a program in 1989 to identify both naturally occurring and man-made environmental hazards located within existing and proposed highway right-of-ways. Since April 1989, the ISGS Environmental Assistance Unit and Engineering Geology Section have completed research on more than 700 projects state-wide, including more than 100 projects in southern Illinois (IDOT districts 7, 8, and 9).

The ISGS reports provide IDOT with an overview of the areal geology and hydrogeology and more detailed information on environmental hazards. Specifically, the reports identify naturally occurring conditions such as wetlands, landslides, flood-prone areas, and earthquake hazards as well as human-induced hazards such as soil contamination and mine subsidence. IDOT may respond by altering project plans to avoid problem areas or, if avoidance is not possible, IDOT may mitigate or remediate. Mitigation is an effort to minimize the impact of construction; for example, if a wetland is to be destroyed, a new one would be constructed nearby. The ISGS Lakes, Streams, and Wetlands Unit works with IDOT to ensure that these new wetlands will be successful. Remediation usually refers to the clean-up of environmental contamination, and IDOT hires private environmental consultants to plan and conduct the removal of hazardous substances.
<table>
<thead>
<tr>
<th>Mileage</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.0</td>
<td>Leave STOP 6. NOTE: We will exit the park from the entrance on North Broadway. TURN RIGHT onto Broadway (SR 37).</td>
</tr>
<tr>
<td>0.05</td>
<td>To the left is the statue of William Jennings Bryan.</td>
</tr>
<tr>
<td>0.05</td>
<td>Intersection of Boone Street and Broadway (SR 37). CONTINUE AHEAD (south).</td>
</tr>
<tr>
<td>0.1</td>
<td>Cross Town Creek. Note the use of concrete slabs along the creek banks to help control erosion.</td>
</tr>
<tr>
<td>0.2</td>
<td>CAUTION: Enter Salem business district. CONTINUE AHEAD (south).</td>
</tr>
<tr>
<td>0.2</td>
<td>CAUTION: Stoplight Intersection of Broadway (SR 37) and Main (US 50). TURN LEFT (east) on Main (US 50).</td>
</tr>
<tr>
<td>0.1</td>
<td>CAUTION: Stoplight at Jefferson Street. CONTINUE AHEAD (east).</td>
</tr>
<tr>
<td>0.4</td>
<td>Underpass, Missouri-Pacific (Mo Pac) railroad. CONTINUE AHEAD (east)</td>
</tr>
<tr>
<td>0.9</td>
<td>Cross Crooked Creek.</td>
</tr>
<tr>
<td>0.2</td>
<td>Intersection of Radio Tower Rd. and East Main. CONTINUE AHEAD (east).</td>
</tr>
<tr>
<td>0.65</td>
<td>CAUTION: Prepare to turn right.</td>
</tr>
<tr>
<td>0.15</td>
<td>CAUTION: Intersection of US 50 and 1300E, County Farm Rd.. TURN RIGHT (south) onto County Farm Rd. Note: the sign is missing.</td>
</tr>
<tr>
<td>0.5</td>
<td>CAUTION: Unguarded (B&amp;O) railroad crossing (1-track). Look both ways. CONTINUE AHEAD (south).</td>
</tr>
<tr>
<td>0.65</td>
<td>Cross Brubaker Creek.</td>
</tr>
<tr>
<td>0.35</td>
<td>CAUTION: Intersection of 1300E, County Farm Rd., and 900N, Cross Road (2-way stop). CONTINUE AHEAD (south).</td>
</tr>
<tr>
<td>1.0</td>
<td>CAUTION: Intersection of 1300E, County Farm Rd., and 800N, Apple Ridge Road (2-way stop). CONTINUE AHEAD (south). NOTE: To the east is a good view of Apple Ridge, the highest land surface on the field trip route.</td>
</tr>
<tr>
<td>0.5</td>
<td>CAUTION: Intersection of 1300E, County Farm Rd., and 750N, Cardinal Ln. not marked (2-way stop). TURN LEFT (east) onto 750N. CAUTION: rough dirt road, muddy when wet.</td>
</tr>
<tr>
<td>0.15</td>
<td>CAUTION: Narrow road at culvert crossing creek.</td>
</tr>
<tr>
<td>0.3</td>
<td>CAUTION: Intersection (750N, Cardinal Ln., and 1325E, Nattier Rd.) TURN LEFT (north) onto 1325E, Nattier Rd.</td>
</tr>
<tr>
<td>0.15</td>
<td>Pull over and park vehicles on the right edge of the road.</td>
</tr>
</tbody>
</table>
STOP 7 At Apple Ridge, we'll discuss the nature of the topography surrounding the area of Salem (SE NE SE NW, Sec. 29 T2N, R3E, 3rd P.M., Marion County; Salem South 7.5-Minute Quadrangle [38088E8]).

We are on Apple Ridge, a prominent mound whose highest point is at least 610 feet above mean sea level (msl) and approximately 80 feet above the surrounding landscape, which is at about 530 feet msl. The road at its highest point here is about 20 feet below the crest of the mound, which is 1/2 mile wide and as much as 1 mile long. The prominent feature of this mound can be illustrated by outlining its contours on a topographic map (see the highlighted area on the route map).

This feature can be interpreted in two different ways. One interpretation is that it is part of the "ridged drift" complex composed of ice-contact material that extends southwestward from the Shelbyville Moraine in Shelby County to the bluffs above the American Bottoms in St. Clair County. The other interpretation is that it is a bedrock-cored hill covered by thin glacial drift.

The mounds and ridges of the ridged drift complex (the first interpretation) are composed of sand, gravel, silt, and gravelly diamicton. These sediments are assigned stratigraphically to the Hagarstown Member of the Pearl Formation. The origin of the ridged drift is controversial. The ridges and knolls may have originated as kames and eskers (kames are mounds of sand and gravel formed when meltwater plunged into crevasses near the ice front and dropped its load of sand and gravel; eskers are long, narrow, sinuous ridges of sand and gravel deposited by meltwater streams flowing underneath a glacier). They may also have formed as infilling of crevasses in the abating ice by meltwater laden with sand and gravel. An alternative explanation is that the Lake Michigan Lobe of the Illinoian glacier was deflected westward by one or more glacial lobes advancing simultaneously from farther east, perhaps out of the Lake Huron basin. The "interlobate" area between the two ice lobes might have resulted in a complex interfingering and coalescing of the ice margins. In this scenario, the eastern lobe extended all the way to the present-day Mississippi River valley from St. Louis southward to its limit, and the deflected Lake Michigan Lobe spread westward across what is now the Illinois River valley and crossed the present Mississippi River valley into Iowa from Hancock County to Carroll County.

The second interpretation is more likely in this case, although we would actually have to drill a hole here to prove or disprove this interpretation. The larger, smoother hills and knolls such as this one are interpreted to be glacially smoothed sandstone hills. The fact that no closed depressions exist on this and similar features is nearly diagnostic. Such closed depressions, along with a northeast-southwest trend, on a more irregularly shaped feature are more likely to turn out to consist of Hagarstown sediments. A careful study of many such features carried out in Effingham, Fayette, and Marion Counties in 1980 shows that many such hills and mounds on the landscape here are loess overlying thin weathered drift over sandstone. A quick perusal of water-well records at the ISGS shows sandstone occurring at a depth of about 15 feet to the north-northeast of the crest of this hill; another record from the southeast corner of section 29 indicates rock at a depth of 13 feet. To the north and northwest, two water-well records show till over sand and gravel at depths of approximately 30 to 50 feet. Our interpretation is that the glacier, following the easiest path as it advanced southwestward, probably scoured out some bedrock as it came into contact with the sandstone knoll, then moved around and over the sandstone. The topographic "tongue" extending southwestward from the hill probably consists of sand and gravel outwash as the ice advanced rapidly downslope from the sandstone crest. Generalizing from this specific feature to a number of similar features in the area, therefore, one can surmise that such mounds in general may reflect the interaction between glacial processes (differential erosion and deposition of the ice) and the isolated sandstone hills that comprise the part of the original topography of the bedrock surface in this region.
0.0 6.6 Leave Stop 7, CONTINUE (north).

0.4 7.0 CAUTION: T-intersection (800N, Apple Ridge Rd., and 1350E, Nattier Rd.). TURN RIGHT (east) onto 800N, Apple Ridge Rd.

0.5 7.5 CONTINUE AHEAD (east) at T-intersection from the left (800N, Apple Ridge Rd., and 1400E, Peach Tree Rd.).

0.5 8.0 CAUTION: Road curves to the right 90 degrees (800N, Apple Ridge Rd., and 1450E, Foxville Rd.). NOTE: Apple Ridge Rd. and Foxville Rd. run together. FOLLOW ROAD (south) 1450E.

0.5 8.5 CAUTION: Road curves to the left. Intersection (750N, Apple Ridge Rd., and 1450E, Foxville Rd.). TURN LEFT (east) onto 750N, Apple Ridge Rd.

0.7 9.2 CAUTION: STOP (2-way) at intersection of 750N (Apple Ridge Rd.) and 1500E (Bannister Rd.). TURN LEFT (north) onto 1500E, Bannister Rd.

0.5 9.7 CONTINUE AHEAD (north) at T-intersection from the right (800N, Mud Rd., and 1500E, Bannister Rd.).

1.0 10.7 CAUTION: Crossroad intersection (900N, Cross Rd., and 1500E, Bannister Rd.) CONTINUE AHEAD (north) on 1500E, Bannister Rd.

0.85 11.55 CAUTION: unguarded B&O railroad crossing (1 track); look both ways and proceed with caution. CONTINUE AHEAD (north).

0.55 12.1 CAUTION: Prepare to stop.

0.1 12.2 CAUTION: STOP (2-way) at crossroad intersection of US 50 and 1500E (Bannister Rd.). TURN RIGHT (east) onto US 50. NOTE: In this vicinity, notice how generally flat the upland surface appears to be.

0.5 12.7 T-intersection from the left (1525E) just before the bridge. CONTINUE AHEAD (east).

0.05 12.75 Cross Dums Creek. NOTE: The water is flowing from left to right. Dums Creek follows a series of meanders located on the right side of the road.

0.55+ 13.3 Cross Dums Creek. NOTE: The flow is now from right to left.

0.65 13.95 T-intersection from the right (1700E, Metcalf Rd.). CONTINUE AHEAD (east).

0.5 14.45 Prepare to turn left.

0.5 14.95 TURN LEFT from 1050N (US 50) onto 1800E (Keller Road, unmarked). USE EXTREME CAUTION. There is a possibility of fast approaching traffic.

0.95 15.9 CAUTION: Descend hill and prepare to stop.

0.1 16.0 CAUTION: Cross one-lane bridge over Dums Creek. DO NOT PARK on the bridge. Pull over and park vehicles on the right edge of the road.
STOP 8 We'll be discussing the upper Pennsylvanian sandstone exposures along Dums Creek. Sandstone overlies silty shale on both sides of the bridge. To the east and west of the bedrock exposure on the south side of the creek are two fairly large slump blocks that have slid into the creek (fig. 21) (SW SW SW NW, Sec. 6 T2N, R4E, 3rd P.M., Marion County; Omega 7.5-Minute Quadrangle [38088F7]).

Here we have our second opportunity to examine some of the Pennsylvanian bedrock present in Marion County. Some of the typical sandstone found in the upper Pennsylvanian, near the middle of the Mattoon Formation, caps the underlying silty shales and siltstones. These less resistant shales and siltstones are better exposed here because of two factors. First, the overlying sandstone acts a protective cap for the underlying shale and siltstone, keeping it from being completely eroded. Second, we are along a stream bank where the active erosion of the stream keeps the exposures of the shale and siltstone fresh. Without this active erosive power of the stream, the shale and siltstone would still eventually erode to the point that the overlying sandstone would slump. It would eventually be covered by the overlying soils and glacial materials and eventually vegetation.

Composite section of rocks exposed along creek

<table>
<thead>
<tr>
<th>Top</th>
<th>4 ft. +</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pleistocene</td>
<td>Medium bedded; 1 ft. 6 in.</td>
</tr>
<tr>
<td>Sandstone</td>
<td>Weathered, mostly covered; 4 ft.</td>
</tr>
<tr>
<td>Shale</td>
<td>Gray, weathered. Discontinuous sandstone lens up to 1 ft. thick at base of unit; 6 ft.</td>
</tr>
<tr>
<td>Shale</td>
<td>Gray, thin bedded, contains reddish iron concretions at base; 2 ft.</td>
</tr>
<tr>
<td>Claystone/shale</td>
<td>Light gray thin bedded, fissile; 3 ft. 6 in.</td>
</tr>
<tr>
<td>Siltstone</td>
<td>At Creek level</td>
</tr>
</tbody>
</table>

Note: There appears to be a lower sandstone ledge within the creek.

We can only generally locate our stratigraphic position here as somewhere in the middle of the Mattoon Formation. These sandstones (and shales and siltstone for that matter) are unnamed and have not been precisely correlated with other outcrops in the area. The majority of the Pennsylvanian bedrock in the area consists of clastic rocks such as these, and these units all look pretty much alike, having a lack of many distinctive features (including fossils, which would allow us to identify the precise stratigraphic position). In addition, as previously mentioned, many of these sandstones are lenticular and interbedded with the shales and siltstones in a complex fashion as one would expect from deposits of the fluvial systems that formed these units (see supplemental reading for discussion of the nature and formation of the Pennsylvanian rocks).

Look at the colors, bedding, and other features you might see here. Keep what you see in mind as we examine other exposures of clastic rocks at later stops today. Can you distinguish between these units? Do they look similar or can you see differences that would allow you to determine whether these are distinctive units?

In order to map these rocks, geologists need key beds that contain distinctive features (such as fossils, or a different lithology). Second, they need units that are more or less continuous, which will allow them to physically trace the units. Coals and limestones (and associated black shales) are typically continuous units, and we can correlate them and make a stratigraphic framework like the one shown in figure 12. Finally, as you can see here, many of the exposures are not continuous, so geologists often rely on the information obtained from drill-hole records in correlating rock units beneath the surface.
Figure 21 Slump block located east of the bridge over Dums Creek, Stop 8.

As we leave this location, notice the roadcut a short distance to the north (mileage 16.2). It exposes more of the sandstone and illustrates some of the other typical features (cross-bedding) that identify these sandstones as fluvial deposits that were part of an ancient stream channel system.

<table>
<thead>
<tr>
<th>Mileage</th>
<th>Time</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.0</td>
<td>16.0</td>
<td>Leave STOP 8 and CONTINUE AHEAD (north).</td>
</tr>
<tr>
<td>0.2</td>
<td>16.2</td>
<td>To the left is some crossbedded sandstone that appears to be part of an ancient stream channel that was later filled with sandstone. Just ahead and to the right below the road are a number of large sandstone blocks, which indicate the road here was cut through the sandstone exposure and some of the large pieces had to be rolled out of the way.</td>
</tr>
<tr>
<td>0.25+</td>
<td>16.45</td>
<td>CONTINUE AHEAD (north) at the T-intersection from the left (1200N, Quail Run Rd., and 1800E, Hiestand Rd.).</td>
</tr>
<tr>
<td>1.0</td>
<td>17.45</td>
<td>STOP (2-way); crossroad (1300N, Bee Branch Rd., and 1800E, Keller Rd.). TURN RIGHT (east) onto 1300N, Bee Branch Rd.</td>
</tr>
<tr>
<td>0.75</td>
<td>18.2</td>
<td>T-intersection from the left (1875E, Bruce Rd.) CONTINUE STRAIGHT (east).</td>
</tr>
<tr>
<td>0.3</td>
<td>18.5</td>
<td>Cross Bee Branch of Dums Creek. DO NOT PARK on the bridge. Pull over and park vehicles on the right edge of the road.</td>
</tr>
</tbody>
</table>
STOP 9 We'll view exposures of upper Pennsylvanian sandstone overlying silty shale from near the middle of the Mattoon Formation, along the creek bank and in the roadcut east of the Bee Branch bridge. Some of the sandstone is calcareous and crops out in the valley wall (NW NW NW, Sec. 32 T3N, R4E, 3rd P.M., Marion County; Omega 7.5-Minute Quadrangle [38088F7]).

At this location we can see about 10 feet of sandstone and associated silty shale exposed. Do you remember Stop 8 where we examined similar rocks on the stream banks of both sides of the bridge over Dums Creek? Do you see much difference in these strata? Probably not, and neither have geologists. Although we know, based on mapping of key units in the subsurface, that we are in the middle Mattoon, we again cannot precisely map our stratigraphic position because these sandstones and siltstones are too similar to one another to correlate them or distinguish them from other sandstone exposures in the area. These units are also lenticular and probably do not physically correlate over a wide area with other sandstones even if they do lie at the same stratigraphic position.

Again we do know, on the basis of the type of rocks (sandstones and siltstones that interbed) and key features (bed forms such as cross-beds and ripple marks), that these are typical fluvial and deltaic rocks found in the repetitive cycles (called cyclothsms—see the supplemental reading in the back of the guidebook for an explanation of cyclothsms and the nature of these fluvial-deltaic rocks) that occur in the Mattoon and other Pennsylvanian formations.

Once again, please note the key features you see in these rocks (i.e., color, grain size, bed forms, thickness of beds, and relationship of the siltstones and sandstones). Keep this information in mind at Stop 10, which is a spillway where we can see one of the better exposures of the sandstone and siltstone. We will see how these units are similar but are often lenticular and too complex in their relationships to allow them to be correlated or given names.

<table>
<thead>
<tr>
<th>Distance</th>
<th>Mileage</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.0</td>
<td>18.5</td>
</tr>
<tr>
<td>0.2</td>
<td>18.7</td>
</tr>
<tr>
<td>0.25</td>
<td>18.95</td>
</tr>
<tr>
<td>0.50</td>
<td>19.45</td>
</tr>
<tr>
<td>0.5+</td>
<td>19.95</td>
</tr>
<tr>
<td>0.5</td>
<td>20.45</td>
</tr>
<tr>
<td>0.5</td>
<td>20.95</td>
</tr>
<tr>
<td>0.6</td>
<td>21.55</td>
</tr>
<tr>
<td>0.15</td>
<td>21.7</td>
</tr>
<tr>
<td>0.95</td>
<td>22.65</td>
</tr>
</tbody>
</table>

Leave STOP 9. CONTINUE AHEAD (east).
T-intersection from right (1925E, Cash Rd.) CONTINUE STRAIGHT (east).
STOP (2-way) (1300N, Bee Branch Rd., and 1950E, Omega Rd.). TURN LEFT (north) onto 1950E, Omega Rd.
CONTINUE AHEAD (north) at T-intersection from the right (1350N, Monical Rd., and 1950E, Omega Rd.).
CONTINUE AHEAD (north) at T-intersection from the left (1400N, Diss Rd., and 1950E, Omega Rd.).
CONTINUE AHEAD (north) at T-intersection from the right (1450N, Penrod Rd., and 1950E, Omega Rd.).
CONTINUE AHEAD (north) at T-intersection from the right (1500N, Robert Rd., and 1950E, Omega Rd.).
CAUTION: entering the community of Omega.
STOP (4-way), crossroad (1575N, Brubaker Rd., and 1950E, Omega Rd.). TURN RIGHT (east) onto 1575N, Brubaker Rd.
CONTINUE AHEAD (east) at T-intersection from the right (1575N, Brubaker Rd., and 2050E, Landmark Rd.).
Oil tank battery on the right.

Oil tank battery and pump jack in field on the right.

Cross Lost Fork Creek.

Road curves 90 degrees to the left and heads north. You are now on 2150E, Brubaker Rd.

CONTINUE AHEAD (north) at T-intersection from the right (1600N, Wilcoxen Rd., and 2150E, Meacham Rd.). Note: Meacham and Brubaker Roads run together.

Entrance to Sam A. Parr Fisheries Research Lab on the left. This is a cooperative facility between the Illinois Natural History Survey and the Illinois Department of Conservation. CONTINUE AHEAD (north).

Prepare to turn left.

TURN LEFT: entrance to Stephen A. Forbes State Park. Note: TURN LEFT at the T-intersection approximately 100 feet after you enter the park.

STOP 10, TURN RIGHT into Lakeview Picnic Area parking lot and park.

STOP 10 We'll view and discuss the Pennsylvanian channel sandstones exposed in the east bank of the creek just below the spillway. CAUTION: Traffic may be heavy at times along the road. Be careful where you stand (SE SW NE SW, Sec. 10, T3N, R4E, 3rd P.M., Marion County; Xenia 7.5-Minute Quadrangle [38088F6]).

Figure 22 Pennsylvanian channel sandstone along the creek below the spillway at Stephen A. Forbes State Park.
The purpose of this stop is to help put together a more complete picture of the nature of the upper Pennsylvanian sandstones and associated siltstones and shales. First, remember the much smaller exposures of sandstone we saw at Stops 1, 8, and 9. Now, examine the nature of the sandstone in this much larger exposure beneath the spillway (fig. 22).

**Description of the exposure on the north side of creek**

<table>
<thead>
<tr>
<th>Top</th>
<th>Sandstone</th>
<th>Siltstone</th>
<th>Sandstone</th>
<th>Base</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Siltstone</strong></td>
<td>Thin bedded, with thin shale laminae separating siltstone layers; 3 ft.</td>
<td>Fine grained, micaceous, light tan, sideritic pebbles at the base of the sandstone, plant fossils present near the base of sandstone (identified calamities), thin cross lamination cross bedding near the base of the unit. Iron staining along joints. Thickness increases from 3 ft. to approximately 6 ft. from left to right.</td>
<td>Thin bedded, light gray, with some thin sandstone lenses, ripped up coal clast present in middle of the unit. Thin shale laminae separate siltstone layers. Thickness decreases from 6 ft. on the left and pinches out to nothing near the middle of the exposure.</td>
<td>Light gray, beds appear to be massive, contains ripple marks. Thin siltstone lens on the far left end of the exposure separates a lower sandstone unit approximately 2 ft. thick, which is only partially exposed. Thickness decreases from 8 ft. to 4 ft. from left to right.</td>
</tr>
<tr>
<td><strong>Sandstone</strong></td>
<td>Thin bedded, light gray, with some thin sandstone lenses, ripped up coal clast present in middle of the unit. Thin shale laminae separate siltstone layers. Thickness decreases from 6 ft. on the left and pinches out to nothing near the middle of the exposure.</td>
<td>Light gray, beds appear to be massive, contains ripple marks. Thin siltstone lens on the far left end of the exposure separates a lower sandstone unit approximately 2 ft. thick, which is only partially exposed. Thickness decreases from 8 ft. to 4 ft. from left to right.</td>
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<td></td>
</tr>
<tr>
<td><strong>Base</strong></td>
<td>At creek bed</td>
<td>At creek bed</td>
<td>At creek bed</td>
<td>At creek bed</td>
</tr>
</tbody>
</table>

**Note:** On the south side of the creek, the sandstones are not as evident as they are on the north side of the creek. This may be a result of the discontinuous nature of these sandstones.

The exposure is actually made up of several sandstone bodies and interbedded siltstone that are not continuous but pinch out laterally (fig. 22). In other words, as previously mentioned, these sandstones are lenticular bodies deposited in ancient stream channels. Each lens represents a different stream channel over time. The sandstones in these paleochannels (formerly sands in river bars) show crossbedding and ripple marks as well as other sedimentary features characteristic of deposits formed in stream channels. They interfinger with siltstones and shales (formerly silts and muds) that were part of the *flood plain* deposits of these fluvial systems along the ancient shorelines of 285 million years ago.

As you can see, the nature of these sandstone bodies and associated siltstones and shales is actually quite complex. Now try to imagine tracing these over a larger area with only limited exposures or drill hole data. Because many of these bodies are not continuous and each of the channels is related to the other sediments (and each other) in such a complex fashion, it is nearly impossible for the geologist to map these units given the limited data available. Thus, we are not able to trace and map these units like we can the thin, but much more laterally continuous marine units (limestones and black shales) and coals associated with these clastic deposits. In fact, although we might be able to trace say one of the coals throughout the entire area, a given sandstone overlying the coal a short distance above may not be the same channel deposit at each location but merely approximately the same age.

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<table>
<thead>
<tr>
<th>Mileage</th>
<th>Distance</th>
<th>Instruction</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.0</td>
<td>24.7</td>
<td>Leave STOP 10. Resume mileage figure at the picnic area entrance. TURN RIGHT (southerly) on the main park road.</td>
</tr>
<tr>
<td>0.15</td>
<td>24.85</td>
<td>Cross spillway bridge and CONTINUE AHEAD on the park road.</td>
</tr>
</tbody>
</table>
Lookout Point Picnic Area to the right on the sharp curve. CONTINUE AHEAD on the park road.

Good view of Forbes Lake.

Black Oak Picnic Area to the right. CONTINUE AHEAD on the park road.

Sassafras Picnic Area to the right. CONTINUE AHEAD on the park road.

Whippoorwill Picnic Area to the right.

The ditch on the right has eroded down through glacial drift, exposing some thin sandstone beds that form a stair-step waterfall down to the bottom of the draw. Glacial erratics, which have been weathered out of the glacial drift material, can be found along most of the ravines in the park. CONTINUE AHEAD on the park road.

Entrance to Circle Drive Picnic Area on the right. CONTINUE AHEAD on the park road.

Y-intersection of Marina/Concession and Boat Ramp to the right. BEAR LEFT (northwesterly).

STOP 4-WAY: TURN LEFT.

Straight ahead is the drive to the Site Superintendent's Office in front of which are two large glacial erratics. Both of these erratics were uncovered when Boston Pond, southeast of the office was constructed in the early days of the park's development. The larger of these igneous rocks is almost 4 feet in its longest dimension and nearly 3 feet high.


CONTINUE AHEAD (south) at crossroad with 2-way stop (1650N, Prairie Rd., and 1950E, Omega Rd.).

STOP (4-way), crossroad (1575N, Brubaker Rd., and 1950E, Omega Rd.). CONTINUE AHEAD (south) on 1950E, Omega Rd.

CONTINUE AHEAD (south) at T-intersection from the left (1500N, Robert Rd., and 1950E, Omega Rd.).

CONTINUE AHEAD (south) at T-intersection from the left (1450N, Penrod Rd., and 1950E, Omega Rd.).

CONTINUE AHEAD (south) at T-intersection from the right (1400N, Diss Rd., and 1950E, Omega Rd.).

CONTINUE AHEAD (south) at T-intersection from the left (1350N, Monical Rd., and 1950E, Omega Rd.).

Prepare to turn right.
STOP 11 Abandoned Shoots Quarry. The limestone was mined from the Omega Limestone, which is stratigraphically in the lower middle of the Mattoon Formation. Typical fossils found in upper Pennsylvanian marine units can be collected at this locality. You must have permission to enter this property (NE NE, Sec. 25, T3N, R3E, 3rd P.M., Marion County; Omega 7.5-Minute Quadrangle [38088F7]).

The purpose of our visit to this site is to examine and collect some of the fossils found in the Omega Limestone (figs. 2 and 23). These fossils are records of the organisms that once lived in these shallow seas and evidence that these rocks are marine (as opposed to non-marine). Some of the fossils you may see and collect include gastropods (snails), brachiopods (bivalved clam-like animals), and pelecypods (clams). Other fossils you might find include crinoid stems (parts of animals related to starfish), bryozoans (colonial animals that form lacy leaf-like "fronds"), and fusulinids (shells like wheat grains from single-celled organisms—they are very important for correlation).

The Omega Limestone is one of the key members of the Mattoon Formation. Because this is an abandoned quarry and the pits have been flooded for some time, the exposures cannot be seen. Instead, we will be able to find abundant fossils in the spoil piles left behind from the quarrying operations (fig. 24).

The Omega Limestone is named for the village of Omega just 1 3/4 miles northeast of here. Formations and members are given geographic names, usually the name of a nearby town or natural feature. The Omega was named for exposures of the limestone found in quarries just 1/2 mile east of this abandoned quarry, where the limestone was between 9 and 11 feet thick. The Omega is very argillaceous (dirty, containing much clay) and fossiliferous; although sporadic in occurrence, it appears to be widespread across parts of central Illinois.

A number of named and correlated limestones, such as the Omega, are found in the upper Pennsylvanian. They were deposited in shallow seas that repeatedly covered the area about 285 million years ago. As previously mentioned, most of the Pennsylvanian is made up of shales, siltstones, and sandstone (such as that seen at two previous stops) with minor amounts of limestone (such as we see here), black shale, coal, and claystone. The relationship of these various rock types is characterized by a repetitive sequence of strata called cyclothems. Although no one cyclothem can be found that contains all of the lithologies seen in the ideal cyclothem, most cyclothems contain a number of these in a repeated sequence (for a more complete discussion of cyclothems, please see the supplemental reading at the back of the book).
Claystone, olive gray, with some black manganese staining, faintly laminated, 1.58 ft. thick.

Shale, olive gray, well laminated, some manganese staining and siderite partings, becomes silty near base and grades into underlying unit, 3.42 ft.

Siltstone, light greenish gray to light gray, thinly and irregularly interlaminated with thin clay, coarsely micaceous on some partings, contains occasional weathered sideritic and silty nodules, sharp contact below, 5.42 ft.

Omega Limestone Member, Mattoon Formation
Limestone, light gray, mottled with brown, massive, very fossiliferous, with very numerous fusulinids, occasional large brachiopods and other invertebrates, 3.5 ft.

Limestone, light gray, dense, massive, much less fossiliferous than above, brachiopods most common, occasional fusulinids, 5.5 ft.

Shale, light greenish gray, fossiliferous, calcareous with thin limestone bands increasing upward, 1.83 ft.

Calhoun Coal Member, 0.1 to 1.0 ft.

Claystone, light greenish gray, stigmaria, coaly smut bands, limestone nodules downward, 0.5 ft.

Shale, light olive gray, slightly silty, well laminated, 3.25+ ft.

Figure 23 Generalized section of Omega Limestone and associated rock strata in the field trip area. See figure 2 for the stratigraphic position in the upper Pennsylvanian succession.
These cyclothems resulted from the ongoing retreat and advance of shallow seas across much of the area while Illinois was at or near the shoreline of the ancient continental seas. In particular, the advance of the sea is marked by black shales and associated marine limestones, such as the Omega. The maximum of marine transgression is usually marked by a black shale often seen beneath these limestones, while the later limestones represent periods of shallower and more oxygenated waters in the beginning of a regressive phase of the marine portion of the cycle.

A short distance below the Omega Limestone, a coal (the Calhoun Coal) is known to be present. The coal is quite variable in thickness, ranging from 0 to 2 feet. In some areas, the Calhoun Coal has also been mined as part of the surface mining process in quarries mining the Omega Limestone.

END OF FIELD TRIP

Have a safe journey home! Join us at Pekin on May 20, 1995.
Clark, P.U., M.R. Greek, and M.J. Schneider, 1988, Surface morphology of the southern margin of the Laurentide ice sheet from Illinois to Montana (Abstr.) in Program and Abstracts of the Tenth Biennial Meeting: American Quaternary Association, University of Massachusetts, Amherst, p. 60.
Herzog, B.L., B.J. Stiff, C.A Chenoweth, K.L. Warner, J.B. Sieverling, and C. Avery, 1994, Buried Bedrock Surface of Illinois: Illinois State Geological Survey, Illinois Map 5; scale, 1:500,000; size, 33.25"x 60.75".


GLOSSARY

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

Ablation — Separation and removal of rock material and formation of deposits, especially by wind action or the washing away of loose and soluble materials.
Age — An interval of geologic time; a division of an epoch.
Aggrading stream — One that is actively building up its channel or floodplain by being supplied with more load than it can transport.
Alluviated valley — One that has been at least partially filled with sand, silt, and mud by flowing water.
Alluvium — A general term for clay, silt, sand, gravel, or similar unconsolidated detrital material deposited during comparatively recent time by a stream or other body of running water as a sorted or semisorted sediment in the bed of a stream or on its floodplain or delta, etc.
Anticline — A convex upward rock fold in which strata have been bent into an arch; the strata on each side of the core of the arch are inclined in opposite directions away from the axis or crest; the core contains older rocks than does the perimeter of the structure.
Aquifer — A geologic formation that is water-bearing and which transmits water from one point to another
Argillaceous — largely composed of clay-sized particles or clay minerals.
Base level — Lowest limit of subaerial erosion by running water, controlled locally and temporarily by water level at stream mouths into lakes or more generally and semipermanently into the ocean (mean sea level).
Basement complex — Largely crystalline igneous and/or metamorphic rocks of complex structure and distribution that underlie a sedimentary sequence.
Basin — A topographic or structural low area that generally receives thicker deposits of sediments than adjacent areas; the low areas tend to sink more readily, partly because of the weight of the thicker sediments; this also denotes an area of deeper water than found in adjacent shelf areas.
Bed — A naturally occurring layer of Earth material of relatively greater horizontal than vertical extent that is characterized by a change in physical properties from those overlying and underlying materials. It also is the ground upon which any body of water rests or has rested, or the land covered by the waters of a stream, lake, or ocean; the bottom of a watercourse or of a stream channel.
Bedrock — The solid rock underlying the unconsolidated (non-indurated) surface materials, such as, soil, sand, gravel, glacial till, etc.
Bedrock valley — A drainageway eroded into the solid bedrock beneath the surface materials. It may be completely filled with unconsolidated (non-indurated) materials and hidden from view.
Braided stream — A low gradient, low volume stream flowing through an intricate network of interlacing shallow channels that repeatedly merge and divide, and are separated from each other by branch islands or channel bars. Such a stream may be incapable of carrying all of its load.
Calcarenite — Limestone composed of sand-sized grains consisting of more or less worn shell fragments or pieces of older limestone; a clastic limestone.
Calcareous — Containing calcium carbonate (CaCO3); limy.
Calcite — A common rock-forming mineral consisting of CaCO3; it may be white, colorless, or pale shades of gray, yellow, and blue; it has perfect rhombohedral cleavage, appears vitreous, and has a hardness of 3 on the Mohs' scale; it effervesces (fizzes) readily in cold dilute hydrochloric acid. It is the principal constituent of limestone.
Chert — Silicon dioxide (SiO2); a compact, massive rock composed of minute particles of quartz and/or chalcedony; it is similar to flint but lighter in color.
Clastic — Fragmental rock composed of detritus, including broken organic hard parts as well as rock substances of any sort.
Closure — The difference in altitude between the crest of a dome or anticline and the lowest contour that completely surrounds it.

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

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

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

Detritus — Material produced by mechanical disintegration.

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

Dolomite — A mineral, calcium-magnesium carbonate (Ca,Mg[CO3]2); applied to those sedimentary rocks that are composed largely of the mineral dolomite; it also is precipitated directly from seawater. It is white, colorless, or tinged yellow, brown, pink, or gray; has perfect rhombohedral cleavage; appears pearly to vitreous; effervesces feebly in cold dilute hydrochloric acid.

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

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

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

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

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

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.

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

Fluvial — Of or pertaining to a river or rivers.

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

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

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

Geophysics — Study of the Earth by quantitative physical methods.

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

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

Gradient — A part of a surface feature of the Earth that slopes upward or downward; a slope, as of a stream channel or of a land surface.
Igneous — Said of a rock or mineral that solidified from molten or partly molten material, i.e., from magma.

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

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

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

Lacustrine — Produced by or belonging to a lake.

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

Outwash plain — The surface of a broad body of outwash formed in front of a glacier.
**Oxbow lake** — A crescent-shaped lake in an abandoned bend of a river channel.

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

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

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

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

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

**Physiographic province (or division)** — (1) A region, all parts of which are similar in geologic structure and climate and which has consequently had a unified geologic history; (2) a region whose pattern of relief features or landforms differs significantly from that of adjacent regions.

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

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

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

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

**Sinkholes** — Small circular depressions that have formed by solution in areas underlain by soluble rocks, most commonly limestone and dolomite.

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

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

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

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

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

**Syncline** — A downfold of strata which dip inward from the sides toward the axis; youngest rocks along the axis; the opposite of anticline.
System — the largest and fundamental geologic time-rock unit; the strata of a system were deposited during a period of geologic time.

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

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

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

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

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

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

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

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

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

Water table — The upper surface of a zone of saturation.

Weathering — The group of processes, chemical and physical, whereby rocks on exposure to the weather change in character, decay, and finally crumble into soil.
ERRATICS ARE ERRATIC
Myrna M. Killey

You may have seen them scattered here and there in Illinois—boulders, some large, some small, lying alone or with a few companions in the corner of a field, at the edge of a road, in someone's yard, or perhaps on a courthouse lawn or schoolyard. Many of them seem out of place, like rough, alien monuments in the stoneless, grassy knolls and prairies of our state. Some—the colorful and glittering granites, banded gneisses, and other intricately veined and streaked igneous and metamorphic rocks—are indeed foreign rocks, for they came from Canada and the states north of us. Others—gray and tan sedimentary rocks—are native rocks and may be no more than a few miles from their place of origin. All of these rocks are glacial boulders that were moved to their present sites by massive ice sheets that flowed across our state. If these boulders are unlike the rocks in the quarries and outcrops in the region where they are found, they are called erratics.

The continental glaciers of the Great Ice Age scoured and scraped the land surface as they advanced, pushing up chunks of bedrock and grinding them against each other or along the ground surface as the rock-laden ice sheets pushed southward. Hundreds of miles of such grinding, even on such hard rocks as granite, eventually rounded off the sharp edges of these passengers in the ice until they became the rounded, irregular boulders we see today. Although we do not know the precise manner in which erratics reached their present isolated sites, many were probably dropped directly from the melting front of a glacier. Others may have been rafted to their present resting places by icebergs on ancient lakes or on the floodwaters of some long-vanished stream as it poured from a glacier. Still others, buried in the glacial deposits, could have worked their way up to the land surface as the surrounding loose soil repeatedly froze and thawed. When the freezing ground expands, pieces of rock tend to be pushed upward, where they are more easily reached by the farmer's plow and also more likely to be exposed by erosion.

An eight-foot boulder of pink granite left by a glacier in the bed of a creek about 5 miles southwest of Alexis, Warren County, Illinois. (From ISGS Bulletin 57, 1929.)
Generally speaking, erratics found northeast of a line drawn from Freeport in Stephenson County, southward through Peoria, and then southeastward through Shelbyville to Marshall at the east edge of the state were brought in by the last glacier to enter Illinois. This glaciation, called the Wisconsinan, spread southwestward into Illinois from a center in eastern Canada, reaching our state about 75,000 years ago and (after repeated advances and retreats of the ice margin) melting from the state about 12,500 years ago. Erratics to the west or south of the great arc outlined above were brought in by a much older glacier, the Illinoian, which spread over most of the state about 300,000 to 175,000 years ago. Some erratics were brought in by even older glaciers that came from the northwest.

You may be able to locate some erratics in your neighborhood. Sometimes it is possible to tell where the rock originally came from by determining the kind of rock it is. A large boulder of granite, gneiss, or other igneous or metamorphic rock may have come from the Canadian Shield, a vast area in central and eastern Canada where rocks of Precambrian age (more than 600 million years old) are exposed at the surface. Some erratics containing flecks of copper were probably transported here from the "Copper Range" of the upper peninsula of Michigan. Large pieces of copper have been found in glacial deposits of central and northern Illinois. Light gray to white quartzite boulders with beautiful, rounded pebbles of red jasper came from a very small outcrop area near Bruce Mines, Ontario, Canada. Purplish pieces of quartzite, some of them banded, probably originated in the Baraboo Range of central Wisconsin. Most interesting of all are the few large boulders of Canadian tillite. Tillite is lithified (hardened into rock) glacial till deposited by a Precambrian glacier many millions of years older than the ones that invaded our state a mere few thousand years ago. Glacial till is an unsorted and unlabeled mixture of clay, sand, gravel, and boulders that vary widely in size and shape. Tillite is a gray to greenish gray rock containing a mixture of grains of different sizes and scattered pebbles of various types and sizes.

Many erratics are of notable size and beauty, and in parts of Illinois they are commonly used in landscaping. Some are used as monuments in courthouse squares, in parks, or along highways. Many are marked with metal plaques to indicate an interesting historical spot or event. Keep an eye out for erratics. There may be some of these glacial strangers in your neighborhood that would be interesting to know.
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
More than 300 inches
150 - 300 inches
50 - 150 inches
Up to 50 inches
Little or no loess

Boundary of last glacial advance in Illinois

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.
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.
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.
<table>
<thead>
<tr>
<th>Stage</th>
<th>Substage</th>
<th>Nature of Deposits</th>
<th>Special Features</th>
</tr>
</thead>
<tbody>
<tr>
<td>Holocene</td>
<td>Years</td>
<td>Soil, youthful profile of weathering, lake and river deposits, dunes, peat</td>
<td>Outwash along Mississippi Valley</td>
</tr>
<tr>
<td></td>
<td>Before</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Present</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>10,000</td>
<td>Outwash, lake deposits</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Valderan</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>11,000</td>
<td>Peat and alluvium</td>
<td>Ice withdrawal, erosion</td>
</tr>
<tr>
<td></td>
<td>Twocreekan</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>12,500</td>
<td>Outwash, lake deposits</td>
<td></td>
</tr>
<tr>
<td>Wisconsinan</td>
<td>Woodfordian</td>
<td>Drift, loess, dunes, lake deposits</td>
<td>Glaciation; building of many moraines as far south as Shelbyville; extensive valley trains, outwash plains, and lakes</td>
</tr>
<tr>
<td></td>
<td>25,000</td>
<td>Soil, silt, and peat</td>
<td>Ice withdrawal, weathering, and erosion</td>
</tr>
<tr>
<td></td>
<td>Farmdalian</td>
<td></td>
<td>Glaciation in Great Lakes area, valley trains along major rivers</td>
</tr>
<tr>
<td></td>
<td>28,000</td>
<td>Soil, mature profile of weathering</td>
<td>Important stratigraphic marker</td>
</tr>
<tr>
<td>Sangamonian</td>
<td>Altonian</td>
<td>Drift, loess</td>
<td>Glaciers from northeast at maximum reached Mississippi River and nearly to southern tip of Illinois</td>
</tr>
<tr>
<td></td>
<td>75,000</td>
<td>Soil, mature profile of weathering</td>
<td></td>
</tr>
<tr>
<td>Illinoian</td>
<td>Jubileeian</td>
<td>Drift, loess, outwash</td>
<td>Glaciers from northeast and northwest covered much of state</td>
</tr>
<tr>
<td></td>
<td>Monican</td>
<td>Drift, loess, outwash</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Liman</td>
<td>Drift, loess, outwash</td>
<td></td>
</tr>
<tr>
<td></td>
<td>300,000?</td>
<td>Soil, mature profile of weathering</td>
<td>Important stratigraphic marker</td>
</tr>
<tr>
<td>Yarmouthian</td>
<td>Kansan*</td>
<td>Drift, loess</td>
<td>Glaciers from northeast and northwest covered much of state</td>
</tr>
<tr>
<td></td>
<td>(glacial)</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>500,000?</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Aftonian*</td>
<td>Soil, mature profile of weathering</td>
<td>(hypothetical)</td>
</tr>
<tr>
<td></td>
<td>(interglacial)</td>
<td></td>
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</tr>
<tr>
<td></td>
<td>700,000?</td>
<td>Soil, mature profile of weathering</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Pre-Illinoian</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>900,000?</td>
<td>Drift (little known)</td>
<td>Glaciers from northwest invaded western Illinois</td>
</tr>
<tr>
<td></td>
<td>Nebraska*</td>
<td>Drift (little known)</td>
<td></td>
</tr>
<tr>
<td></td>
<td>(glacial)</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>1,600,000 or more</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

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

SEQUENCE OF GLACIATIONS AND INTERGLACIAL DRAINAGE IN ILLINOIS

PRE-PLEISTOCENE major drainage

PRE-ILLINOIAN inferred glacial limits

YARMOUTHIAN major drainage

LIMAN glacial advance

MONICAN glacial advance

JUBILEEAN glacial advance

SANGAMONIAN major drainage

ALTONIAN glacial advance

WOODFORDIAN glacial advance

WOODFORDIAN Valparaiso ice and Kankakee Flood

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

Le Roy Named moraine
ILLIANA Named morainic system
Intermorainal area

0 10 20 30 Miles
0 20 40 Kilometers

ILLINOIS STATE GEOLOGICAL SURVEY
GLACIAL MAP OF ILLINOIS

H.B. WILLMAN and JOHN C. FRYE
1970

EXPLANATION

HOLOCENE AND WISCONSINAN
- Alluvium, sand dunes, and gravel terraces

WISCONSINAN
- Lake deposits

WOODFORDIAN
- Moraine
  - Front of morainic system

ALTonian
- Till plain

ILLINOIAN
- Moraine and ridged drift
  - Groundmoraine

KANSAN
- Till plain

DRIFTLESS

Modified from maps by Leverett (1899), Ekblaw (1959), Leighton and Brophy (1966), Willman et al. (1967), and others.
QUATERNARY DEPOSITS OF ILLINOIS

Jerry A. Lineback
1981

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

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.
<table>
<thead>
<tr>
<th><strong>McCORMICK GROUP</strong></th>
<th><strong>KEWANEE GROUP</strong></th>
<th><strong>McCLEANSBORO GROUP</strong></th>
</tr>
</thead>
<tbody>
<tr>
<td>Caseyville Fm.</td>
<td>Spoon Fm.</td>
<td>Bond Fm.</td>
</tr>
<tr>
<td>Abbott Fm.</td>
<td>Carbondale Fm.</td>
<td>Mattoon Fm.</td>
</tr>
</tbody>
</table>

- **SANDSTONE**
  - 25%
  - Clean quartz sandstones
  - Quartz pebble conglomerates
  - Transitional sandstones
  - Argillaceous and micaceous sandstone
  - Calcareous sandstones common

- **SHALE**
  - 25%
  - Shales silty and sandy – siltstones prominent
  - Shales commonly less silty than below; underclays well developed; black fissile shales common

- **COAL**
  - 5%
  - Cools thin and discontinuous
  - Cools generally thin but traceable
  - Principal minable coals
  - Cools generally thin but widely traceable

- **LIMESTONE**
  - 5%
  - Limestones rare to absent
  - A few thin fossiliferous sandstones
  - Limestones generally thin but traceable
  - Limestones relatively uniform and widely traceable
  - Contains two extensively thick and relatively pure limestones
  - Limestones generally thin but numerous

---

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 cycloths 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 cyclothsems. 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, fern-like 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 course. 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
MISSISSIPPIAN TO ORDOVICIAN SYSTEMS

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.

References


Common Pennsylvanian plants: lycopods, sphenophytes, and ferns

- Lepidodendron aculeatum X0.8
- Lepidophloios laricinus X0.63
- Sigillaria mammilans X0.5
- Stigmia dicoides X0.32
- Pecopteris miltonii X2.0
- Pecopteris hemitelioides X1.0
- Calamites suckowii X0.5
- Annularia steliata X0.63
- Lepidostrobus ovatifolius X0.8
- 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

- Sphenopteris rotundiloba
- Artisia transversa
- Cordaicladus sp.
- Neuropteris rarinervis
- Trigonocarpus parkinsonii
- Cordaicaron major
- Cordaites principalis

J. R. Jennings, ISGS
TRILOBITES
- Ameura sangamonensis 1/3 x
- Ditomopyge parva 1 1/2 x

CORALS
- Lophophoria crassa 1 x

FUSULINIDS
- Fusulina acme 5 x
- Fusulina girtyi 5 x

CEPHALOPODS
- Pseudolithosaurus knoxense 1 x
- Glaphytes welleri 2/3 x
- Metacoceras cornutum 1 1/2 x

BRYOZOANS
- Fenestrella mimica 9 x
- Fenestrella modesta 10 x
- Fistulipora carbonaria 3 1/3 x
- Prismopora triangulata 12 x

CORALS
- Lophophoria crassa 1 x
- Metacoceras cornutum 1 1/2 x

FUSULINIDS
- Fusulina acme 5 x
- Fusulina girtyi 5 x
Nucula (Nuculopsis) giryi 1x

Edmania ovata 2x

Astartella concentrica 1x

Dunbarella knighti 1½x

Cardiomorpha missouriensis "Type A" 1x

Cardiomorpha missouriensis "Type B" 1½x

GASTROPODS

Euphemites carbonarius 1½x

Trepaspira illinoisensis 1½x

Donaldina robusta 8x

Naticopsis (Jedria) ventricosa 1½x

Trepaspira sphaerulata 1x

Knightites montfortianus 2x

Glabrocingulum (Glabrocingulum) grayvillense 3x
BRACHIPODS

Wellerella tetrahedra 1 1/2 x

Juresmania nebrascensis 2/3 x

Derbya crassa 1 x

Composita argentina 1 x

Neospirifer camerosus 1 x

Chonetes granulifer 1 1/2 x

Mesolobus mesolobus var. evamygys 2 x

Marginifera splendens 1 x

Linoproduxus "cora" 1 x

Crurithyris planoconvexa 2 x
BRESEE AREA
GEOLOGICAL SCIENCE FIELD TRIP
MAY 11 and OCTOBER 26, 1974

- INACTIVE OR ABANDONED COAL MINE (NO. 6 COAL)
- AREA IN WHICH COAL IS MINED OUT
- ACTIVE LIMESTONE QUARRY
- INACTIVE OR ABANDONED LIMESTONE QUARRY
- EXPOSURES OF SHOAL CREEK LIMESTONE
- INFERRED BURIED BEDROCK CONTACT BETWEEN THE PENNSYLVANIAN BOND (Pb) AND THE UNDERLYING MODESTO (Pm) FORMATIONS
- ACTIVE SAND AND/OR GRAVEL PIT
- AREA IN WHICH THERE IS RECORD OF OIL PRODUCTION